



A new anthracological sequence from Niğde-Kınık Höyük (Turkey): woodland vegetation and arboriculture in southern Cappadocia from the Late Bronze Age to the Ottoman Period

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Abstract

This article presents a new anthracological sequence from the archeological site of Niğde-Kınık Höyük, in southern Cappadocia (Turkey), spanning from the Late Bronze Age to the Ottoman Period, which provides important insights into the vegetation history of Cappadocia and its change through time. The local woody vegetation was composed of deciduous oaks, with an important contribution, especially in the earlier periods, of riparian trees (Salicaceae). Conifers played a minor role but indicate the possible presence of cedar and fir stands in the site's vicinity. Starting in the mid-1st millennium BCE, wood charcoal data shows a well-defined and coherent anthracological phase characterized by abundant evidence of arboreal crops, especially grapevine. This evidence is here connected to the Beyşehir Occupation Phase phenomenon, and its economic and historic implications are discussed.

Keywords Anthracology · Arboriculture · *Vitis vinifera* · Pruning · Deforestation · Beyşehir Occupation Phase

Introduction

In a review published in 1996, Nesbitt and Samuel summarized the state of the art of archeobotanical research in Turkey. The picture drawn by the authors was undoubtedly positive, recognizing the Anatolian peninsula as one of the most intensively studied Near Eastern regions. One caveat in their discussion was, however, the uneven chronological distribution of published studies: “while archeobotany has long been an integral part of prehistoric excavations in central and southeast Turkey, little work has been done at later sites” (Nesbitt and Samuel 1996: 91). More than 20 years after the review of Nesbitt and Samuel, this imbalance is surely more attenuated. Yet, important regional gaps are still present.

Emblematic in this regard is the case of south-central Anatolia, the portion of the plateau south of the Tuz Gölü basin, comprising the provinces of Aksaray, Niğde, Konya, and Karaman. In this region, prehistoric archeobotanical

research has a long tradition of study, especially on the Epipaleolithic and Neolithic sites in the Konya plain, primarily Çatalhöyük (e.g., Bogaard et al. 2017). In contrast to the wealth of data for these earlier periods, protohistoric and historic south-central Anatolia is today *terra incognita* to archeobotany. This marked contrast is due, at least in part, to the long-standing priorities in the regional archeobotanical and archeological agenda, which has prioritized the study of the transition to agriculture and the development of early agricultural societies (Baird et al. 2018). Without denying the far-reaching and undeniable importance of this tradition, the potential for study of later periods in this region is considerable.

Notwithstanding the lack of on-site archeobotanical research, the Late Holocene vegetation and agricultural history of the region is of great interest for paleoenvironmental and historical studies, as exemplified by the so-called Beyşehir Occupation Phase: a Late Holocene palynological phase of massive forest clearance and coincident expansion of pasturelands, cereal fields, and arboreal crop cultivation (Bottema et al. 1986, 1990; Eastwood et al. 1998; Roberts 2018; van Zeist et al. 1975; Woodbridge et al. 2019). This prolonged and intensive period of agricultural expansion and land-cover change is dated between the mid-2nd/mid-1st millennium

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BCE and the mid-1st millennium CE, with differential onset in different areas (Roberts 2018).

In spite of the ubiquitous palynological identification of the Beyşehir Occupation Phase in several Anatolian lake cores (including those of the southwestern Anatolian Lake District and Cappadocia), we currently lack archeobotanical sequences from Anatolia directly associated with this phenomenon, hampering our ability to fully characterize this phase and to locate it in its proper historical and archeological context. With the aim to partially fill this gap, here, I present the first component of a new archeobotanical study conducted at the site of Niğde-Kınık Höyük, in southern Cappadocia (Fig. 1). Wood charcoal analyzed from samples spanning from the Late Bronze Age to the Early Ottoman period provides insights into firewood management and exploitation, from which further information on the woodland vegetation present in the region surrounding the site and its diachronic change are inferred. Confirming regional palynological evidence, the anthracological data from Niğde-Kınık Höyük indicates the presence of a major expansion of arboreal cultivation (orchards and vineyards) starting in the first half and peaking in the second half of the 1st millennium BCE, providing the first

on-site archeobotanical evidence of the otherwise only palynologically documented Beyşehir Occupation Phase.

History and environment of the Bor-Ereğli plain

Environmental setting

Niğde-Kınık Höyük (37.9373° N, 34.3802° E, 1100 m asl) is located in the northern fringes of the Bor-Ereğli plain, an agriculturally rich region of southern Cappadocia defined to the north by the Hasan and the Melendiz mountains, to the south and east by the Taurus and Anti-Taurus ranges, and to the west by the Karacadağ volcanic system—the latter partially dividing the Bor-Ereğli from the Konya basin (Fig. 1c). The plain was formerly part of a closed lacustrine system (Bayer Altın et al. 2015), with the presence during the Late Pleistocene of a pluvial lake in many respects similar to the nearby Konya paleolake (Kuzucuoğlu et al. 1999). Ongoing research is investigating the Holocenec history of the lake, characterized by several phases of expansion and retreat due

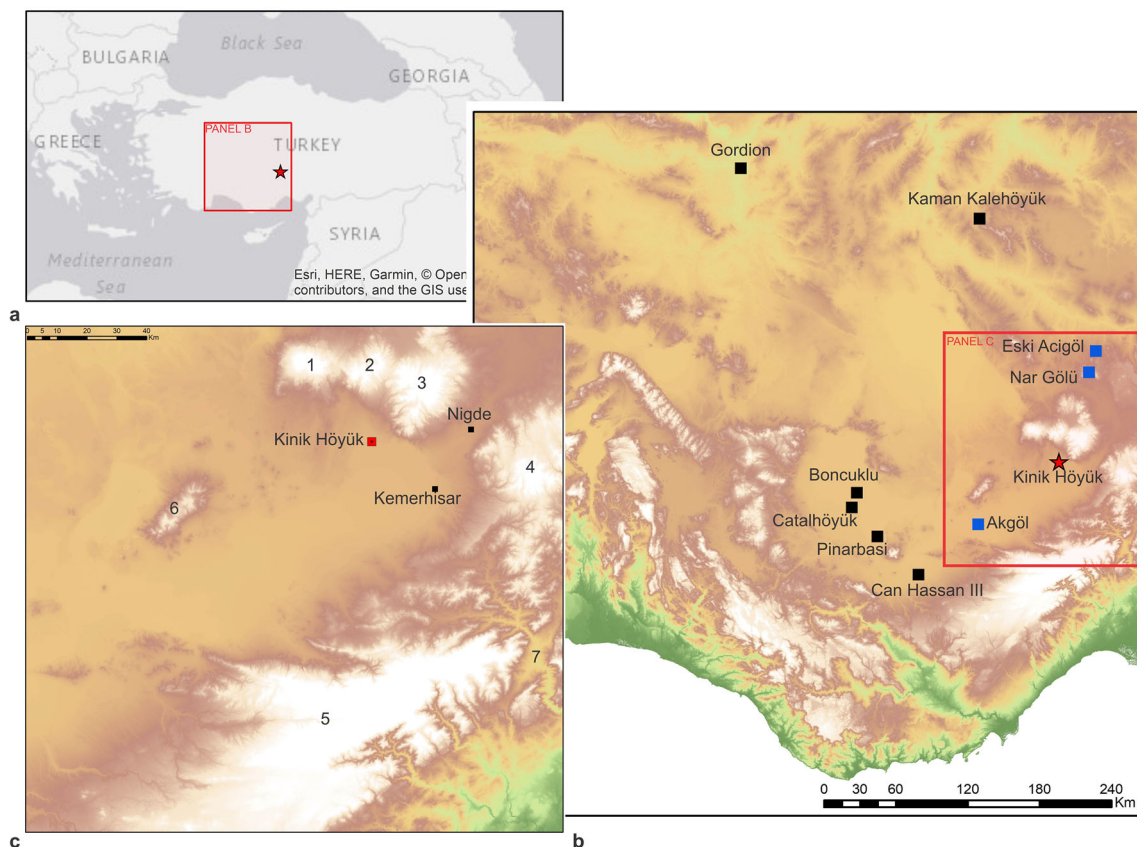


Fig. 1 **a** Map of Turkey and surrounding regions; the red star indicates the location of Kınık Höyük. **b** Digital Surface Model of south-central and central Anatolia, extracted from ALOS World 3D-30m (AW3D30) (Tadono et al. 2014), anthracological (black squares) and palynological (blue squares) sequences discussed in the text are located. **c** Detail of the

Bor-Ereğli plain and surrounding mountains: Hasan Mt. (1), Keçiboyduran Mt. (2), Melendiz Mt. (3), Itulumaz Mt. (4), Bolkar Mts. (5), Karacadağ volcanic field (6), Cilician Gates (7). The site of Kınık Höyük, and the towns of Niğde (ancient *Nahita-Nahitiya*) and Kemerhisar (ancient *Tuwaniwa-Tuwana-Tyana*) are located

to changes in hydrographic balance (Matessi et al. 2018). Following the construction (between 1985 and 1988) of a dam in Altunhisar and other drainage works, today no natural bodies of water, either perennial or intermittent, are present around the site. The earlier presence of marshes in its proximity, the last remains of the Late Pleistocene paleolake, is documented in mid-twentieth century cartography (d'Alfonso and Mora 2008) and in Kürschner's (1984) survey.

The climate of the region is cold semi-arid with average total annual precipitation of about 370 mm, mean January temperature of 0 °C, and mean July temperature of 22 °C. Rainfall is mostly distributed in spring and winter, with summer the driest season of the year (Fig. 2). Both in terms of cumulative annual values and monthly averages, the described climate falls in the expected Central Anatolian regime (e.g., Turkes 2003).

Despite the semi-arid conditions, patches of lush vegetation are present both in the immediate surroundings of the site and on the nearby colluvial deposits, where extensive orchards, vineyards, and rows of poplars are present (e.g., Bayer Altın 2008). Arboriculture is often sustained thanks to supplementary irrigation, crucial especially during the summer dry months, facilitated by groundwater availability and the presence of numerous karstic springs and mountain streams. The vegetation of the region has been subject to a number of studies, with particular emphasis on the Melendiz (Kenar 2014; Kenar and Katenoğlu 2016) and Hasan (Başköse and Dural 2011) mountains. On a coarser scale, the local vegetation is described in the Flora of Turkey (Davis 1965–1985), the Central Taurus vegetation survey of Kürschner (1984), and the Taurus-Pontus transect of Zohary (1973).

Outside the cultivated and ruderal areas, the vegetation is characterized by steppe and dry forests (Fig. 3). Today, woodlands are limited to the slopes of the nearby mountains, where they form a discontinuous and patchy vegetation belt of cold deciduous broad-leaved scrub or forest dominated by deciduous oaks, with a lower tree line usually at ca. 1300–1400 m asl

(Kenar 2014). The non-forested areas on the mountains' slopes are otherwise mainly occupied by either pastures with isolated trees or xeromorphic dwarf-shrublands frequently characterized by the presence of thorn-cushions, a secondary vegetation unit resulting from deforestation and intensive grazing (Kürschner 1984). Currently, no natural pine stands occur in the region (Başköse and Dural 2011; Kenar 2014; Kenar and Katenoğlu 2016; Kürschner 1984). The only conifer today naturally occurring is *Juniperus*, which appears, however, confined to the northwestern (Kenar and Katenoğlu 2016) and northern (Kürschner 1984) slopes of the Melendiz mountain. On the Taurus range (Bolkar Mountains, Fig. 1c), to the southwest and south of the Bor-Ereğli plain, a richer arboreal vegetation is present, both in terms of forest cover and arboreal floristic diversity (Kürschner 1984; Parolly 2015), including on the wetter (southern) slopes Lebanese cedar (*Cedrus libani*) and Taurus fir (*Abies cilicica*) forests.

Historical background

The Bor-Ereğli plain, stretching south of the Central Anatolian Volcanic province up to the Taurus mountains and the Cilician Gates (Fig. 1c), is a region strategically located on the main routes connecting the Central Anatolia plateau with Cilicia and the Levant (Matessi 2016). During the Late Bronze Age (ca. 1600–1180 BCE), the Bor-Ereğli plain was included in the Hittite polity, possibly as part of the so-called Lower Land, a larger and loosely defined administrative province of the Hittite Empire (Forlanini 2017). At least from the second half of the eighth century BCE, this region became the core of the Neo-Hittite kingdom of Tuwana (Hawkins 2000), with its capital-eponym city identified with the modern town of Kemerhisar (classical *Tyana*, Late Bronze Age *Tuwanuwa*), about 20 km to the south-east of Niğde-Kınık Höyük (Fig. 1c). As for the rest of Central Anatolia, the period between the end of the eighth century BCE and the

Fig. 2 Ombrothermic diagram for Kınık Höyük, data extracted from WorldClim2 30 seconds dataset 1970–2000 (Fick and Hijmans 2017)

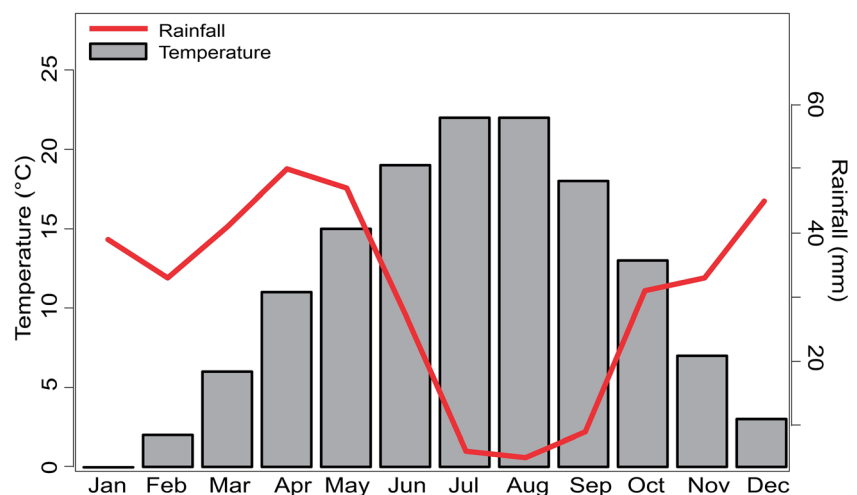
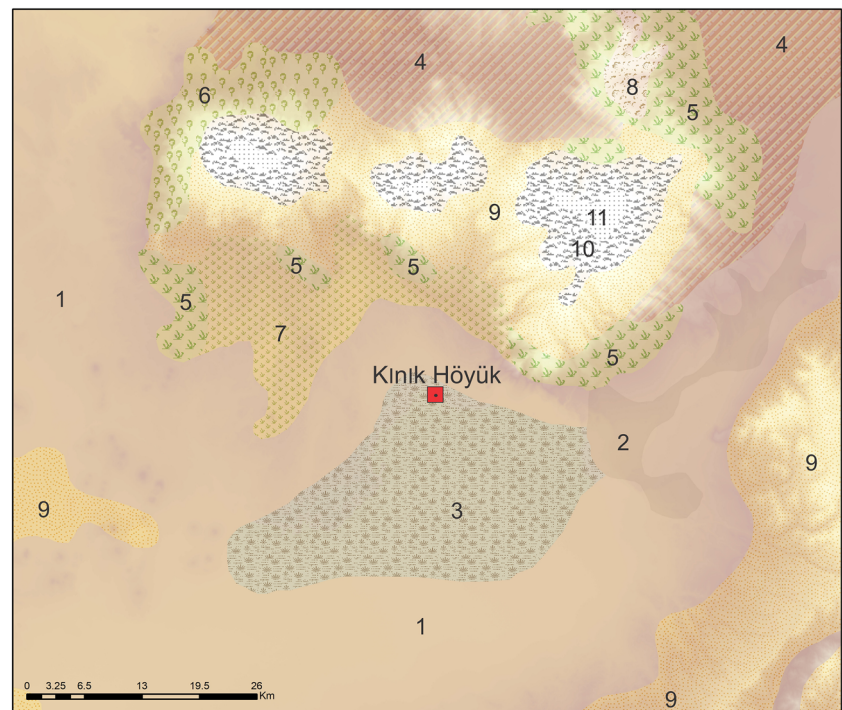


Fig. 3 Simplified vegetation map of the surroundings of Kınık Höyük (redrawn after Kürschner 1984) overlapped to a Digital Surface Model. Symbology: not-irrigated arable land (1), irrigated arable land (2), mixed rush and salt swamp, currently reclaimed (3), not irrigated arable land potentially open forest (4), cold-deciduous scrub (5), cold-deciduous woodland (6), xeromorphic dwarf-shrublands with thorn-cushions mixed with not irrigated arable land potentially open forest (7), *Juniperus* woodland (8), xeromorphic dwarf-shrublands with thorn-cushions (9), sub-alpine vegetation (10), alpine vegetation (11)



consolidation of the Hellenistic kingdoms is little known, although from the mid-sixth century BCE, as most of Anatolia (Herodotus, *Histories*: 1.71-72), the region was incorporated within the Persian Empire (satrapy of Cappadocia). In the Hellenistic period, the Bor-Ereğli plain was part of the Kingdom of Cappadocia, a Hellenized polity ruled by local dynasties of Persian lineage (Berges and Nollé 2000). Cappadocia was incorporated as a frontier province under the Roman Empire by Tiberius in 17 CE. Kemerhishar-Tyana continued to be the main center in the plain (Strabo, *Geography*: XII.2.7), second in the province only to the capital *Mazaca-Caesarea-Kayseri* (Berges and Nollé 2000). After a Late Antique phase characterized by a degree of prosperity, starting in the seventh century CE the changed geopolitical scenario, with the frontier between the Byzantine Empire and the Caliphate located along the nearby Taurus Mountains, was likely responsible for important changes in settlement pattern (Matessi et al. 2018), communication routes (Turchetto 2017), and economy (Eastwood et al. 2009). Cappadocia fell under Seljuk control in the late eleventh century CE (Peacock 2015).

In order to gain archeological insight into this historically promising yet overlooked region, since 2011 a joint New York University (USA) and Pavia University (Italy) excavation project has been investigating the site of Niğde-Kınık Höyük (d'Alfonso and Castellano 2018). Lacking epigraphic sources, the ancient toponym of the site is today unknown, although an identification with Hittite *Tupaziya*, Hellenistic *Dratai*, Roman *Tracias*, and Byzantine *Idrizion/Drizion* has been speculatively proposed (Matessi et al. 2019). According

to survey data (d'Alfonso 2010), the site was a first-tier center of regional importance from the Bronze Age until the end of the Hellenistic period, and on the basis of the limited historical information available, for most of this time likely under the political hegemony of the nearby city of *Tuwaniwa-Tuwana-Tyana-Kemerhisar*.

The archeological site of Niğde-Kınık Höyük

Niğde-Kınık Höyük is an elliptic (180 × 120 m), 20-m-high mound, set on a 9-ha square terrace rising ca. 2 m from the surrounding plain (Fig. 4). The site is currently being investigated in five excavation areas: operation A on the northern slope of the mound, operations E and B on the top of the mound, operation C on the southern slope, and operation D investigating the large lower town surrounding the mound (Fig. 5). An introduction to the site, with further bibliography, is provided by Highcock et al. (2015), d'Alfonso and Castellano (2018), Lanaro et al. (2020), and d'Alfonso et al. (2020), and summarized below.

The earliest known occupation of the site dates to the Early (KH-P VIII; 3200–2000 BCE) and Middle (KH-P VII; 2000–1600 BCE) Bronze Age, although to date these levels are documented only in a limited sounding in the lower town (operation D) (Highcock and Matessi forthcoming). More substantial, while still limited, is the evidence dated to Late Bronze Age (KH-P VI; 1600–1180 BCE), which includes the earliest exposed phase of the citadel walls in operation A (Lanaro et al. 2020), and the deposits reached at the bottom of a deep trench in operation C (d'Alfonso et al. 2019).



Fig. 4 Drone photo of the site (2015). The photo is taken from south to north: in foreground the archeological mound with exposed the Iron Age citadel walls (operation C), in the background Mt. Hasan and Mt. Keçiboğduran. (Kınık Höyük Excavation Project)

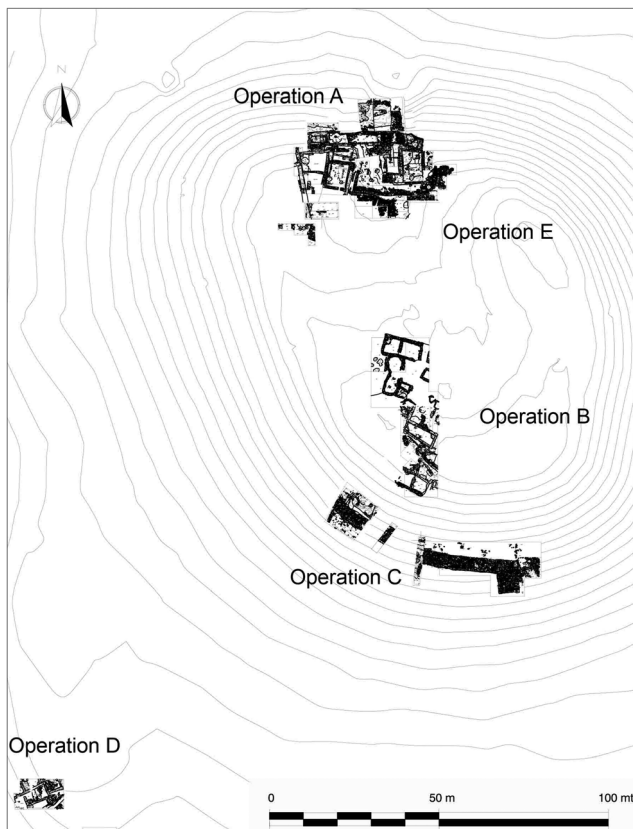


Fig. 5 Topographic plan of the site with indication of the excavation areas (updated to the end of the 2018 excavation campaign). (Survey Leonardo Davighi)

The Iron Age occupation of the site is divided into two main periods: KH-P V (1200–800 BCE) and KH-P IV (800–500 BCE) (Lanaro et al. 2020). At the beginning of the first millennium BCE, during KH-P V, the Iron Age citadel walls were built (Lanaro et al. 2020). The urban layout of the site during this occupation period included large-scale underground granaries, brought to light on the southern slope of the mound (operation C) (Castellano 2018). To KH-P IV are attributed building structures abutting the inner façade of the citadel walls in operation A, interpreted as having an official/public rather than domestic function (Lanaro et al. 2020).

The second half of the 1st millennium BCE is documented at Niğde-Kınık Höyük by two occupation periods: KH-P III (Achaemenid/Early Hellenistic period; 500–200 BCE), and KH-P II (Late Hellenistic period; 200–1 BCE). To KH-P III is attributed a large building exposed in operation A, the dimensions and plan of which likely exclude a domestic function. An interpretation of this building as part of a sanctuary has been proposed, as further corroborated by the presence of highly distinctive zoomorphic materials (statuettes, figurines, and vessels) (d’Alfonso et al. 2020). KH-P III deposits have been reached also in operation B, where a portion of a building dated to this period has been brought to light (Highcock et al. 2015). Due to a limited exposure, to date, the function of this building cannot be reconstructed. Operation B during the Late Hellenistic occupation (KH-P II) appears to have contained mixed residential and production areas (Highcock et al. 2015). Late Hellenistic (KH-P II) levels have been extensively exposed in operation A, where a terrace storage area was built

on top of the aforementioned KH-P III building (d'Alfonso et al. 2020). In an adjoining excavation trench (operation E), a stone-paved plaza has been exposed (d'Alfonso et al. 2020). The cult function of the area, continuing the previous tradition, is corroborated by the presence of a Greek inscription mentioning the god Zeus, a marble eagle statue, and a number of terracotta bovine figures, including fragments of close-to-life size statues (d'Alfonso et al. 2020). A portion of a domestic building attributed to KH-P II was exposed in the lower town (operation D), built on top of an earlier (KH-P III) construction phase (Highcock et al. 2015).

The currently available evidence points to an occupation hiatus of the citadel extending from the end of the Late Hellenistic (around the end of the first century BCE) to the Seljuk and Ottoman habitation phases (Period KH-P I; 1200–1450 CE). No evidence of Roman and Late Antique occupation is known to date from the mound, although Late Roman/Early Byzantine surface materials are found in the lower town, which was thus possibly in part settled during Late Antiquity (d'Alfonso and Castellano 2018). Substantial evidence dated to KH-P I is limited to operation B (Highcock et al. 2015). Considering the poor architectural configuration—pit-houses, animal enclosures, and structure interpreted as retaining walls for tents—this latest settlement is to be considered a modest village (d'Alfonso et al. 2017; Highcock et al. 2015), possibly a seasonal campsite.

Materials and methods

Sampling and sample preparation

In planning sampling for this study, it was decided to cover as much as possible the different array of depositional contexts exposed during the excavation, as opposed to selecting only domestic trash deposits. The latter are traditionally favored in anthracological research, in light of their long-term deposition and the assumed lack of taxonomic firewood selection in domestic fires (Chabal 1992). While those methods have proven to be extremely successful in pre- and protohistoric contexts (Asouti and Austin 2005), their suitability and applicability to urban sites need to be critically assessed on a case by case basis, first and foremost considering the diverse functional organization of the urban space (e.g., Novak 1999). At Niğde-Kınık Höyük, during most of its history, at least in the areas investigated to date, the citadel was in large part occupied by public infrastructure, large-scale storage, cultic, and production areas. At present, truly domestic trash deposits have yet to be exposed, most likely to be found in the largely unexplored lower town. The sampling strategy adopted thus reflects the variety of stratigraphic contexts exposed through excavation. The incorporation of samples that originated from different functional and depositional contexts is expected to

correspond to a degree of sample-specific variability (Chabal 1992; Asouti and Austin 2005), which must be accounted for in the quantitative evaluation of the results obtained.

This study presents the analysis of 174 samples, resulting from 2214 L of sampled sediment (Table S11). Samples were selected in order to represent the different occupation periods and depositional contexts exposed to date (Table 1). The samples included in this research originated from the different excavation areas (Fig. 5), although thus far not all the occupation periods are either present or reached in all the trenches (d'Alfonso and Castellano 2018). The availability of Late Bronze Age (KH-P VI) samples is conditioned by the currently limited exposure of those levels (d'Alfonso and Castellano 2018). No samples are currently available for the Middle (KH-P VII) and Early (KH-P VIII) Bronze Age.

Following anthracological literature (Chabal 1992; Chabal et al. 1999; Asouti and Austin 2005), the sampled stratigraphic units are classified as long-term (here represented by accumulation layers and pit fills) and short-term (here represented by pyrotechnic structure fills, occupation layers, and burnt layers) deposits (Table 1). The charcoal fragments found in short-term deposits correspond to in situ concentrations resulting from single/few fire events (primary refuse), while in long-term deposits charcoal fragments are dispersed in the unit matrix (Chabal 1992) and interpreted to originate from multi-episodic depositions (secondary refuse) (Asouti and Austin 2005). The latter deposits are to be favored in order to investigate general patterns of firewood use through time (Chabal 1992; Chabal et al. 1999; Asouti and Austin 2005). In this study, samples from short-term contexts are used to corroborate and integrate the anthracological results from secondary refuse deposits. Furthermore, in a subsequent stage of the archeobotanical project, a sample-by-sample comparison of anthracological and carpological data from in situ concentrations will allow to better characterize and understand the range of pyrotechnic activities occurring at the site.

Context size permitting, samples were collected as 3 to 5 large plastic bags of sediment for each sampled stratigraphic unit, averaging ~ 13 L/sample. The sample size of 10–15 L was chosen following a preliminary evaluation that averages botanical macroremain content (wood charcoal and seed/fruit), and with the aim of sampling a diverse set of areas and contexts across the site. Samples were processed through manual (wash-over technique and bucket flotation; Pearsall 2000) and machine-assisted (Siraf-Type flotation machine; Williams 1973) flotation (Table S11), the latter introduced at a successive stage in the project. The heavy fraction resulting from flotation was screened in order to collect any non-floating charcoal fragment. Once extracted and dried, the organic floated debris was sorted through 4-, 2-, 1-, 0.5-, and 0.25-mm geological sieves.

Table 1 Kınık Höyük occupation periods and number of samples/charcoal considered in this study. Sample (charcoal), number of samples (number of charcoal) analyzed; Sample-by-sample information

KH-period	Conventional period	Date	Samples (charcoal)	Samples provenience
KH-P I	Seljuk/Early Ottoman	1200–1450 CE	25 (444)	Excavation area: B (25) Long-term deposits (17), short-term deposits (8)
KH-P II	Late Hellenistic	200–1 BCE	41 (1405)	Excavation areas: A (19), B (19), D (3) Long-term deposits (21), short-term deposits (20)
KH-P III	Achaemenid/Hellenistic	500–200 BCE	56 (2328)	Excavation areas: A (24), B (13), D (19) Long-term deposits (32), short-term deposits (20)
KH-P IV	Neo Hittite and LIA I	800–500 BCE	31 (1461)	Excavation areas: A (8), C (23) Long-term deposits (25) short-term deposits (6)
KH-P V	Post Hittite (EIA and MIA I)	1200–800 BCE	19 (1049)	Excavation areas: A (6), C (13) Long-term deposits (17), short-term deposits (2)
KH-P VI	Late Bronze Age (LBA)	1500–1200 BCE	2 (92)	Excavation area: C (2) Long-term deposits (2)
KH-P VII	Middle Bronze Age (MBA)	2000–1600 BCE	–	No samples available to date
KH-P VIII	Early Bronze Age (EBA)	3000–2000 BCE	–	No samples available to date

Table 1 summarizes the number of samples available for each occupation period, excavation area, and stratigraphic context type. Detailed sample-by-sample information is provided in Table SII.

Lab protocol

Because of the abundance of medium-large sized charcoal fragments (average > 4-mm fraction 6.86 g charcoal/10 L of sediment), analysis of the 2-mm fraction was not considered necessary, reducing the number of unidentifiable fragments due to small specimen size (Asouti and Austin 2005). The study was thus conducted exclusively on the > 4-mm fraction. Charcoal fragments were viewed in three sections, having been manually broken and observed under an optical episcopic microscope (Meiji MT7530) equipped with $\times 5$, $\times 10$, $\times 20$, $\times 50$ lenses and a brightfield-darkfield illumination system. For part of the photographic documentation, a Hitachi TM3000 tabletop scanning electron microscope was employed. For taxon identification, the author's modern reference collection (housed at New York University) and specialized literature (e.g., Akkemik and Barbanos 2012; Fahn et al. 1986; Schweingruber 1990) were used. Botanical identification criteria, phytogeographic assumptions, and candidate taxa in the current Turkish flora are provided in Table SI2.

All the charcoal fragments present in the > 4-mm fraction were analyzed, with the only exception of 15 samples subjected to subsampling: the analysis was stopped at 50 (4 samples) and 75 (1 sample) fragments in samples very strongly dominated by a single taxon (i.e., accounting for the 97–100% of the total); in 10 samples particularly rich in charcoal, the first 100 (7 samples) and 200 (3 samples) fragments were

analyzed. These arbitrary cut-off values were chosen for the purpose of efficiency, considering previous anthracological research. A 100-fragment subsample has been suggested as satisfactory to capture the floristic richness in temperate environments (Keepax 1988), whereas higher counts are to be favored in regions characterized by greater floristic diversity (Chabal et al. 1999; Asouti and Austin 2005). Recent research conducted in Central Anatolia confirms the overall adequacy of a 100-fragment cut-off value, although minor taxa could result partially undercounted (Wright et al., 2015 and 2017).

The number of charcoal fragments analyzed in each sample is reported in Table SII, together with other quantitative data.

Quantification and elaborations

Identified taxa were quantified using ubiquity, absolute count, and relative (percentage) abundance. As expected (after Chabal 1992), relative abundances calculated on the basis of weights and counts are very strongly correlated ($R = 0.95$, Fig. 6), with only minor discrepancies indicating atypical sample-specific taphonomic and/or depositional processes. Hence, the two values are here considered equivalent. Raw data are provided both in form of weight and fragment count (Table SI3), with the latter values chosen for use in figures and analysis due to their standard use in the majority of the anthracological literature. Relative (percentage) abundances were calculated including unidentifiable fragments in the sum.

The identified taxa are grouped following mixed ecological and economic criteria. A precise ecological grouping of the identified flora is hampered by the cosmopolitan character of several taxa and the taxonomic level of some identifications

(Table S12). Considering those limits, taxa are assigned to six main analytical groups: (i) conifers, which includes all the needle-leaved trees regardless of ecology; (ii) cold-deciduous broadleaf forest taxa, oak dominated; (iii) riparian woodland vegetation, Salicaceae dominated; (iv) economic trees, accounting for taxa potentially bearing edible fruits/products of known economic importance in Anatolia; (v) woody herbs and small shrubs; and (vi) taxa regarded here as exotic on the basis of their current distribution and ecological requirements (Davis 1965–1985).

The anthracological results were subjected to multivariate ordination analysis, aiming to further explore the patterns and trends present in the dataset. In order to limit redundancy and noise, samples with fewer than 15 charcoal analyzed were excluded from the data matrix, unsure identifications (cf) were removed, and if needed, identifications were harmonized to the lowest taxonomic level present (e.g., *Celtis* sp., *Ulmus* sp. → Ulmaceae). Following Legendre and Birks (2012), in order to decide whether to employ a linear or unimodal ordination method, the length of the gradient in the dataset was calculated through a Detrended Correspondence Analysis (DCA). As a rule of thumb, if the gradient length is less than 2.5 SD units, a linear approach (Principal Component Analysis, PCA) might be considered appropriate, while unimodal methods (Correspondence Analysis, CA; or DCA) are generally to be favored for gradients longer than 3.0 SD (Legendre and Birks 2012). A DCA of the data matrix returned a gradient length of 2.5 SD, thus warranting the use of either a linear or unimodal method. Following testing, PCA was chosen on the basis of a better performance in explaining the variance in the dataset.

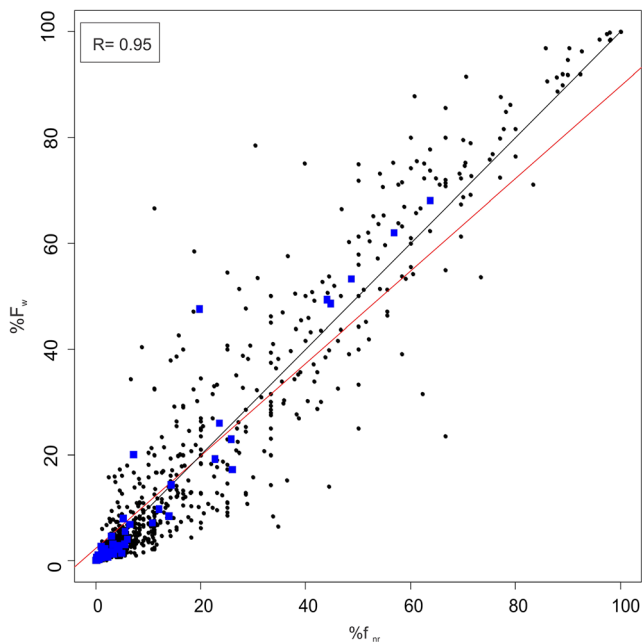


Fig. 6 Correlation plot between percentages calculated on the basis of fragment counts (%F_{fr}) and weight (%F_w). Black dots represent single taxa within a sample, blue squares single taxa within an occupation period

Prior to the analysis, abundance count values were subjected to Hellinger transformation, a recommended step for the ordination of species abundance data through linear models (Legendre and Gallagher 2001; Borcard et al. 2011; Legendre and Birks 2012). PCA was computed on the covariance matrix. Results are presented as correlation biplot (‘scaling 2’ in Oksanen et al. 2019), thus maintaining the angle between descriptor vectors (species) reflecting their correlation. Following initial screening, 6 samples highly dominated by single taxa (respectively 88%, 93%, 97%, 98% of *Vitis*; 100% of *Amygdalus*-type; and 98% of Salicaceae) were considered extreme values and excluded from the final computation. Multivariate analysis was carried out in R 3.5.1 package Vegan version 2.5.5 (Oksanen et al. 2019).

Results

Following the aforementioned methodology, 6779 charcoal fragments from 174 samples were analyzed, resulting in the identification of 29 taxa (Table 2; Figs. 7 and 8). Results are provided in Table S13 (sample-by-sample raw data) and graphically presented in Fig. 9. Samples from short-term and long-term deposits (as defined in the previous section) were analyzed separately, considering the better suitability of the latter to provide general patterns of firewood use through time (Chabal 1992; Chabal et al. 1999; Asouti and Austin 2005). Accordingly, in the following paragraphs, the cumulative values (percentage abundance and ubiquity scores) provided for each occupation period are based exclusively on samples from long-term deposits (Table 3, Fig. 10).

Period KH-P VI (Late Bronze Age; ca. 1600–1200 BCE). Only two samples are available for this occupation period (total 92 charcoal fragments), originating from strata reached at the bottom of a deep trench in operation C. A low floristic diversity was detected (9 taxa identified), likely resulting from the low number of samples available and the low fragment count. *Quercus* spp. deciduous (deciduous oaks) is the dominant taxon (abundance 63%, calculated on the basis of fragment counts), followed by *Juniperus* sp. (juniper; 12%) and Salicaceae (willow/poplar; 5%). Other taxa are only sporadically attested (Table 3).

Period KH-P V (Early-Middle Iron Age; ca. 1200–800 BCE). 17 samples from long-term deposits were analyzed (total 899 fragments). The floristic diversity increases (19 taxa), likely reflecting the increased number of samples and specimens analyzed. *Quercus* spp. deciduous remains the dominant taxon (abundance 55%, ubiquity 100%), followed by Salicaceae (a. 16%, u. 88%). Conifers are well represented by *Juniperus* sp. (a. 8%, u. 88%) and *Pinus nigra*-type (Scots/black pine; a. 5%, u. 71%). Sporadic fragments of *Pinus brutia*-type (Aleppo/Turkish pine; 1 fragment) and *Abies* sp. (fir; 6 fragments, from 2 samples) charcoal are present. *Vitis*

Table 2 List of the anthracological taxa identified at Kınık Höyük, English common names, and analytical group. *C*, conifers; *B*, cold-deciduous broadleaf forest taxa; *R*, riparian woodland vegetation; *S*, woody herbs and small shrubs; *E*, economic taxa (as defined in the Materials and methods section); *Ex*, possible exotic taxa. Information on identification criteria, phytogeographic assumptions, and candidate species in the Anatolian flora are provided in Supplementary Table S12

Taxa	Common name	Group
<i>Abies</i> sp.	Fir	C
<i>Cedrus</i> sp.	Cedar	C
<i>Pinus nigra</i> -type	Scots or black pine	C
<i>Pinus brutia</i> -type	Turkish or Aleppo pine	C
<i>Juniperus</i> sp.	Juniper	C
<i>Quercus</i> spp. deciduous	Deciduous oaks	B
<i>Hippophae rhamnoides</i>	Seaberry	B
<i>Acer</i> spp.	Maple	B
<i>Ostrya carpinifolia</i>	Hop-hornbeam	B
<i>Rhamnus</i> sp.	Buckthorn	B
Salicaceae	Willow/Poplar	R
<i>Tamarix</i> sp.	Tamarisk	R
<i>Celtis</i> sp.	Hackberries	R
<i>Ulmus</i> sp.	Elm	R
<i>Buxus sempervirens</i>	Boxwood	Ex
Asteraceae-type	Aster family type	S
<i>Euphorbia</i> sp.	Spurges	S
Chenopodiaceae	Goosefoot family	S
Monocotyledonae	Monocots	S
Cf <i>Ficus carica</i>	Common fig (tentative)	E
<i>Fraxinus angustifolia/ornus</i>	Narrow-leaved or manna ash	E
<i>Elaeagnus angustifolia</i>	Russian olive	E
<i>Juglans regia</i>	Walnut	E
<i>Morus</i> sp.	Mulberry	E
Maloideae	Apple subfamily	E
<i>Pistacia</i> sp.	Pistachio	E
<i>Amygdalus</i> -type	Almond type	E
<i>Prunus</i> -type	Plums type	E
<i>Vitis vinifera</i>	Grapevine	E

vinifera (grapevine) is documented for the first time (10 fragments, u. 29%). *Pistacia* sp. (pistachio) is attested in low abundance (16 fragments) but high ubiquity (53%). Other taxa are represented sporadically (Table 3). Two additional samples (total 150 fragments analyzed) from burnt layers in operation C were analyzed; both samples are highly dominated by Salicaceae charcoal (respectively, 77% and 98%) (Fig. 9).

Period KH-P IV (Middle-Late Iron Age; ca. 800–500 BCE). 25 samples from long-term deposits are available for this period, with a total of 1240 charcoal fragments analyzed. The floristic diversity is stable (18 taxa). As in the previous phases, *Quercus* spp. deciduous is the dominant taxon, although with a slight decrease in abundance (a. 41%, u.

100%), followed by Salicaceae (a. 28%, u. 76%). Conifers drop in abundance, mostly represented by *Juniperus* sp. (a. 3%, u. 64%) and *Pinus nigra*-type (a. 3%, u. 56%). *Pinus brutia*-type (2 fragments, from 2 samples), *Abies* sp. (1 fragment), and *Cedrus* sp. (cedar; 3 fragments, from 3 samples) are only sporadically attested. *Vitis vinifera* increases both in terms of abundance and ubiquity (a. 2%, u. 44%), as does Maloideae (a. 8%, u. 52%). Among minor taxa, we find the first attestation of *Fraxinus angustifolia/ornus* (narrow-leaved/manna ash; 1 fragment) and *Hippophae rhamnoides* (seaberry; 2 fragments, from 1 sample) (Table 3). Six further samples were analyzed from short term deposits (total 221 charcoal fragments analyzed), collected from pyrotechnic installations (2 samples) and occupation layers (4 samples) (Fig. 9). Worthy of note is a sample (KIN18C2874s5) from an occupation layer in operation C returning particularly high values of *Vitis vinifera* charcoal (47%) (Fig. 9).

Period KH-P III (Achaemenid-Early Hellenistic; ca. 500–200 BCE). From this period, 2056 charcoal fragments from 36 long-term deposit samples were analyzed. The floristic diversity significantly increases (27 taxa). *Quercus* spp. deciduous remains dominant (a. 57%, u. 100%). A significant drop in frequencies is documented for the Salicaceae family (a. 4%, u. 62%). Conifers continue a decreasing trend, now being only sporadically attested: *Pinus nigra*-type (3 fragments, from 3 samples), *Pinus brutia*-type (1 fragment), *Abies* sp. (2 fragments, from 2 samples), *Cedrus* sp. (1 fragment), and *Juniperus* sp. (4 fragments, from 3 samples). Remarkable is the rise of grapevine, both in terms of abundance and ubiquity (a. 16%, u. 78%), coupled by a generalized increase of other economic taxa. Among these are the first attestations of *Elaeagnus angustifolia* (Russian olive; 14 fragments, from 6 samples) and *Juglans regia* (walnut; 3 fragments, from 2 samples). Among minor taxa, an increase in *Hippophae rhamnoides* charcoal (15 fragments, from 4 samples) and Chenopodiaceae (12 fragments, from 9 samples) is noted (Table 3). Twenty additional samples from short-term deposits were analyzed (total 272 charcoal fragments), including pyrotechnic installations (12 samples) and occupation layers (6 samples) (Table S13). The samples available from occupation layers (5 samples) and pyrotechnic installations (8 samples) in the domestic building in operation D are composed almost exclusively of ash with the sporadic presence of macroscopic charcoal: only one sample returned more than 10 charcoal fragments in the > 4-mm fraction (sample KIN14D1166s138, from the fill of an oven). In this sample, atypical is the abundance of Asteraceae-type (8 fragments). Short-lived samples from operation B stand out for comparatively high counts of *Hippophae rhamnoides* (Fig. 9).

Period KH-P II (Late Hellenistic; ca. 200–1 BCE). 755 charcoal fragments from 22 samples originating from long-term deposits were analyzed, which show continuity with the previous period. *Quercus* spp. deciduous is the dominant

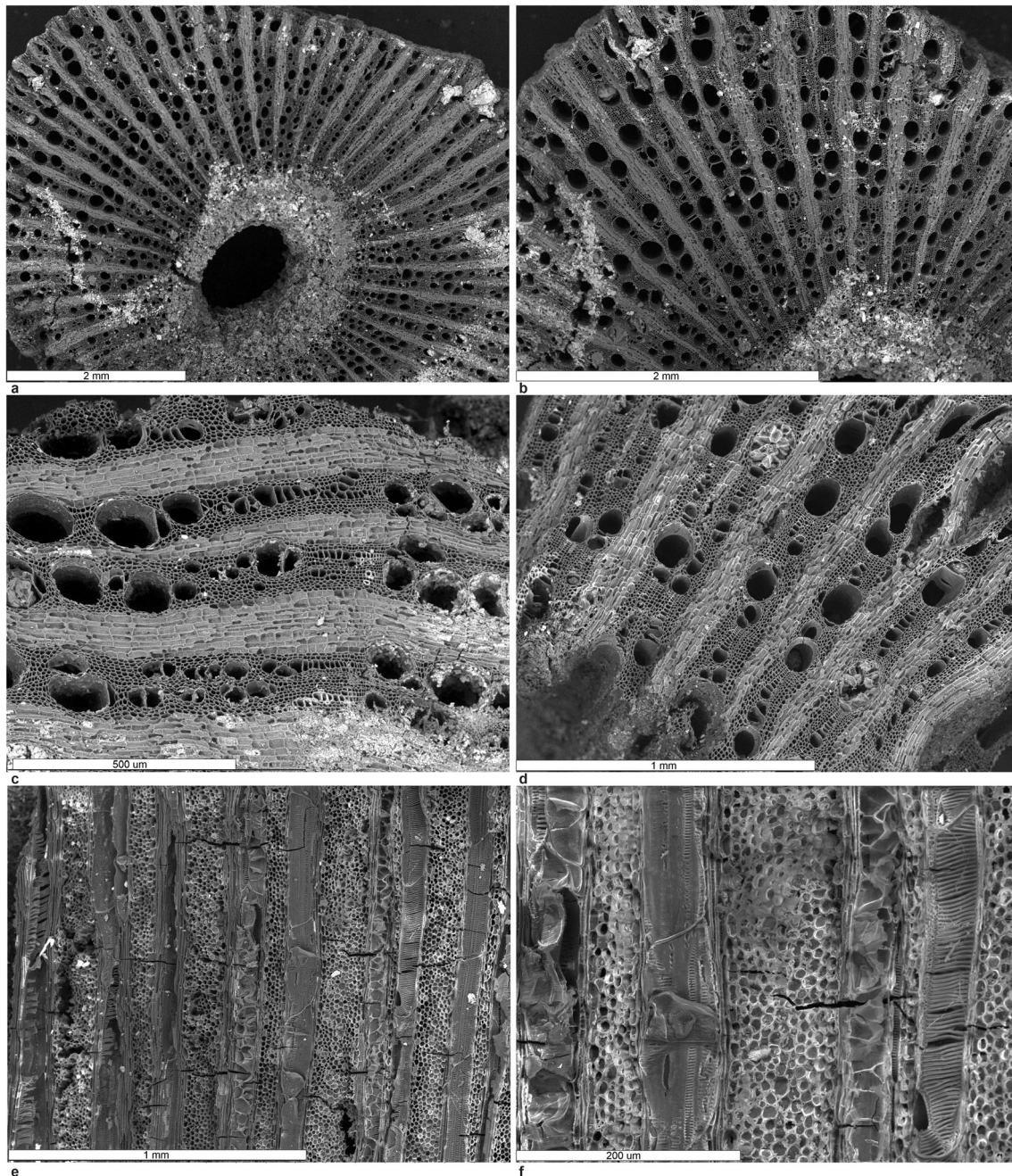


Fig. 7 SEM photos of *Vitis Vinifera* (grapevine) charcoal from Kınık Höyük. **a** Transversal section, sample KIN13B608s39; note “flattened zone” with atypical porosity in the upper right corner of the image. **b** Detail of (a). **c** Transversal section, sample KIN14A146s61. **d**

Transversal section, sample KIN18A1987s73. **e** Tangential section, sample KIN18A1987s73. **f** Detail of (e); note scalariform intervacular pits

taxon (a. 51%, u. 86%) and Salicaceae remain stable at low values (a. 4%, u. 52%). Conifer charcoal is still poorly attested: *Pinus nigra*-type (3 fragments, from 3 samples), *Pinus brutia*-type (5 fragments, from 3 samples), and *Juniperus* sp. (5 fragments, from 2 samples). Economic taxa continue their increasing trend, with *Vitis vinifera* charcoal reaching percentage fragments counts of 26% and a ubiquity score of 48% (Table 3). Overall a higher degree of sample variability is registered, both among and within the different

excavation areas (Fig. 9). Twenty additional samples (648 charcoal fragments) from short-term deposits were analyzed. Notable is the presence of *Abies* sp. (KIN14B2032s135_a) and *Juglans regia* (KIN14B2032s135) in these samples, taxa otherwise unattested during this occupation period (Fig. 9). Samples from fire residues associated with a hearth in operation A (KIN14A1540s98) and the fill of an oven excavated in operation D (KIN13D1070s71) are both dominated by *Vitis vinifera* charcoal (respectively 97% and 93%) (Fig. 9).

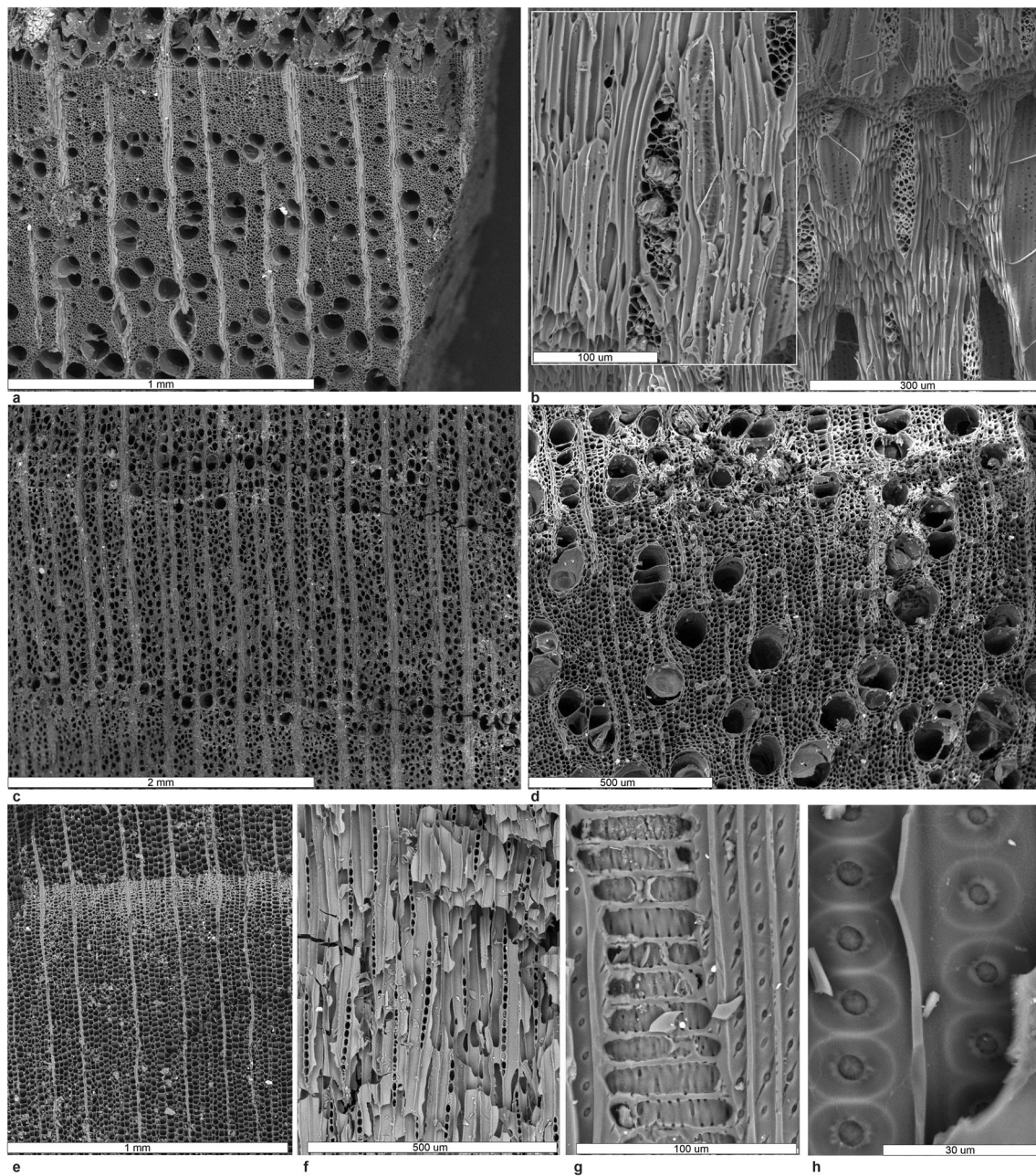


Fig. 8 SEM photos of wood charcoal of selected taxa. **a** Transversal section of *Elaeagnus angustifolia* (Russian olive), sample KIN14B870s23. **b** Tangential section of *Elaeagnus angustifolia* (Russian olive), sample KIN14B870s23. In the inset, it is possible to notice a fine spiral thickening in a latewood vessel. **c** transversal section of *Amygdalus*-type (almond type), sample KIN12B727s417. **d**

Transversal section of *Juglans regia* (walnut), sample KIN14B2052s135a. **e** Transversal section of *Abies* sp. (fir), sample KIN18C2897s35. **f** Tangential section of *Abies* sp. (fir), sample KIN18C2897s35. **g** Radial section of *Abies* sp. (fir), sample KIN18C2897s35. **h** Radial section of *Cedrus* sp. (cedar), sample KIN17C2812s39; note scalloped tori

Period KH-PI (Seljuk-Early Ottoman; ca. 1200–1450 CE). After a possible hiatus following the end of the Late Hellenistic occupation, the mound was resettled in the late Medieval period (“The archeological site of Niğde-Kınık Höyük”). For this period 293 charcoal fragments from 17 long-term deposit samples were analyzed resulting in 21 taxa identified. *Quercus* spp. deciduous for the first time experienced a significant drop (a. 23%, u. 59%), while Salicaceae

charcoal increased in frequency (a. 19%, u. 76%). *Abies* sp. and *Cedrus* sp. are no longer attested, while an increase is evident for *Pinus nigra*-type (a. 6%, u. 35%). *Pinus brutia*-type is only sporadically attested (7 fragments, from a single sample). Economic taxa remain quantitatively important, with *Amygdalus*-type (almond type) experiencing an increase (a. 6%, u. 35%). *Vitis vinifera* charcoal is still frequently attested (a. 13%, u. 59%), although in lower values than previously.

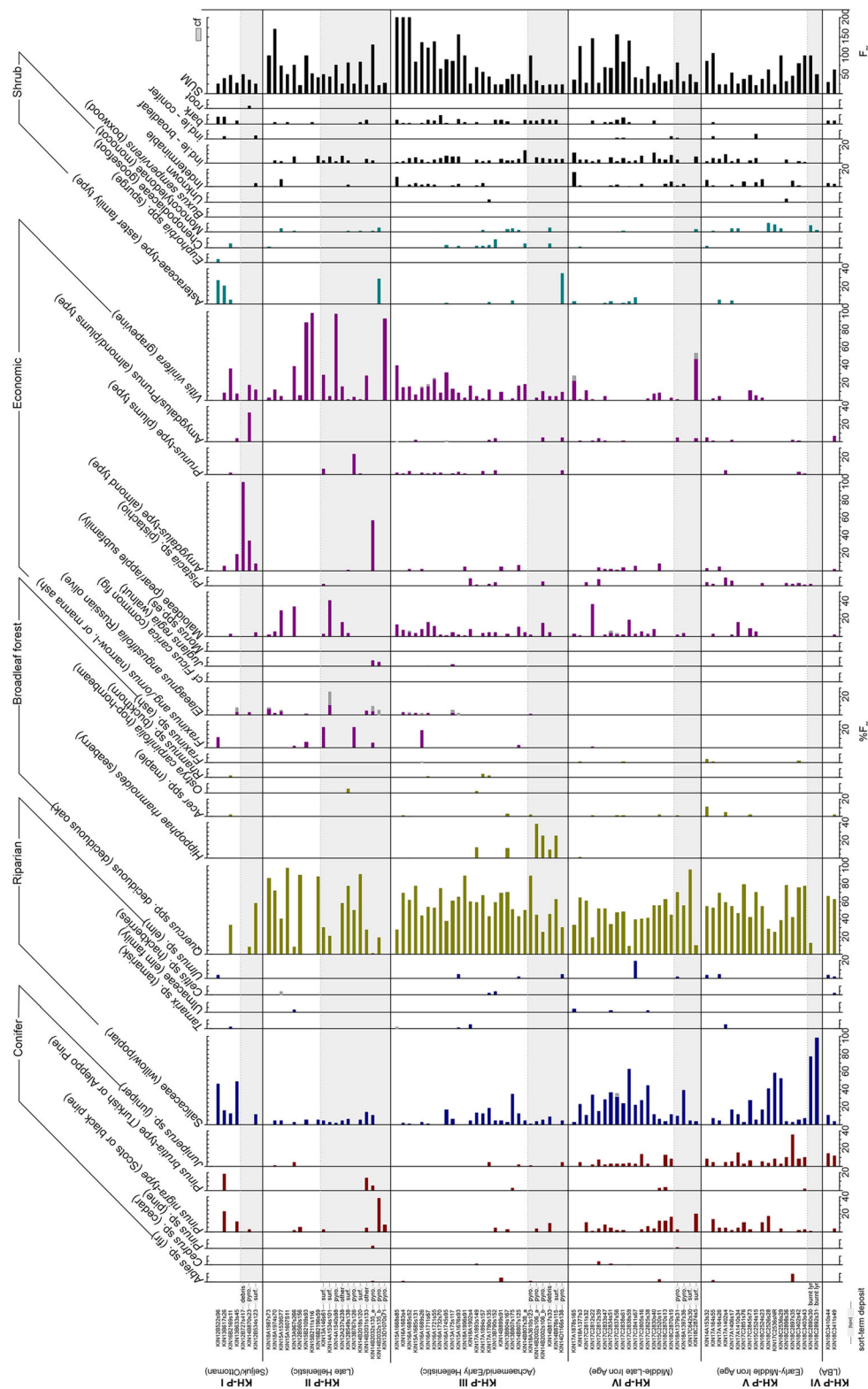


Fig. 9 Plot of the anthracological results. Only samples with more than 20 charcoal fragments analyzed are represented. The graph is based on relative abundances (%), calculated on the basis of fragment counts and including in the sum indeterminate fragments. Samples from short-term and long-term deposits are distinguished; the former are represented at the beginning of each occupation period on a gray background. As the samples originate from different excavation areas without physical

continuity, within each period samples are ordered according to operation and secondarily to their stratigraphic position. The following taxa are attested exclusively in samples with less than 20 fragments analyzed: *Buxus* sp. (KIN16D2416s37, KH-P III), cf *Ficus carica* (KIN15D2379s117, KH-P III), and *Morus* sp. (KIN13B762s122 and KIN15B2082s42, KH-P I)

Table 3 Absolute count (A_{long}), relative percentage abundance ($\%U_{long}$), absolute ubiquity (U_{long}), and percentage ubiquity score ($U\%_{long}$) for long-term deposit samples (secondary refuse) grouped by occupation periods. Sample-by-sample results are available in Supplementary Table S13

Taxon (English name)	KH-P I			KH-P II			KH-P III			
	Seljuk/Early Ottoman			Late Hellenistic			Achaemenid/Hellenistic			
	A_{long}	$A\%_{long}$	$U\%_{long}$	A_{long}	$A\%_{long}$	$U\%_{long}$	A_{long}	$A\%_{long}$	$U\%_{long}$	
Conifers										
<i>Abies</i> sp. (fir)	—	—	—	P	P	P	2	0.10	2	6.25
<i>Cedrus</i> sp. (cedar)	—	—	—	—	—	—	1	0.05	1	3.13
<i>Pinus</i> sp. (pine)	—	—	—	P	P	P	—	—	—	—
<i>Pinus nigra</i> -type (Scots or black pine)	19	6.48	35.29	3	0.40	3	3	0.15	3	9.38
<i>Pinus brutia</i> -type (Turkish or Aleppo pine)	7	2.39	5.88	5	0.66	3	1	0.05	1	3.13
<i>Juniperus</i> sp. (juniper)	—	—	—	5	0.66	2	4	0.19	3	9.38
Riparian vegetation										
Salicaceae (willow family)	56	19.11	76.47	29	3.84	11	88	4.28	20	62.50
cf Salicaceae (cf willow family)	—	—	—	—	—	—	—	—	—	—
<i>Tamarix</i> sp. (tamarisk)	1	0.34	5.88	—	—	—	2	0.10	2	6.25
cf <i>Tamarix</i> sp. (cf tamarisk)	—	—	—	—	—	—	4	0.19	1	3.13
Ulmaceae (elm family)	—	—	—	2	0.26	1	—	—	—	—
<i>Celtis</i> sp. (hackberries)	—	—	—	—	—	—	2	0.10	2	6.25
cf <i>Celtis</i> sp. (cf hackberries)	—	—	—	3	0.40	1	—	—	—	—
<i>Ulmus</i> sp. (elm)	1	0.34	5.88	2	0.26	2	8	0.39	2	6.25
Deciduous forest-scrub										
<i>Quercus</i> spp. deciduous oaks)	68	23.21	58.82	385	50.99	18	1162	56.52	32	100.00
<i>Hippophae rhamnoides</i> (seaberry)	—	—	—	—	—	—	15	0.73	4	12.50
<i>Acer</i> spp. (maple)	2	0.68	11.76	1	0.13	1	5	0.24	3	9.38
<i>Ostrya carpinifolia</i> (hop-hornbeam)	—	—	—	P	P	P	1	0.05	1	3.13
<i>Rhamnus</i> sp. (buckthorn)	1	0.34	5.88	—	—	—	4	0.19	3	9.38
<i>Fraxinus</i> sp. (ash)	1	0.34	5.88	—	—	—	—	—	—	—
cf <i>Fraxinus</i> sp. (cf ash)	—	—	—	—	—	—	1	0.05	1	3.13
Economic trees										
<i>Fraxinus angustifolia</i> (narrow-l. or manna ash)	3	1.02	5.88	7	0.93	2	27	1.31	2	6.25
<i>Elaeagnus angustifolia</i> (Russian olive)	12	4.10	41.18	18	2.38	7	14	0.68	6	18.75
cf <i>Elaeagnus angustifolia</i> (cf Russian olive)	1	0.34	5.88	2	0.26	2	7	0.34	4	12.50
cf <i>Ficus carica</i> (cf common fig)	—	—	—	—	—	—	1	0.05	1	3.13
<i>Juglans regia</i> (walnut)	1	0.34	5.88	P	P	P	3	0.15	2	6.25
<i>Morus</i> sp. (mulberry)	5	1.71	11.76	—	—	—	—	—	—	—
Maloideae (apple subfamily)	10	3.41	29.41	56	7.42	4	123	5.98	21	65.63
cf Maloideae (cf apple subfamily)	—	—	—	—	—	—	1	0.05	1	3.13
<i>Pistacia</i> sp. (pistachio)	P	P	P	—	—	—	5	0.24	4	12.50
<i>Amygdalus</i> -type (almond type)	16	5.46	35.29	P	P	P	14	0.68	5	15.63
<i>Prunus</i> -type (plums type)	1	0.34	5.88	P	P	P	29	1.41	12	37.50
<i>Amygdalus/Prunus</i> (almond/plums type)	6	2.05	29.41	1	0.13	1	6	0.29	5	15.63
cf <i>Prunus</i> -type (cf plums genus)	2	0.68	11.76	—	—	—	2	0.10	2	6.25
<i>Vitis vinifera</i> (grapevine)	37	12.63	58.82	197	26.09	10	322	15.66	25	78.13
cf <i>Vitis vinifera</i> (cf grapevine)	—	—	—	—	—	—	4	0.19	3	9.38
Shrubs										
Asteraceae-type (aster family type)	22	7.51	35.29	P	P	P	4	0.19	3	9.38

Table 3 (continued)

Taxon (English name)	KH-P IV		KH-P V		KH-P VI	
	A _{long}	U _{%long}	A _{long}	U _{%long}	A _{long}	U _{%long}
	Neo Hittite and LIA I		Post Hittite (EIA and MIA I)		Late Bronze Age	
	A _{long}	U _{%long}	A _{long}	U _{%long}	A _{long}	U _{%long}
Conifers						
<i>Abies</i> sp. (fir)	1	0.08	6	0.67	—	—
<i>Cedrus</i> sp. (cedar)	3	0.24	—	—	—	—
<i>Pinus</i> sp. (pine)	P	P	—	—	—	—
<i>Pinus nigra</i> -type (Scots or black pine)	43	3.47	45	5.01	2	2.17
<i>Pinus brutia</i> -type (Turkish or Aleppo pine)	2	0.16	1	0.11	—	—
<i>Juniperus</i> sp. (juniper)	43	3.47	68	7.56	11	11.96
Riparian vegetation						
Salicaceae (willow family)	354	28.55	145	16.13	5	5.43
cf Salicaceae (cf willow family)	5	0.40	—	—	—	—
<i>Tamarix</i> sp. (tamarisk)	—	—	1	0.11	—	—
cf <i>Tamarix</i> sp. (cf tamarisk)	—	—	—	—	—	—
Ulmaceae (elm family)	3	0.24	—	—	—	—
<i>Celtis</i> sp. (hackberries)	—	—	—	—	—	—
cf <i>Celtis</i> sp. (cf hackberries)	—	—	—	—	—	—
<i>Ulmus</i> sp. (elm)	8	0.65	4	0.44	2	2.17
Deciduous forest-scrub						
<i>Quercus</i> spp. deciduous (deciduous oaks)	510	41.13	498	55.39	58	63.04
<i>Hippophae rhamnoides</i> (seaberry)	2	0.16	—	—	—	—
<i>Acer</i> spp. (maple)	4	0.32	11	1.22	1	1.09
<i>Ostrya carpinifolia</i> (hop-hornbeam)	—	—	—	—	—	—
<i>Rhamnus</i> sp. (bue kthorn)	—	—	—	—	—	—
<i>Fraxinus</i> sp. (ash)	2	0.16	5	0.56	—	—
cf <i>Fraxinus</i> sp. (cf ash)	—	—	—	—	—	—
Economic trees						
<i>Fraxinus angustifolia</i> (narrow-l. or manna ash)	1	0.08	—	—	—	—
<i>Elaeagnus angustifolia</i> (Russian olive)	—	—	—	—	—	—
cf <i>Elaeagnus angustifolia</i> (cf Russian olive)	—	—	—	—	—	—
cf <i>Ficus carica</i> (cf common fig)	—	—	—	—	—	—
Exotic taxa						
<i>Buxus sempervirens</i> (boxwood)	—	—	—	—	P	P
Indeterminable charcoals						
Unknown taxa	—	—	—	—	1	0.05
Indeterminable	1	0.34	7	0.93	48	2.33
Indeterminable broadleaf	7	2.39	16	2.12	75	3.65
Indeterminable conifer	1	0.34	—	—	—	—
Root broadleaf	P	P	—	—	—	—
Bark	6	2.05	6	0.79	47	2.29
Sums	293	17	755	21*	2056	32*

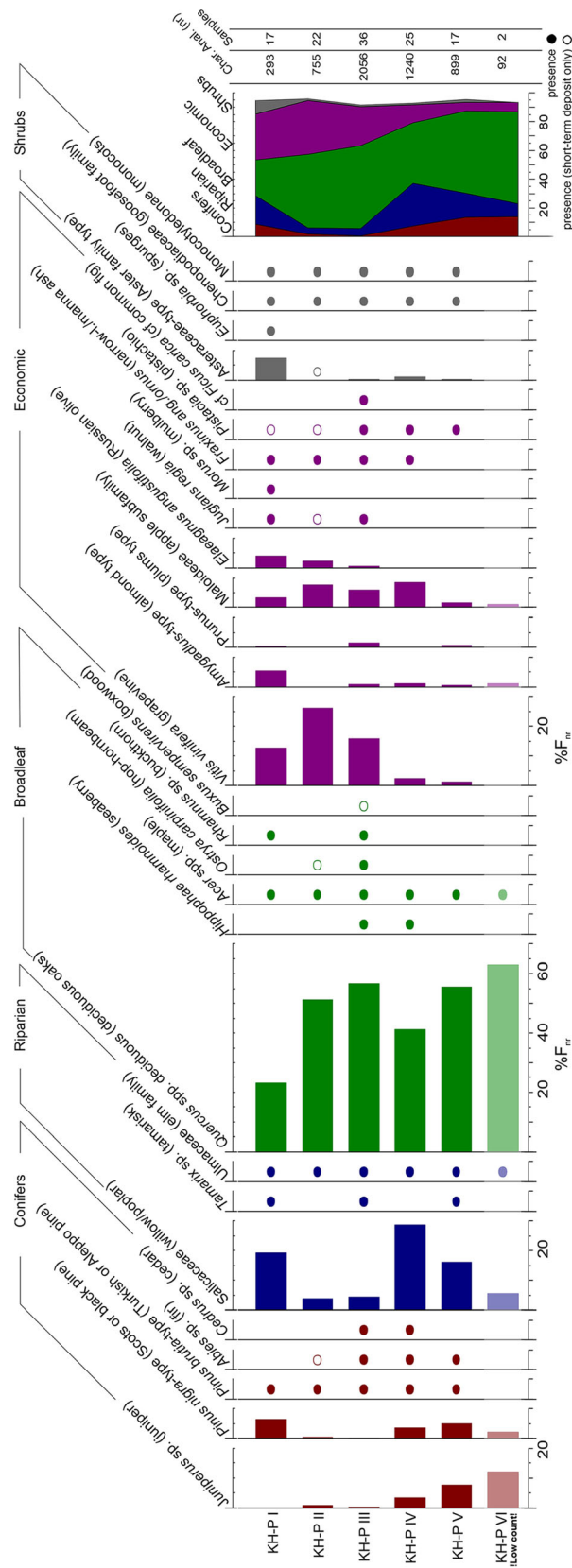


Fig. 10 Anthracological results of samples from long-term deposits (secondary refuse) grouped for occupation periods. Relative abundances are calculated for each occupation period on the basis of the fragment

counts (indeterminate fragments included in sum). Minor and secondary taxa are represented only as presence/absence.

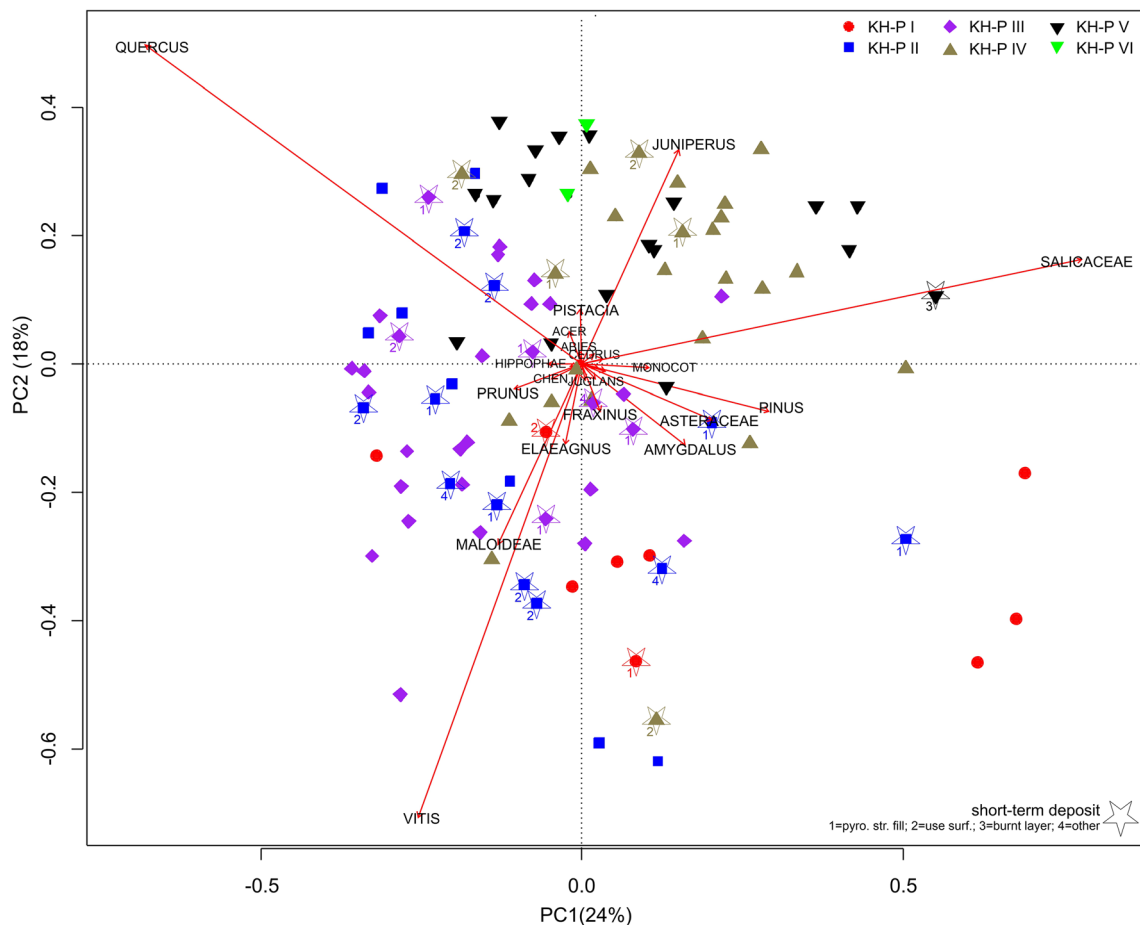


Fig. 11 PCA of the anthracological data from Kınık Höyük. Results are presented as correlation biplot (scaling 2), thus maintaining the angle between descriptor vectors (species) reflecting their correlation: small angles indicate high positive correlation, opposite angles high negative

correlation, right angles lack of correlation. Right-angled projections of a sample (point) on the vector of a taxon (descriptor) approximates the value of that taxon in the sample.

Asteraceae (Aster family) become relatively common (a. 8%, u. 35%). 8 additional samples (151 charcoal fragments) from short-term deposits were analyzed. These samples confirm the increased importance of *Amygdalus*-type (Fig. 9). Also notable is the presence of *Vitis vinifera* charcoal in samples collected from a hearth deposit (sample KIN14B870s23) and from an occupation layer (KIN12B534s123), demonstrating that grapevine charcoal in this level was not redeposited from earlier phases.

The multivariate plot (PCA) presented in Fig. 11 summarizes the main trends in the wood charcoal record from Niğde-Kınık Höyük. Samples from the earlier occupation periods (KH-P VI, V, and IV) cluster in the upper part of the diagram, defined by the presence of *Juniperus*. Their distribution on the PC1 axis mainly reflects the variable contribution of *Quercus*, *Salicaceae*, and—to a lesser extent—*Pinus*. Samples from the second half of the 1st millennium BCE (KH-P III and II) are characterized by a higher contribution of *Vitis*, which is negatively correlated with *Juniperus* and other minor taxa characteristic of the earlier portion of the sampled sequence (e.g.,

Acer, *Abies*, *Cedrus*, *Pistacia*), and positively correlated with the other main economic taxa, with the sole exception of *Amygdalus*-type. KH-P III and KH-P II samples are mostly located in the portion of the plot defined by negative values of PC1, thus associated with a lower contribution of *Salicaceae*. A clear distinction between the two periods is not evident, supporting a degree of similarity between these two occupation phases. The Late Medieval (KH-P I) samples are relatively scattered in the plot, mostly located by the PCA in the bottom right quadrant, defined by atypical low values of *Quercus* and a positive contribution of *Amygdalus*, *Asteraceae*, *Pinus*, and *Salicaceae*.

Discussion

General interpretation of the anthracological results

The wood charcoal assemblage from Niğde-Kınık Höyük is characterized by a remarkably high taxonomic diversity, with

29 identified taxa (Table 2), a value significantly higher than contemporary anthracological sequences from Central Anatolia—i.e., 22 taxa at Gordion, including exotic wood taxa from the tumuli (Marston 2017), and 19 taxa at Kaman-Kalehöyük (Wright et al. 2015 and 2017; Wright 2018). This floristic richness might be interpreted as resulting from the presence (and exploitation as firewood) of a more diverse and fragmented vegetation landscape. The diachronic changes detected through the sequence (Fig. 10) might reflect thus phases of expansion and retreat of those associations (Asouti and Austin 2005), or changes in preferences for the exploitation of some vegetation communities for fuel instead of others. Lacking evidence of non-native wood (with the only possible exception being sporadic *Buxus* charcoal; Davis 1982), non-local firewood resources are considered to have played a marginal role (if any) in the observed anthracological record.

Deciduous oaks are the dominant taxon throughout the sampled sequence. During the earliest periods (KH-P VI, V, IV), conifers (especially junipers and Scots/black pine) and riparian trees (mainly Salicaceae) are frequently attested (Fig. 10). Starting with period KH-P V, a steady increase in the relative abundance of economic tree charcoal (as defined in the Materials and methods section) is documented, reaching remarkably high values during the Achaemenid/Early Hellenistic (KH-P III) and Late Hellenistic (KH-P II) periods (Fig. 10). This trend is interpreted as resulting from an important phase of expansion of vineyards and orchards, promoting a systematic exploitation of pruning residues for fuel purposes. This phase of agrarian expansion might be connected to broader changes in the local vegetation, as discussed below.

Salicaceae (willow/poplar) charcoal is particularly abundant during periods KH-P V and KH-P IV (Fig. 10), indicating an intensive exploitation of riparian habitats for firewood purposes. This hydrophilous vegetation is expected to be associated with the Late Holocene remains of the paleolake (Bayer Altın et al. 2015; Matessi et al. 2018) and the number of streams discharging into it. An abrupt reduction in the relative abundance of Salicaceae charcoal is documented during period KH-P III and KH-P II, corresponding to the second half of the 1st millennium BCE (Fig. 10). To date, pending high-resolution local paleoclimatic data, a climatic explanation of this drop appears unlikely. Paleoclimatic evidence from the Cappadocian limnological sequences of Eski Acıgöl and Nar Gölü suggests the presence of an important dry phase at ca. 1200–900 BCE (Roberts et al. 2016), followed by a degree of amelioration in the climatic conditions and a more stable increase in the moisture balance during the second half of the 1st millennium BCE (Allcock 2017). Rather than to climatic factors, it is thus to date considered more plausible to ascribe the drop in Salicaceae either to changes in firewood preferences or to some forms of anthropic pressure on the riparian habitats. The latter hypothesis is consistent with the coeval evidence of intensification of arboreal crop cultivation (Fig.

10), which might be reasonably considered indicative of a more generalized expansion of the agricultural landscape.

Fruit tree farming in Central Anatolia generally necessitates a degree of irrigation during the summer dry months (Gorny 1995); it is thus possible that arboricultural expansion targeted areas in proximity to water sources, potentially resulting in partial clearance of the riparian vegetation. Furthermore, the hypothetical expansion and/or intensification of irrigation—due to the increased cultivation of water-demanding crops—could have caused a disruption in the natural hydrographic system, possibly resulting in a reduction of water entering the floodplain and consequently a contraction of the riparian habitats present in the proximity of the site. Pending geomorphological evidence, this hypothesis remains, however, speculative. Finally, the overexploitation of willows and poplars for firewood purposes during the Early and Middle Iron Age (KH-P V and KH-P IV) could have further contributed to their local decline. Although in lower quantities, Salicaceae charcoal is ubiquitously attested during KH-P III and KH-P II (Fig. 9), pointing to the continued presence of riparian woodlands within the firewood catchment area of the site. Considering the ability of these taxa to colonize and grow rapidly (e.g., Dickmann and Kuzovkina 2014), their continuous attestation in low numbers suggests an enduring anthropic pressure on these environments (Wright et al. 2015). Deciduous oaks, on the other hand, remain the dominant taxon throughout the 1st millennium BCE (Fig. 9), indicating that the nearby mountain slopes were still, at least partially, forested and that the oak woodland was systematically exploited as a major fuel source. A complete clearance of the oak forest during the 1st millennium BCE is thus not observed, in line with the anthracological evidence from Kaman-Kalehöyük (Wright et al. 2015).

After a hiatus in the archeological sequence following the end of the Late Hellenistic occupation (KH-P II), the mound was resettled in the Seljuk/Early Ottoman period (KH-P I). The very ephemeral architecture defining these latest phases—limited to animal enclosures, pit houses, and possible retaining walls for tents (Highcock et al. 2015; d'Alfonso et al. 2017)—suggests the presence of a very modest rural settlement, consistent with an interpretation of the village as a seasonal campsite. Changes in the anthracological sequence in this latest occupation of the mound are interpreted as due to changes in vegetation community structure, the nature of occupation at the site, and potentially also to different cultural preferences of the site's inhabitants. Crabtree and Campana (2014) identify changes in diet and economy, and on the basis of the absence of pig remains in the KH-P I zooarcheological record they suggest, with due caution, the presence of a Muslim village. Along these lines, the increased importance of *Amygdalus*-type charcoal (Fig. 9) could be due to cultural and economic orientations brought by the new groups

settling in this area. A degree of economic continuity is, however, documented by the continuous attestation of grapevine, although in lower frequencies than in previous periods (Fig. 10). The simultaneous drop in oak use, for the first time in the sampled sequence (Fig. 9), can be interpreted either as an indication of a significant contraction of the oak woodland directly impacting firewood availability or as resulting from the exploitation of the fuel resources available in the immediate proximity of the site rather than from the slopes of the surrounding mountains. The latter hypothesis would suggest a shift towards using immediately available resources rather than an organized year-round exploitation of a greater diversity of regional landscape units, in line with the predictive model proposed by Asouti and Austin (2005) for nomadic communities. A reduction of the oak forest, on the other hand, is consistent with the coeval palynological evidence from Nar Gölü, in the Göllüdağ region (England et al. 2008). Thus, both hypotheses are to date valid, and, perhaps more realistically, it should be considered the possibility that the observed drop in oak charcoal originated from a combination of both factors.

In the following sections, the main trends here introduced will be further discussed, in terms of vegetation history (“Late Holocene vegetation history in southern Cappadocia”), agricultural activities (“Arboriculture in southern Cappadocia”), and fuelwood acquisition strategies (“Agricultural byproducts as firewood resources”).

Late Holocene vegetation history in southern Cappadocia

Today, most of our knowledge of Cappadocian Late Holocene vegetation relies on palynological sequences from the lake cores of Eski Acıgöl (Woldring and Bottema 2003) and Nar Gölü (England et al. 2008; Roberts et al. 2016), both of which lie in the Göllüdağ, north of the study region (Fig. 1b). Unfortunately, the second half of the Holocene is not represented in the nearby (Fig. 1b) sequence of Akgöl Adabag (van Zeist and Bottema 1991:75). Pending publication of the Neolithic and Chalcolithic results from Tepecik-Çiftlik, the only archeobotanical sequence published from the broader region is from the pre-pottery Neolithic site of Aşıklı Höyük (Ergun et al. 2018). The archeobotanical dataset from Niğde-Kınık Höyük can thus shed light on the Late Holocene vegetation history of the region, integrating and complementing the available palynological evidence.

As previously noted, deciduous oaks are the most common taxon throughout the entire anthracological sequence (Fig. 10), in accordance with the vegetation history of the broader Irano-Anatolian region (Asouti and Kabukcu 2014) and current local vegetation (Kürschner 1984). As of today, oaks most likely grew on the slopes of the mountains present to the north of the site (Hasan, Keçiboyduran, and Melendiz; Fig. 1c). The presence of oak populations in the floodplain should likely be excluded, considering the preference of this genus for well-drained soils (Asouti and Kabukcu 2014). The wetter

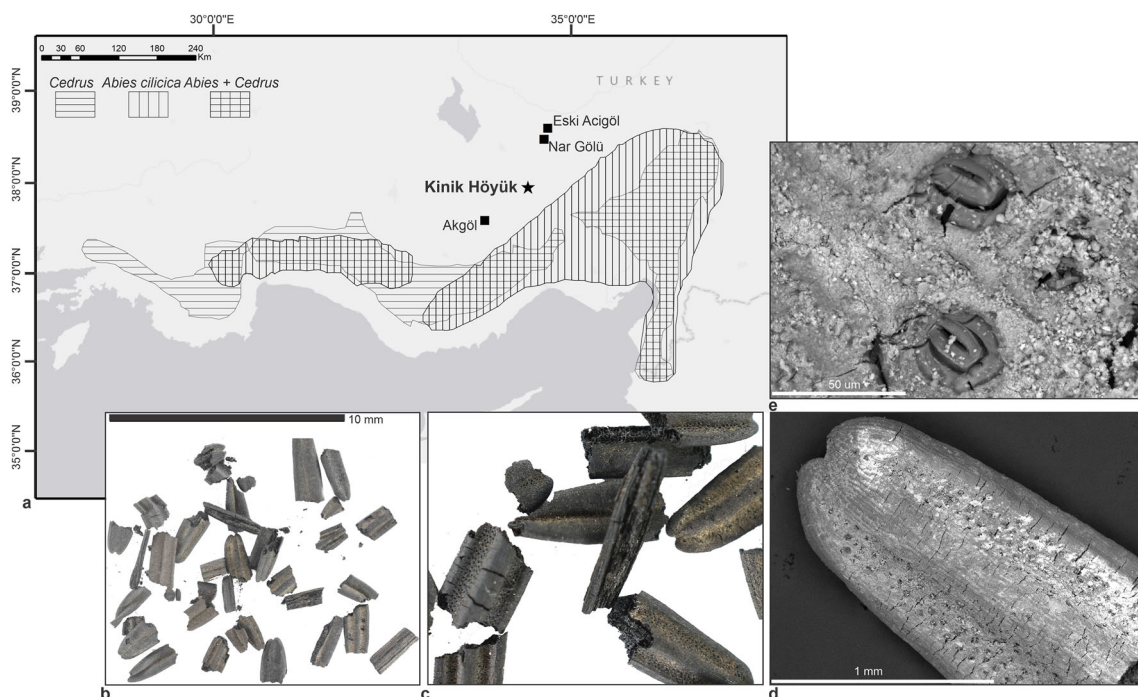


Fig. 12 a Approximative distribution map of *Abies cilicica* (Taurus fir) and *Cedrus libani* (cedar) in Turkey (redrawn from Davis 1965). Sites discussed in the text in reference to those taxa are located in the map. **b**

Abies sp. needle fragments from Kınık Höyük (sample KIN15A1539s77). **c** Detail of (b). **d** SEM photo of distal end of *Abies* needle from the same sample. **e** Detail of (d), picturing stomata

soils present in the floodplain were suitable for riparian woodlands, abundantly documented in the sequence by Salicaceae charcoal and the sporadic attestations of *Ulmus*, *Celtis*, and *Tamarix* (Fig. 10). Riparian habitats appear to have been particularly extensive during the earliest occupation periods of the site (KH-P V and IV), and later reduced, likely as a result of some combination of fuel harvesting pressure and agricultural land expansion, as discussed in the previous section).

Pine charcoal is found in low amounts (Fig. 10), in glaring contrast to contemporary anthracological data from Gordion (Miller 2010; Marston 2017) and Kaman-Kalehöyük (Wright et al. 2017) (Fig. 1b). The recognition of a minor contribution of pine to the Late Holocene vegetation of the study region closely parallels the current Cappadocian flora, characterized by no natural occurrences of this taxon (e.g., Woldring and Bottema 2003). Following these considerations, Woldring and Bottema (2003) interpreted the *Pinus* pollen record from Eski Acigöl as due to long-distance transport from the Taurus and Pontic mountain ranges. The same interpretation was more recently sustained by England et al. (2008) and Roberts et al. (2016) for the Nar Gölü sequence. In these terms, wood charcoal data from Niğde-Kınık Höyük confirms the marginal role of pine trees in the Late Holocene Cappadocian vegetation, although the presence of some Scots/black pine charcoal suggests that limited populations of pine trees were likely present within the standard fuel catchment region of the site. The alternative hypotheses of either a northern expansion of the Taurus pine forest into the Bor-Ereğli Plain or of a significant larger firewood catchment area reaching the Taurus chain are discounted: the first hypothesis is rejected due to the presence in the southern portion of the Bor-Ereğli plain of environments (wetlands and marshes; Fontugne et al. 1999) unsuitable for pine growth, and the second rejected because several urban centers lie in the surroundings of Niğde-Kınık Höyük, presumably limiting the area exploitable for routine fuel acquisition by inhabitants of the site well short of the Taurus.

Juniperus shows an interesting trend in the sequence: attested in significant amounts during the earliest occupation periods (KH-P VI, V, IV), the taxon becomes only sporadically documented in the Achaemenid and Hellenistic phases (KH-P III, II) and completely unattested during the Medieval occupation (KH-P I) (Fig. 10). This progressively decreasing trend, leading to a complete disappearance of the taxon from the record, recalls similar dynamics documented at Gordion (Marston 2017:76). The evidence from Gordion is interpreted by Miller (2010) and Marston (2017) as resulting from an ecological succession triggered by forest clearance, with oaks replacing junipers due to the ability of the former to regrow more rapidly after cutting. Without fully ruling out alternative explanations, this interpretation might apply also for the record from Niğde-Kınık Höyük, considering the simultaneous evidence of expansion of arboriculture (Fig. 10) as a

possible indication of a more generalized intensification of anthropic pressure on the broader landscape.

Despite their sporadic attestation, worthy of note and discussion is the presence of *Abies* and *Cedrus* charcoal fragments within this anthracological record (Fig. 10). Sharing similar ecological demands, today firs (*Abies cilicica*) and cedars (*Cedrus libani*) grow on the wetter slopes of the Taurus chain (Fig. 12a), often forming mixed stands (Atalay et al. 2014). Woldring and Bottema (2003) interpreted the relatively high percentages of *Cedrus* pollen from Eski Acigöl as possible evidence of a former northern expansion of the cedar forest during the wetter phases of the Holocene, reaching the Melendiz mountain and possibly the Göllüdağ. The presence of sporadic *Cedrus* charcoal from Kınık Höyük might support this hypothesis of a former northern presence of the taxon, with relict populations still present in the Cappadocian mountains during the Late Holocene and sporadically exploited by the local population. The recycling for firewood purposes of cedar timbers harvested for building or manufacturing purposes on the south slopes of the Taurus cannot be fully ruled out, however, considering the renowned quality of *Cedrus* wood and its documented extensive trade (e.g., Liphshitz and Bigger 1991). More explicitly indicative of a local occurrence is the exceptional discovery at the site of charred *Abies* (fir) needles (samples KIN15A1539s77 and KIN15B2113s108, both dating to KH-P II), likely incorporated into the archeological record via burning ruminant dung as fuel (Fig. 12b–e). The co-occurrence of *Abies* needles and charcoal speaks more directly for the presence of this taxon in the proximity of the site, perhaps growing in the wettest areas of Melendiz mountain. Although in low numbers, *Abies* pollen—which deposition is generally considered local (Pidek et al. 2013)—is documented in the Cappadocian pollen sequences (Woldring and Bottema 2003; England et al. 2008). *Abies* and *Cedrus* charcoal are unattested in the latest occupation phase (KH-P I), suggesting that by the early 2nd millennium CE those trees were no longer growing in the region.

Arboriculture in southern Cappadocia

The wood charcoal assemblage from Kınık Höyük stands out for the ubiquitous and abundant attestation of charcoal fragments from economic trees, as defined in the Materials and methods section (Figs. 10 and 11). Leaving to the next sections the contextualization of this evidence within a broader chronological and geographic scope, here the characteristics of the economic taxa in the Niğde-Kınık Höyük record are discussed.

Rosaceae (rose family)

It is difficult to interpret charcoal of the Rosaceae family (Figs. 9 and 10). Three main anthracological types were identified in

this family: (i) Maloideae, which includes among others the genera *Malus*, *Pyrus*, *Sorbus*, *Crataegus*, and *Mespilus*; (ii) *Prunus*-type, including among others *Prunus avium*, *P. cerasus*, *P. divaricata*, *P. domestica*, *P. mahaleb*, *P. spinosa*; (iii) and *Amygdalus*-type, including *Prunus persica*, *P. armeniaca*, *P. dulcis*, *P. webbii*, *P. korshinsky*, *P. orientalis* (for identification criteria see Table S12). Each type thus includes both cultivated and wild species, whose distinction on the basis of wood anatomy is either impossible or highly problematic (Schweingruber 1990). *Amygdalus*-type is the only category of the Rosaceae which is interpreted (at least in part) as cultivated, considering its increase through the sequence (especially in the Medieval period, KH-P I) as reflecting a possible expansion of the cultivation of almond/peach/apricot trees. In addition to the taxonomic level of the identifications, the distinction between cultivated and non-cultivated Rosaceae is further challenged by a traditional intensive use of the wild species, exploited for both their edible fruits (e.g., *Mespilus*, *Crataegus*, *Pyrus*, *Prunus*; see Dogan et al. 2004) and as rootstock for domestic varieties (Zohary et al. 2012).

The cultivation of apples, pears, plums, and other Rosaceae is well documented in the Anatolian historical record, starting from the Late Bronze Age (Hoffner 1974). It is interesting that the Hittite documents relatively frequently mention (e.g., Hittite Law §105; Hoffner 1997) mixed orchards, with grapevines (^{GI}GIŠTIN) present together with several other fruit trees, such as apple trees (^{GI}HAŠHUR), possibly pears (^{GI}HAŠHUR.KUR.RA, literally ‘apples from the mountain/foreign land’), and possibly plums or medlars (^{GI}SENNUR). It should be mentioned, however, that the cultivation of most Rosaceae prior to a significantly later time is a matter of debate, considering the assumed necessity of grafting to maintain selected characters in domesticated apple, pear, and plum trees, a technique allegedly considered to be a later (second half of the 1st millennium BCE) introduction in the Mediterranean (Zohary et al. 2012). Carpological remains of almond (*Amygdalus dulcis*), plum (*Prunus domestica*), and various Maloideae were, however, recently reported from the Middle Bronze Age site of Büklükale (Kırıkkale Province) (Fairbairn et al. 2019).

***Fraxinus* (ash)**

Fraxinus angustifolia/ornus (narrow-leaved or manna ash) is another taxon difficult to interpret. On the one hand, significantly earlier anthracological evidence from the nearby Konya Plain (Kabukcu 2017) clearly indicates that ash was a component of the regional vegetation; on the other hand, extensive palynological evidence indicates an abrupt increase in *Fraxinus ornus*-type pollen during the Beyşehir Occupation Phase (Eastwood et al. 1998), regarded as an indication of its cultivation for manna production (Bottema 2000), an

important and often underestimated source of sugars. In the Mediterranean basin manna is traditionally produced by extracting sap from *Fraxinus angustifolia* and *F. ornus* (Guarcello et al. 2019), planted in groves or present in the natural vegetation. Considering the possibility of the presence of ash trees (*F. ornus* or *angustifolia*) in the natural vegetation surrounding Niğde-Kınık Höyük, the appearance of the taxon alongside other important tree crops leaves open the possibility that it was exploited for manna extraction.

***Juglans regia* (walnut)**

Juglans regia (walnut) is attested as early as period KH-P III (Achaemenid/Early Hellenistic), then continuously documented, although in low numbers, during the rest of the sequence (Fig. 10). The domestication and cultivation history of walnut is still poorly known (Zohary et al. 2012). Regardless of the center of origin, after an almost total absence from the palynological record during the Early and Middle Holocene, in the late 2nd–early 1st millennium BCE *Juglans* pollen becomes abundantly attested in eastern Mediterranean sequences, suggesting its widespread cultivation (Bottema 2000). Data from Niğde-Kınık Höyük agrees with a diffusion of walnut cultivation during the 1st millennium BCE.

***Elaeagnus angustifolia* (Russian olive)**

Together with walnut, *Elaeagnus angustifolia* (Russian olive) makes its first appearance in the Achaemenid/Early Hellenistic period (KH-P III) and thereafter is continuously attested (Fig. 10). In the plain surrounding the site, Russian olive is today very common along canals and roads, and serving as living fences. In addition, its edible, elliptic-oblong fruits are widely consumed. Despite its abundant presence throughout Anatolia, the origin of this taxon and its status in the Turkish flora are still mostly unknown. Davis (1982) considered it an unlikely native species in Turkey, interpreting the widespread modern populations as resulting from the naturalization of feral populations, a process facilitated by its rapid growth and invasive character. This hypothesis is challenged by the occurrence of *Elaeagnus* pollen in sequences from the vicinity of Sagalassos around 2600–2500 BCE (Bakker et al. 2012). This palynological evidence remains singular in the Anatolian record, however.

In addition to the anthracological data from Niğde-Kınık Höyük, *Elaeagnus angustifolia* charcoal is attested in significant quantities in the Early and Late Medieval levels of Aşvan (Elazığ Province), where its sudden appearance is interpreted as indicating the introduction of this taxon sometime before, or during, the Medieval period (Willcox 1974). The evidence from Niğde-Kınık Höyük confirms the chronologically later role of

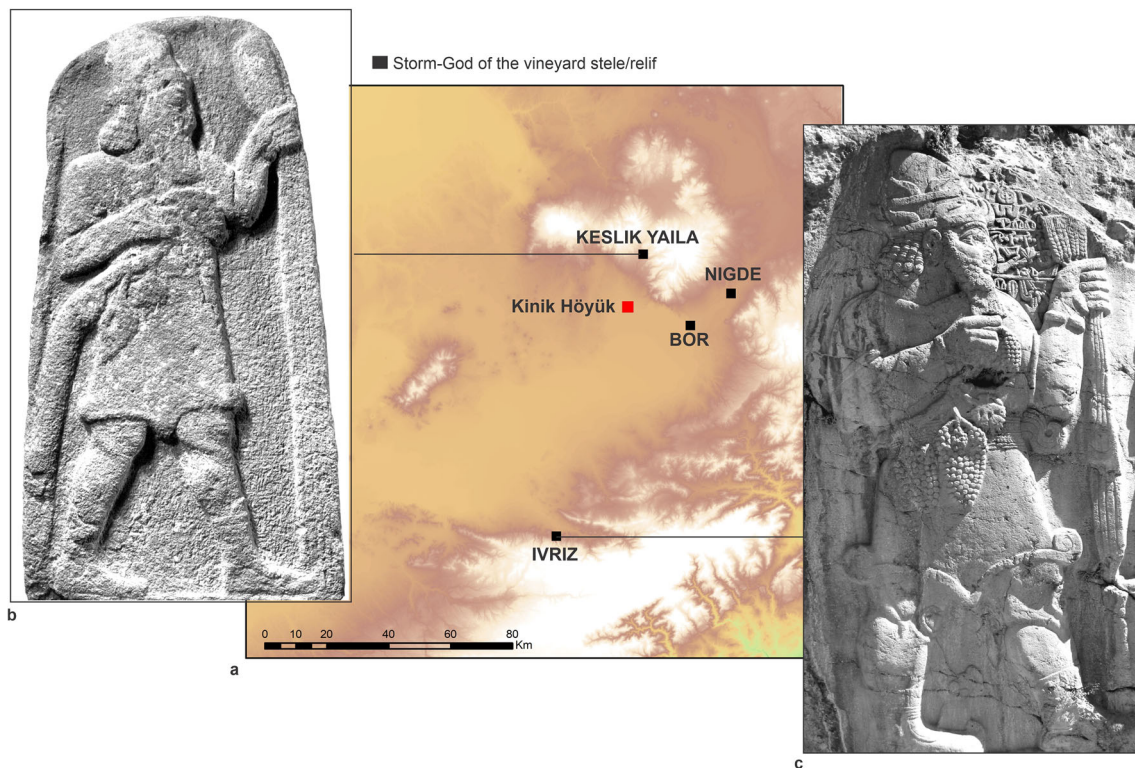


Fig. 13 a Map of the iconographic representations of the Storm-God of the Vineyard (*Tarhunza*). b The Yeslik Yaila stele representing the Storm God of the Vineyard (after (Berges and Nollé 2000). c The Ivriz rock relief, detail of the Storm-God (after www.hittitemonuments.com)

Elaeagnus in the Anatolian vegetation, although it appears significantly earlier than at Aşvan, during the second half of the 1st millennium BCE. Its sudden appearance together with other fruit crops and its subsequent continuous attestation suggests that Russian olive was introduced as a cultivated crop. Considering the widespread attestation of the taxon in Central Asia, matched by relatively extensive archeobotanical documentation (e.g., Hovsepyan and Willcox 2008; Smith et al. 2014; Spengler et al. 2018; Spengler and Willcox 2013), it is tempting to correlate its appearance to a Persian influence, although first its status within the Anatolian flora must be clarified.

Morus (mulberry)

Chronologically, *Morus* sp. (mulberry) is the latest arboreal crop attested in the sequence, documented only during the Seljuk/Early Ottoman period (KH-P I) (Fig. 10). To my knowledge, this find represents the first archeobotanical attestation of mulberry in Central Anatolia, without considering a tentative identification (cf *Morus* sp.) of a significantly earlier (YHSS-4, 540–330 BCE) wood charcoal fragment from the site of Gordion (Miller 2010) and modern (nineteenth century CE) evidence from Aşvan (Willcox 1974). The attestation of mulberry in Late Medieval levels matches the documented archeobotanical record: from Central or East Asia, mulberry

made its sporadic appearance in the Mediterranean during the 1st millennium BCE (e.g., seventh century BCE finds from Samos; Kučan 2000), but only becomes relatively common in the European and Mediterranean archeobotanical record during the Medieval period (Livarda 2008). The introduction and increased importance of mulberry in late medieval Anatolia might have been promoted by the Central Asian heritage of Turkish populations and by the important role of sericulture during the Ottoman period (Yilmaz et al. 2015).

***Vitis vinifera* (grapevine)**

Grapevine (*Vitis vinifera*) is the most important arboreal crop in the sampled charcoal sequence. It is first attested during the Early Iron Age (KH-P V), with an increase in frequency during the Middle-Late Iron Age (KH-P IV, relative abundance on fragment count 2%), but then reaching comparatively high values in the Achaemenid/Early Hellenistic (KH-P III, 16%) and Late Hellenistic (KH-P II, 26%) periods. *Vitis* charcoal is also abundant during the Seljuk/Early Ottoman occupation phase (KH-P I, 13%) (Table 3, Fig. 9). Pending further sampling of Late Bronze Age deposits, it is possible that the absence of *Vitis* from these levels is a result of limited sampling. The distinction between wild (*Vitis vinifera* subsp. *sylvestris*) and domesticated (subsp. *vinifera*) grapevine wood on the basis of anatomy is not possible (although see Limier et al. 2018). However, the high relative frequencies of remains and

the location of the site outside the expected geographic distribution of wild grapevine (Zohary et al. 2012) indicate that the finds from Niğde-Kınık Höyük are likely to represent cultivated varieties. Thus, starting at least in the Iron Age, viticulture played a significant role in the economy of Niğde-Kınık Höyük, and during the Achaemenid and Hellenistic periods might have become a pivotal economic activity of regional importance. The abundant presence at Niğde-Kınık Höyük of grape pips and pedicels, documented by ongoing carpological study (Castellano, *unpublished data*), further supports this reconstruction.

To my knowledge, with the sole exception of a single possible identification from Çatalhöyük (Asouti 2005), grapevine charcoal is to date unreported in other Central Anatolian anthracological sequences (e.g., Asouti 2003; Asouti and Hather 2001; Fairbairn and Wright 2017; Fairbairn et al. 2019; Kabukcu 2017; Marston 2017; Masi et al. 2018; Miller 2010; Willcox, 1974 and 1991; Wright et al. 2015 and 2017; Wright 2018). Grape seeds, on the other hand, are more frequently encountered in archeobotanical samples from the Anatolian Plateau. As pointed out in a recent review of Barjamovic and Fairbairn (2018), *Vitis vinifera* seeds are first attested in Central Anatolia during the Early Bronze Age, for then become a relatively stable component of the Central Anatolian archeobotanical assemblage, although typically found in low concentrations or individual finds. In contrast, *Vitis vinifera* seeds are found in large amounts in Mediterranean (e.g., Kilise Tepe, Tell Atchana, Tell Tayinat) and southeastern Anatolian (e.g., Kenan Tepe, Hirbemerdon) sites (White and Miller 2018). Niğde-Kınık Höyük, in light of the extremely rich attestation of *Vitis vinifera* remains, clearly diverges from the pattern at today known for the Anatolian Plateau, pointing to the high degree of complexity and specialization of Anatolian agropastoral economies and the still incomplete archeobotanical knowledge that we have of them, as discussed below.

The evidence of grapevine cultivation from Niğde-Kınık Höyük is consistent with both local environmental conditions and the available historical and iconographic documentation. Favorable conditions for viticulture exist today in the Bor-Ereğli plain (Bayer Altın 2008; Pfeifer 1957), with frequent feral populations of *Vitis vinifera* thriving in and around abandoned gardens, in addition to extensive vineyards. Historical and iconographic evidence points to both the antiquity and centrality of viticulture in the region of Niğde-Kınık Höyük. Most notably is the local Iron Age cult of the “Storm God of the Vineyard” (Luwian *Tahrnza*; Weeden 2018), a deity represented in a rich iconographic corpus from the region (Bor, Niğde, Keşlik Yayla, and Ivriz; Fig. 13a) as a standing figure holding bundles of wheat in one hand and bunches of grapes in the other, with fruit hanging from a vine growing from behind the deity (Fig. 13 b and c). Most of these reliefs are associated with Anatolian hieroglyphic inscriptions, dated to

the late eighth–early seventh century BCE (Hawkins 2000) on the basis of synchronism of the local kings mentioned in the inscriptions (Tuwanan dynasty of Warpalawa) with Assyrian rulers. In addition to a more generalized symbolic reference to agricultural abundance and prosperity (Masetti-Rouault 2004; Weeden 2018), this iconographic and epigraphic evidence is to be considered indicative of the importance of viticulture in the region during the Middle Iron Age. The presence of a vineyard and the production of wine is explicitly mentioned in the BOR 1 inscription (Hawkins 2000: 518–521), discovered at Kemerhisar (Ancient *Tuwana*) about 20 km to the south-east of Niğde-Kınık Höyük (Fig. 1c). The local cult of the Storm God of the Vineyard matches the period in which *Vitis vinifera* charcoal begins to increase in the anthracological sequence (Fig. 10), pointing to the Iron Age roots of the centrality of viticulture, both in the cultural and economic life of local communities.

Among later historical sources, of interest is the description of Cappadocia provided by Strabo (*Geography*: XII,1-2). The Greek first century BCE/CE geographer describes *Melitene*-Malatya (central-eastern Anatolia) as “the whole of it (*Melitene*) is planted with fruit-trees, the only country in all Cappadocia (here indicating the entire Asia Minor peninsula) of which this is true, so that it produces not only the olive but also the Monarite wine, which rivals the Greek wines” (Strabo, *Geography*: XII,2,1; Jones 1928). In Strabo’s account, the agricultural richness of Malatya is in open contrast with the otherwise barren Anatolia landscape, such as *Mazaka*-Kayseri: “the districts all round are utterly barren and untilled, although they are level; but they are sandy and are rocky underneath. ... therefore the necessities of life must be brought from a distance” (Strabo, *Geography*: XII,2,7; Jones 1928). The region of Niğde-Kınık Höyük, the historical Tyanitis, is only very briefly mentioned, yet meaningfully described as “for the most part fertile and level” (Strabo, *Geography*: XII,2,7; Jones 1928). The image of the Anatolian Plateau provided by Strabo is of a complex landscape in which agriculturally rich areas (e.g., Malatya and the Bor-Ereğli plain) are interspersed among less productive and less fertile territories (e.g., Kayseri), highlighting in the former (explicitly in the case of Malatya) the presence of orchards and vineyards.

After the occupation hiatus, *Vitis vinifera* charcoal fragments continue to be abundantly attested during the Seljuk/Early Ottoman period (KH-P I) (Fig. 10). Thus, viticulture retained an important role also after the region was incorporated into the Seljuk and the Ottoman Empires, as supported by documentary evidence. Ottoman archival tax records from the nearby town of Bor (ca. 15 km east of Niğde-Kınık Höyük) record large and economically remunerative vineyards in the town territory (Balta 2017). The documentary evidence from Bor fits the general image of Cappadocia emerging from the fifteenth and sixteenth century CE

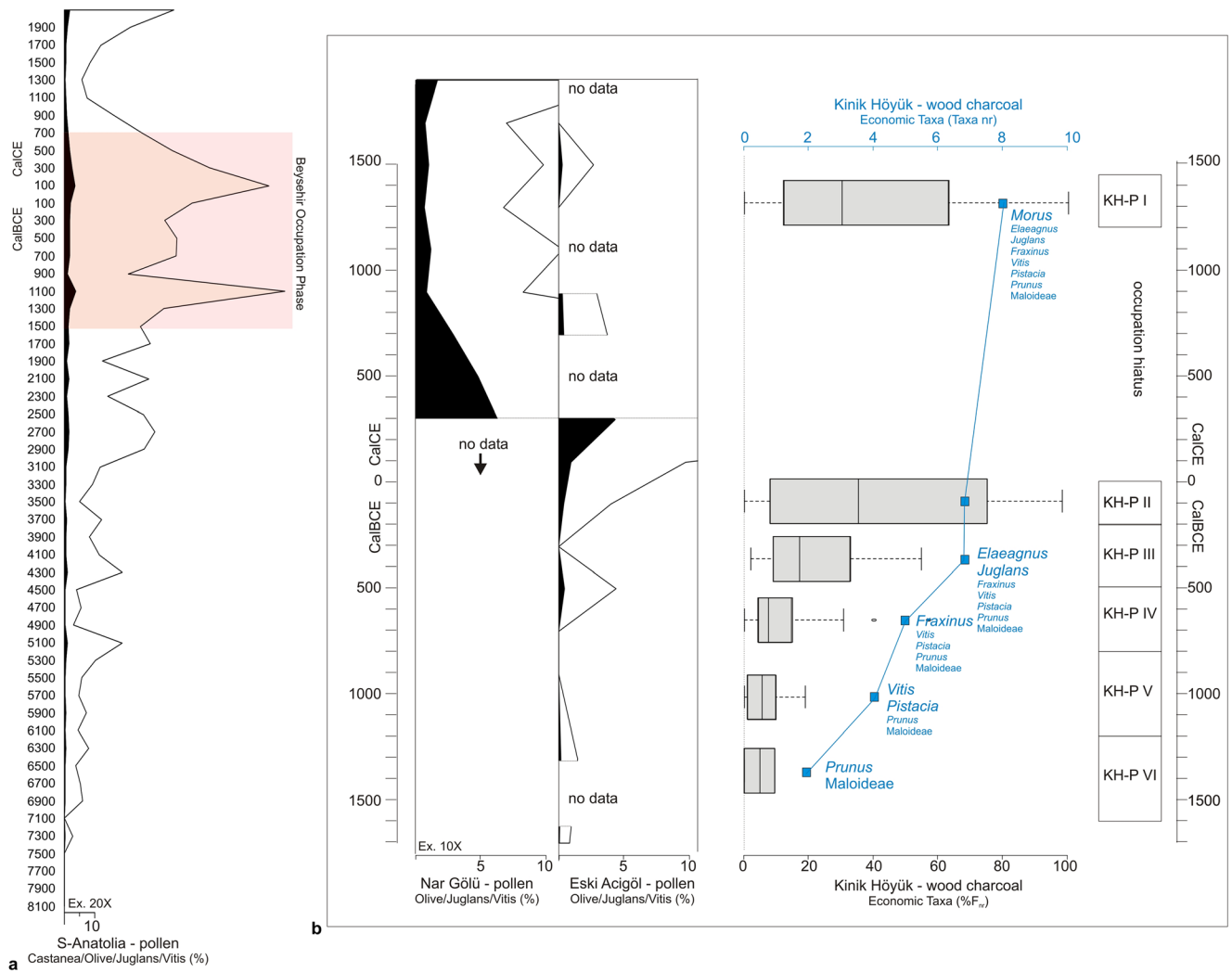


Fig. 14 **a** Cumulative palynological record for *Castanea/Olea/Juglans/Vitis* in S-Anatolia (data from Woodbridge et al. 2019) (allow line 20× exaggeration). The red box indicates the regional upper and lower limits of the Beyşehir Occupation Phase. **b** Late Holocene palynological record for *Olea/Juglans/Vitis* at Nar Gölü and Eski Acıgöl (Cappadocia; data

from Woodbridge et al. 2019) compared with the anthracological record of economic taxa from Kinik Höyük, here represented as boxplots (outliers are detected through interquartile range rule) and number of economic taxa identified for each occupation period

Ottoman sources as a region characterized by thriving viticulture and wine production, with both the sizable local Christian communities and Muslim villages involved in these activities (Balta 2017).

In sum, grape cultivation has a long-standing cultural and economic importance in the region, from protohistory until the present. The evidence from Niğde-Kınık Höyük provides the first direct archeobotanical documentation of such importance and continuity in Central Anatolia.

Agricultural byproducts as firewood resources

In addition to providing evidence of the expansion of arboriculture and viticulture, the wood charcoal record from Niğde-Kınık Höyük permits investigation of the degree to which fuelwood acquisition strategies were impacted by broader

changes in the agricultural system. It is, in fact, a likely hypothesis that the expansion of the farmed land promoted intensive use of the increasingly available biomass produced by agricultural activities, including pruned wood. The anthracological evidence supports this hypothesis, indicating that from the second half of the 1st millennium BCE (KH-P III and KH-P II), the local population intensively exploited for firewood purposes these locally abundant agricultural byproducts, especially grape cuttings.

Viticulture by definition implies pruning and trimming, activities necessary in order to impose a training to the vines and ensure stable fruit production (e.g., Reynolds and Vanden Heuvel 2009). The biomass produced by those activities on a yearly basis is hardly negligible, as exemplified by the general estimation for modern vineyards of 5 tons of pruning residues produced for each hectare under cultivation per annum

(Yeniocak et al. 2014). The extensive vineyards present in the surrounding of Niğde-Kınık Höyük would have surely provided a sizeable quantity of pruning wood, the use of which for firewood in a poorly forested landscape is expected. Historical evidence of grape pruning in Anatolia is scattered yet present, dating as far back as the Hittite period (e.g., ^{GIS}GIŠTIN tuḫšuwaš, festival of the “cutting of the vine”; see Cammarosano 2018:130–131) and abundantly documented afterwards in the iconography of Roman stone monuments from Phrygia (Waelkens 1977).

The exploitation of agricultural biomass as a firewood resource is suspected to be particularly evident in anthracological sequences from regions in which limited woodland cover promotes such exploitation in concomitance to phases of intensification of arboricultural activities. Interestingly, similar anthracological patterns, characterized by extensive use of pruned wood for fuel, have been described in the southern Levant (Fall et al. 2002), a semi-arid region where arboriculture has a significantly longer history.

An anthracological signature of the Beyşehir Occupation Phase

In the previous sections, it was argued that the anthracological sequence from Niğde-Kınık Höyük provides evidence of an important phase of agricultural expansion characterized by arboreal crop cultivation, possibly to be connected to a degree of woodland clearance. This evidence closely matches the palynological record of southwestern and southcentral Anatolia, which documents a well-defined regional phase of deforestation, agricultural expansion, and arboriculture known in the literature as the “Beyşehir Occupation Phase” (Bottema et al. 1986, 1990; Eastwood et al. 1998; Roberts 2018; van Zeist et al. 1975; Woodbridge et al. 2019).

The Beyşehir Occupation Phase is a coherent palynological phase defined by (i) an abrupt, marked decline in forest pollen; (ii) increase of cereal-type pollen and other grasses; (iii) presence and increased attestation of pollen of arboreal crop taxa (e.g., *Olea europaea*, *Juglans regia*, *Fraxinus ornus*, *Castanea*, *Pistacia*, *Vitis vinifera*, *Platanus*). In addition to southwestern and south-central Anatolian sites, coeval evidence from northern and western Anatolia, Cyprus, and the Levant (Roberts 2018) clearly indicates the supraregional character of this phenomenon. Roberts et al. (2018) recognizes the regionally differential onset of this phase, clustered in three main periods: 2nd millennium BCE; early 1st millennium BCE (tenth–eighth century BCE); and mid-1st millennium BCE (sixth–third century BCE). The end of this palynological phase is more consistently dated across its broad geographic spread, with a generalized abrupt end in the mid-1st millennium CE, after which follows a rather abrupt forest expansion (especially of *Pinus*) and the almost complete disappearance of arboreal crop pollen.

In contrast to the abundant palynological evidence, prior to this study, the Beyşehir Occupation Phase has never been directly linked to any Anatolian archeobotanical sequence, due in part to poor archeobotanical sampling of much of the Anatolian Plateau during the Late Holocene, including Cappadocia, the Konya Plain, and the Pisidian Lake District, which are the regions in which this phase is expected to be found. The wood charcoal evidence of fruit growing from Niğde-Kınık Höyük closely matches the chronology of the Beyşehir Occupation Phase as documented in the Cappadocian pollen sequences of Nar Gölü (England et al. 2008) and Eski Acıgöl (Woldring and Bottema 2003) (Fig. 14), thus evidently providing for the first time an anthracological signature of this phenomenon.

In comparing the anthracological evidence from Niğde-Kınık Höyük to coeval Central Anatolian palynological sequences, the respective interpretative limits of wood charcoal and pollen analysis need to be critically considered (Emery-Barbier and Thiebault 2005; Nelle et al. 2010). In off-site pollen profiles, the taphonomic processes accounting for pollen deposition translate into frequent issues of long-distance transport of pollen grains (Gaillard et al. 2008) and a systematic underrepresentation of taxa that are predominantly non-wind pollinated (Prentice 1988). These considerations are particularly important for the history of arboriculture, as well-exemplified by the evidence here discussed. The record of fruit-growing from Niğde-Kınık Höyük is characterized by taxa dominantly entomophilous or self-pollinated—such as *Vitis* (most likely domesticated), Rosaceae, and *Elaeagnus* (Turner and Brown 2004; Pan et al. 2011)—which are expected to be systematically underrepresented (*Vitis*) or entirely absent (Rosaceae, *Elaeagnus*) in pollen diagrams. It is, thus, possible to propose that these crops were an important additional component of the agricultural landscape associated with the Beyşehir Occupation Phase, undetected or overlooked in the palynological sequences. In contrast, *Olea* (olive) is completely unattested in the wood charcoal record from the site, in a clear mismatch with the palynological evidence from the Cappadocian sequences of Eski Acıgöl (Woldring and Bottema 2003) and Nar Gölü (England et al. 2008). Considering the abundant pruning required for olive farming, the lack of any charcoal points to the absence of olive groves in the surroundings of Niğde-Kınık Höyük. Thus, the palynological evidence of *Olea* from cores in Cappadocia can be explained as a local specialization within that region, as a prerogative of the Roman and Byzantine periods (not covered by the Niğde-Kınık Höyük sequence), or—perhaps more realistically—regarded as an indication of the extra-Cappadocian origin of the *Olea* pollen detected in them (see England et al. 2008 for a discussion).

The diachronic analysis of the arboreal crop record from Niğde-Kınık Höyük (Fig. 14) suggests that in southern Cappadocia the beginning of the Beyşehir Occupation Phase



Fig. 15 The modern village of Yeşilyurt and its surroundings (ca. 5 km north of Kınık Höyük). In the foreground note the extensive orchards cultivated with grapevines, various Rosaceae fruit trees, and poplars. In the background note the completely deforested mountain slopes

was gradual rather than abrupt, and in cultural continuity rather than in rupture with the older milieu. This interpretation is based on the explicit emphasis on viticulture in the local cult of *Tarhunza* (Weeden 2018), a deity stemming from the Late Bronze Age milieu. Cultural continuity in the region between the Late Bronze and Iron Age has already been stressed based on several lines of evidence (Mora and d’Alfonso 2012), including the role played by agriculture and agricultural infrastructure in the regional political economy (Castellano 2018). The increase in arboreal crops at Niğde-Kınık Höyük during periods KH-P V and IV can be, thus, understood as a gradual process of transformation and “anthropization” of the landscape, culminating in the marked changes in the anthracological record during the Achaemenid/Early Hellenistic period (KH-P III) that extend into the Late Hellenistic phase (KH-P II).

Due to the hiatus in occupation following the Hellenistic period (KH-P II), evidence from Niğde-Kınık Höyük does not cover the expected end of the Beyşehir Occupation Phase, generally dated in pollen sequences to the mid-1st millennium CE (Fig. 14a). Medieval Cappadocia, however, seems to follow a specific trajectory connected to local historical developments (Eastwood et al. 2009; Roberts 2018; Roberts et al. 2018). The consolidation of the border with the caliphate and the cessation of Arab armies’ raids in

Cappadocia allowed Byzantine resettlement of the countryside during the late ninth–early tenth century CE, which in turn promoted a new phase of forest clearance and agricultural expansion (Allcock 2017; Eastwood et al. 2009; Roberts 2018). Although short-term fluctuations in anthropogenic and arboreal pollen are thereafter detected, the mid-Byzantine land use system is considered to continue into the Seljuk and Ottoman periods (Eastwood et al. 2009). On the basis of the pollen data from Nar Gölü, Eastwood et al. (2009) and Roberts et al. (2018) interpreted the Late Medieval agrarian system as distinct from the previous Classic and Late Antique landscape, with agricultural production in the newly repopulated countryside focusing on cereal production and pastoralism rather than on arboriculture. This hypothesis could be in part challenged by the chronologically later (1200–1450 CE) evidence from Niğde-Kınık Höyük, in which arboreal crops are comparatively still abundantly attested (Fig. 10). This mismatch is likely attributable to the poor palynological representation of the taxa that form the arboreal crop record at Niğde-Kınık Höyük. The presence of local arboriculture is further corroborated by the aforementioned fifteenth and sixteenth century CE documentary evidence (Balta 2017), which confirms the key economic role of fruit-growing in Cappadocia, in continuum with the earlier agricultural tradition.

Conclusions

The anthracological sequence from Niğde-Kınık Höyük (southern Cappadocia), spanning from the Late Bronze Age to the Seljuk/Early Ottoman period, fills a long-standing gap in Anatolian archeobotanical research. Wood charcoal analysis illuminates the Late Holocene vegetation history of the region and its diachronic change and suggests that the floristic distinctiveness of Southern Cappadocia is rooted in local vegetation history. The results confirm the minor role played in the regional flora by conifer trees, especially pine, but suggest the possible former presence in the Cappadocian mountains of relict populations of fir (*Abies cilicica*) and cedar (*Cedrus libani*), supporting the hypothesis of an earlier northward expansion of those taxa during the wettest phases of the Holocene. Furthermore, anthracological data provides a remarkable record of arboriculture, without to date any comparanda in the Anatolian archeobotanical record but closely matching the Beyşehir Occupation Phase phenomenon, a major phase of land-cover change documented in coeval palynological sequences. This distinctive anthracological association indicates how intensification of agricultural activities impacted fuelwood acquisition strategies through time.

The anthracological evidence from Niğde-Kınık Höyük thus corroborates and supports regional and supraregional palynological evidence (Roberts 2018) of large-scale landscape transformation in the 1st millennium BCE, with radical changes in land cover resulting from an unprecedented increase in human activities. Economic and demographic dynamics (Woodbridge et al. 2019) and increased interregional connectivity (e.g., Sherratt and Sherratt 1993) surely played a crucial role in promoting this phase of land-cover modification, with intensified agricultural production aiming to feed expanding demand for commodity crops and/or products obtained from them (e.g., wine). In the specific case of southern Cappadocia, the earliest stages of this process of landscape transformation are coupled with a new emphasis on agricultural production in the epigraphy and iconography of display monuments, as documented in the local Iron Age cult of *Tahrünza* of the vineyard (Weeden 2018).

While agricultural intensification documented at Niğde-Kınık Höyük fits well into this supraregional trend, the archeobotanical evidence of extensive fruit cultivation documented in this study is currently unmatched by any other archeobotanical sequence from the Anatolian Plateau. The uniqueness of this evidence should be weighed in light of the still-limited archeobotanical picture of Asia Minor, a region characterized by a complexity of environments and ecologies, cultures, and economies—a heterogeneity already appreciated by ancient geographers, such as Strabo (*Geography*: XII,1-2). The Late Holocene phase of land-cover change thus occurred differently in different regions of the Plateau, according to specific socio-cultural and ecological realities. Within

this generalized intensification of agropastoral activities, the economic importance of fruit growing might have been limited to specific regions of the Plateau, perhaps where such cultivation was favored by higher water availability sustaining irrigation systems, crucial given extended summer droughts typical of the Central Anatolian climate (Fig. 2). Southern Cappadocia was surely one of these regions, together with the Pisidian Lake District (palynological evidence; Roberts 2018) and Malatya (textual evidence; Strabo, *Geography*: XII,1-2). It is the task of future archeobotanical research to uncover and understand these local trajectories that underlie the broader supra-regional trend well documented in palynological records.

Starting from the mid-1st millennium BCE, the evidence from Niğde-Kınık Höyük points to a remarkably high degree of continuity despite the eventful southern Cappadocian political history. This continuity in arboricultural practices was potentially driven by the environmental setting (e.g., abundance of water sources) and the high degree of cultural resilience and adaptability evident in this region through the ages (e.g., in the transition from the Late Bronze to the Iron Age, or from the Late Antique to the Medieval period). In these terms, the current landscape surrounding the archeological site of Niğde-Kınık Höyük, with deforested mountain slopes, but lush orchards and vineyards, might be seen as the final result of these processes, emerging from the long and complex history of confrontation between local populations and their biotic and abiotic surroundings (Fig. 15).

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