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Archaeobotanical inference of Bronze Age land use and land cover in the eastern Mediterranean

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ABSTRACT

Charcoal and charred seeds at five Bronze Age archaeological sites discern ancient land use in the eastern Mediterranean. Seed frequencies of orchard crops, annual cereals and pulses, and wild or weedy plants are used to characterize plant utilization at different archaeological sites on the island of Cyprus, in the Rift Valley of Jordan, and in the Jabbul Plain and along the upper Euphrates River valley in Syria. Seed to charcoal ratios provide proxies to determine the relative usage of dung versus wood for fuel across the ancient Mediterranean landscape. Greater charcoal and lower charred seed values are interpreted to represent a wooded environment, while higher amounts of charred seeds and minimal wood charcoal suggest a much great use of dung as a fuel source. Interestingly, Politiko-*Troullia* (Cyprus, Cypriot archaeological sites are, by convention, named for the nearest modern village (Politiko), followed by an italicized toponym (*Troullia*) referring to the plot of land that incorporates the site) has the lowest seed to charcoal ratio, suggesting its residents primarily burned wood and that the landscape surrounding *Troullia* remained relatively wooded during the Bronze Age. In contrast, villagers at Tell el-Hayyat (Jordan) utilized a mixture of wood and dung, in contrast to Tell Abu en-Ni'aj (Jordan), and especially Umm el-Marra and Tell es-Sweyhat (Syria), where inhabitants relied solely on dung fuel. Comparative analysis and interpretation of seed and charcoal evidence thus illustrates the variety of fuel use strategies necessitated by the dynamic and diverse Bronze Age landscapes of the Eastern Mediterranean.

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1. Introduction

The landscapes of the eastern Mediterranean have been home to the growth, expansion and collapse of many of the world's earliest civilizations (Blondel, 2006). These societies transformed their landscapes, especially over the last 10,000 years following the advent of agriculture, in a lengthy co-evolution of humans and their environment (di Castri, 1981). This study highlights variability in this co-evolution, as seen in a comparison of Bronze Age land use and landscape in Syria, the southern Levant and Cyprus. The development of agrarian economies in the eastern Mediterranean and Near East incorporated population growth, production of agricultural surpluses and specialized technologies (e.g. plaster, metallurgy) that entailed significant environmental impacts (e.g., exploitation of woodland resources, deforestation; Miller, 1998). Intriguingly, these impacts were manifested in trajectories that varied geographically and temporally. This study focuses on detailed botanical evidence for land use and land cover from five archaeological sites that highlight this inherent variability in the evolution of agrarian landscapes in the ancient eastern Mediterranean and Near East.

Perhaps the most pervasive environmental impacts of human society result from mankind's myriad uses of fire. Economic activities of early agrarian communities often are inferred from analyses of carbonized plant remains as they relate to crop production, processing and consumption (e.g., Renfrew, 1973; Hastorf, 1988; Lipschitz, 1989; Pearsall, 1989; Cotton, 1996). Furthermore, such floral data are often augmented by the integration of the faunal data to assess and compare agroecocomies among sites (Smith and Munro, 2009; Smith and Miller, 2009). Independently studied however, floral remains recovered from archaeological sediments may represent burned refuse, crop processing debris or consumed fuel (Schwartz et al., 2000, pp. 445–446). Seeds originating from burned crop processing debris often are identified by the presence of spikelets, rachis fragments and stalks within the charred remains (Hillman, 1984). The burning of stored supplies or fodder, which is more difficult to determine, often produces carbonized seeds in storage rooms or jars (Miller, 1990). In addition, pyrotechnology

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figures prominently in the development of specialized crafts (e.g., pottery production, metallurgy), as well as general cooking and heating needs (Sillar, 2000; Miller, 2004). As Miller (1997a) notes, however, crop processing, burning of stored foods and craft production tend to be seasonal or episodic, whereas fuel use is more constant. Indeed, fuel use constitutes a major, often under-emphasized, source of carbonized plant macrofossils (Miller, 1996). This evidence provides particularly valuable reflections of land cover and land use, indicative of human interactions with surrounding plant communities.

1.1. Crops, fodder and fuel

In general, fuel wood or charcoal constituted readily utilized sources of fuel for cooking, heating and craft industries in early agrarian societies (Nesbitt, 1995). Fire wood provides a particularly expedient fuel source, but without close monitoring may produce highly variable temperatures. Burning of fuel wood in a reducing environment creates charcoal, which can be stored for later use and produces steady, more easily controllable heat (Sillar, 2000, p. 46). When wood becomes scarce, animal dung provides a more labor-intensive supplemental or alternative fuel (Winterhalder et al., 1974; Anderson and Ertug-Yaras, 1998). In addition to its malodorous characteristics, it must be handled and allowed to dry prior to use or storage. Nevertheless, dung may be hand-formed and ignited in standardized chunks, providing a controllable source of relatively even heat. Dung fuel from ruminants like cattle, sheep and goat, the leading domesticates at our sample of sites, produces more energy than dung from equids (Rhode et al., 2007, p. 207, Table 1). A variety of studies world wide document the use of dung fuel for heating, cooking and firing pottery (e.g., Winterhalder et al., 1974; Sillar, 2000; Rhode et al., 2007).

Archaeobotanical remains provide an avenue for inferring the links between early agrarian communities and their larger environments because so many food, fuel and technological needs of agrarian societies require use of both cultivated and wild plants (see discussion in Hastorf, 1988). Archaeobotanically deduced social interactions with the environment can provide particularly acute reflections of agricultural strategies, deforestation and erosion (e.g., Butzer, 1978, 1996; Kirch, 2005). Although plant macrofossils often are interpreted as indicators of crop management strategies and human food consumption, seeds recovered from trash deposits more likely stem from dung that was burned for fuel, and reflect wild or cultivated pasture vegetation or fodder grown for animal consumption (Miller, 1996). Seeds originating from dung often are highly fragmented or still embedded within charred dung remnants (Miller, 1990). However, increased reliance on animal dung for fuel potentially indicates multiple landscape, economic or climatic characteristics including expansion of uncultivated land due to greater importance of animal grazing, over-utilization of trees, or reduction of woodlands due to climate change. Previous studies at Tepe Malyan, Iran (Miller, 1985) and in the Khabur Basin of Upper Mesopotamia (Wilkinson, 2003, pp. 103–104) suggest ancient deforestation by contrasting the modern degraded steppe with woodland vegetation reconstructed for the mid-Holocene. For example, at Malyan evidence of charcoal decreased as charred seeds increased (Miller, 2004), suggesting that excessive wood harvesting during the third millennium B.C. led local residents to adopt animal dung as an alternative fuel source. Building on these previous insights, our study explores varying combinations of charcoal and plant seed remains as they suggest distinct signatures of crop, herd and fuel management at a series of Bronze Age communities across the eastern Mediterranean and Near East.

We recognize the presence of charred seeds may be the result of many social activities (burning of crop debris, unintentional burning of orchard remnants), and may also contain a temporal element to their frequencies (as is the case with seasonal burning crop debris or stored products). We are assuming that charred botanical remains indeed come from animal dung given the abundance of charcoal at the sites, and thus may be a reflection of land use and land cover; with further rationale ascertaining that if charcoal is preserved at the sites, logically charred seeds, had they been utilized as a fire source, would be preserved as well. Because this evidence differs among the sites, it potentially reflects fundamental regional differences in land cover during the rise of early complex societies. The goal of this paper is to illuminate contrasts in ancient agrarian landscapes on the basis of carbonized plant macrofossils and charcoal recovered from a selection of Bronze Age excavations in Syria, Jordan and Cyprus. In particular, we are concerned with explaining the apparent dearth of carbonized seeds found on Cyprus, not as an issue of archaeological preservation, but as part of fundamental insight on the ancient agrarian landscape of this island.

2. Study areas

This research presents an inter-regional comparison of archaeobotanical evidence from which we may infer distinct differences in land use and landscape formation between Bronze Age agrarian communities in the Near East and on Cyprus. The modern climatic regime of these regions is distinctly Mediterranean, with long, hot summers and short, cool, rainy winters (see discussions in Wigley and Farmer, 1982; Roberts and Wright, 1993; Wilkinson, 2003). We utilize data from five Early and Middle Bronze Age settlements in the eastern Mediterranean that provide substantial bodies of detailed excavated evidence of charcoal and carbonized seeds, including Tell Umm el-Marra and Tell es-Sweyhat in Syria, Tell Abu en-Ni'aj and Tell el-Hayyat in Jordan, and Politiko-*Troullia* in Cyprus (Fig. 1). Tell Umm el-Marra (in the Jabbul Plain) and Tell es-Sweyhat (in the upper Euphrates drainage) sit about 50 km apart amid the rolling steppe of inland Syria. The town of Tell es-Sweyhat (35 ha) witnessed the rise and collapse of Early Bronze Age urbanism in Upper Mesopotamia (ca. 3000–2000 B.C.E.; Danti and Zettler, 2002). Habitation at Umm el-Marra (25 ha) began in the Early Bronze Age (Curvers and Schwartz, 1997) and subsequently experienced the urbanization, collapse and reurbanization of the third and second millennia (ca. 3000–1200 B.C.E.; Schwartz et al., 2000; Schwartz, 2007). A legacy of long-term intensive agriculture and pastoralism has left the region resembling a treeless agro-desert with portions of previously-cultivated land left bare (Wilkinson, 2003, p. 18). During the Bronze Age, however, this region consisted primarily of terebinth-almond woodland steppe, along with shrubby vegetation of almond, cherries, and hawthorns (Moore et al., 2000). Uncultivated portions of this steppe would have been ideal for grazing (Miller, 1997a).

Tell Abu en-Ni'aj and Tell el-Hayyat lie well below sea level in the northern Jordan Valley, Jordan. Early Bronze Age towns in the southern Levant flourished in the early third millennium B.C., experienced near-wholesale abandonment at the end of that millennium, and then during the Middle Bronze Age recovered in greater numbers and sizes than before (Ilan, 1995; Falconer and Savage, 2009). Tell Abu en-Ni'aj (measuring 2.5 ha) represents an agricultural village of about 500–600 people inhabited during the abandonment of towns during the final roughly 300 years of the Early Bronze Age (ca. 2300–2000 B.C.). Abu en-Ni'aj would have been part of a deurbanized settlement system of villages and seasonal encampments in the fertile fields and grazing lands along the Jordan Valley (Falconer et al., 2007). Tell el-Hayyat (0.5 ha) was a hamlet of 100–150 farmers during the redevelopment of Middle Bronze Age towns (ca. 2000–1500 B.C.; Falconer and Fall, 2007). In

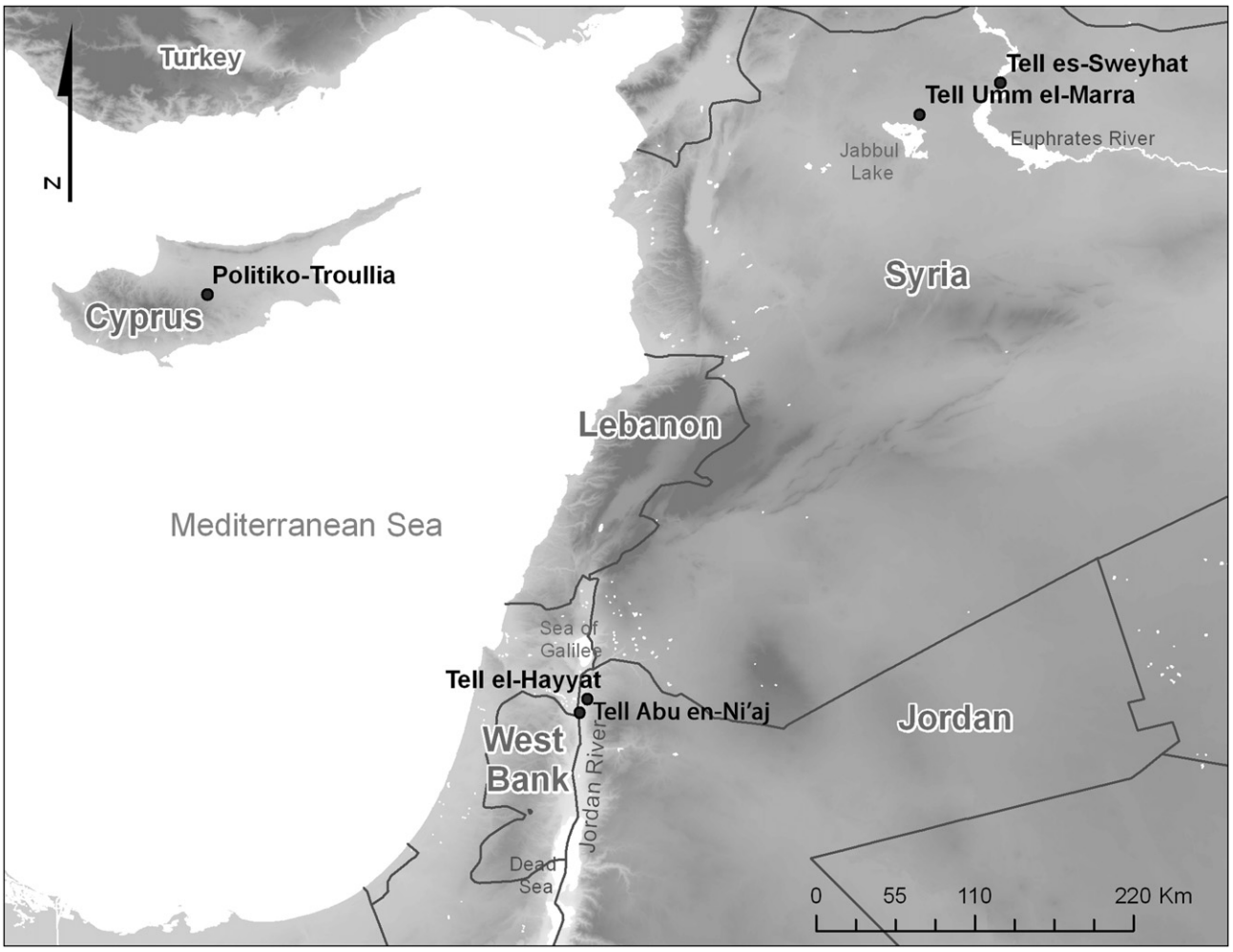

Fig. 1. Map of eastern Mediterranean showing the locations of the study sites in Cyprus, Jordan and Syria.

contrast, this community was part of a well-integrated network of small towns and villages (Falconer and Savage, 1995, 2009). Archaeological and palynological evidence suggests that the bottom lands of the Jordan Rift have undergone multiple eras of agricultural intensification, particularly as signaled by evidence for periodic clearance of native oak woodlands to establish and cultivate orchards (Fall et al., 2002) as part of the secondary products revolution (Sherratt, 1980).

Politiko-*Troullia* lies at the junction of the Mesaoria plain of central Cyprus and the copper-bearing foothills of the Troodos Mountains. Ceramics from the Middle Bronze Age (also known as Middle Cypriot; ca. 2000–1500 B.C.E.), especially Red Polished Ware, cover an expanse of roughly 20 ha between two once-flowing streams, the Pediaios River to the east and Kamaras Creek to the west (Falconer et al., 2005). Within this area, the buried remains of a 2–3 ha village lie at the foot of the heavily terraced hill of Politiko-*Koliokremmos*. To the north, the low hill of Politiko-*Lampertis* holds the rock-cut tombs associated with Politiko-*Troullia* (Fall et al., 2008). Unlike the Near Eastern mainland, the first cities and urbanized society did not appear on Cyprus until the latter half of the second millennium B.C. (i.e., in the Late Bronze Age or Late Cypriot Period, ca. 1400–1200 B.C.). Politiko-*Troullia* thrived during the lead up to the first cities on the island, and thus provides a window on pre-urban agricultural society contemporaneous with episodes of urban rise and collapse on the Near Eastern mainland.

A long-standing assumption holds that plant remains are "not abundant in any site on Cyprus" (Hansen, 2003, p. 450), largely due to poor botanical preservation in shallow, permeable sediments. Recent Neolithic and Chalcolithic excavations have been more botanically productive (Murray, 1998; Willcox, 2003; Colledge and Conolly, 2007; Zeder, 2008), but interpretation of modest Bronze Age seed assemblages tends to be limited to species presence/absence (e.g., Adams and Simmons, 1996, Tables 9.12–9.15). Indeed, our flotation of nearly 500 l of sediment so far has produced seed densities much lower than those reported for Bronze Age settlements on the Near Eastern mainland (e.g., Miller, 1991; Fall et al., 2002). However, outstanding preservation of animal bones and fragile seed types at Politiko-*Troullia* suggests that taphonomic conditions alone do not explain the low seed counts adequately. Instead, a reevaluation of the botanical evidence from Politiko-*Troullia* in comparison with contemporaneous evidence from the mainland Near East holds fundamental implications for a comparative understanding Bronze Age landscape formation (particularly during Early to Middle Bronze Age) on Cyprus and the nearby Near Eastern mainland.

3. Sampling and processing methods

All paleobotanical remains considered in this study were collected using non-random sampling during the excavation of all five archaeological sites. At Tell el-Hayyat (excavated in 1982, 1983 and 1985), Tell Abu en-Ni'aj (1985, 1996 and 2000) and Politiko-*Troullia* (2006, 2007 and 2008) all sediments showing evidence of charred remains were sampled for flotation processing and

botanical analysis at field laboratories in Deir Alla, Jordan and Pera Orinis, Cyprus under the supervision of Patricia Fall (see Falconer and Fall, 2007; Falconer et al., 2005; Fall et al., 2002, 2004, 2008). The excavations at Tell es-Sweyhat (1989, 1991 and 1993; Danti and Zettler, 2007) and Tell Umm el-Marra (1994–1997; see Curvers and Schwartz, 1997; Schwartz et al., 2000; Schwartz and Miller, 2007) produced samples from hearths, ash lenses and trash deposits that were processed and analyzed under the supervision of Naomi Miller (Miller, 1997a, b).

In a consistent manner, the sediment samples from Politiko-*Troullia*, Tell el-Hayyat, Tell Umm el-Marra and Tell es-Sweyhat were processed using manual, non-mechanized flotation equipment (Miller, 1997a; Fall et al., 1998, 2002, 2004, 2008), while the samples collected at Tell Abu en-Ni'aj were processed with a mechanized flotation machine (a Float Tech 2000; Falconer et al., 2004; Fall et al., 1998, 2002). Whether mechanized or not, the flotation methods at all five sites recovered organic remains by utilizing a large tub of water, in which a smaller basket with a 5 mm mesh bottom was suspended. Each sample was placed in the water and agitated to break the sediment and free the charred botanical remains, including charcoal and charred seeds. Light fraction remains (i.e., plant fragments) float to the surface of the water, while heavy fraction remains (i.e., heavier non-organic sediments) sink to the bottom of the basket, but do not pass through the mesh. In order to separate, the light fraction was skimmed from the water's surface using a fine mesh sieve, and the heavy fraction was collected in the mesh-bottomed basket. Both the heavy and light fractions were dried prior to analysis.

Comparable methods were employed for the processing of botanical remains from all five sites (see Fall et al., 1998, 2002, 2008; Miller, 1997a; Schwartz et al., 2000; Falconer and Fall, 2007). The botanical remains from Politiko-*Troullia*, Tell el-Hayyat and Tell Abu en-Ni'aj were processed through a sample splitter that segregated the light fraction from each sample into comparably-sized sub-samples for identification and quantification. Each light fraction sample was then poured through 4.75 mm, 2 mm, 1 mm, and 0.5 mm sieves. Remains measuring two mm or greater were sorted into wood, seed and seed fragments, and straw and chaff remains. For each sample, the charcoal was weighed and recorded, and the seeds and seed fragments were identified and recorded. Any material that fell between 1 and 2 mm was sorted into identifiable seeds and seed fragments, as well as rachis nodes and spikelets. Material falling between 0.5 and 1 mm was scanned, and any identifiable seeds, seed fragments and/or rachis nodes were removed and recorded. Further study involved separating the charcoal from the seeds within each sample by collecting all charcoal 2 mm or greater and weighing and recording that amount.

All economic seed remains at Tell es-Sweyhat and Tell Umm el-Marra (i.e., cereals, pulses and orchard crops) were counted and weighed, based on whole seeds and seed fragments 1 mm or larger (Miller, 1997a). All seeds from non-economic taxa (i.e., wild and weedy seeds) were counted and weighed when 2 mm or larger. Seeds from wild and weedy plants smaller than 2 mm were not weighed, but were counted, and finally, the counts and/or weights of any identified rachis internodes, spikelets and other plant parts were recorded as separate categories.

3.1. Analytical methods

As with sample collection and processing, the methods used to analyze the botanical remains from Tell el-Hayyat, Tell Abu en-Ni'aj and Politiko-*Troullia* are largely consistent with those used for Tell Umm el-Marra and Tell es-Sweyhat. All samples were sorted under a binocular microscope to identify the charred botanical remains to the most specific taxonomic level possible. Seeds were identified by comparison to reference materials and seed identification manuals based on overall appearance, including characteristics of size, shape and surface texture. For example, Pearsall (1989) details diagnostic features used for plant identification, such as texture and attachments of the seed coat and other distinctive surface elements. Since carbonized cereal grains and some wild seeds are more susceptible to fragmentation and distortion than the seeds of many orchard species (e.g., olive, grape), the identification of these annual species was aided by descriptions and drawings in Pearsall (1989) and Renfrew (1973). In quantifying archaeologically-recovered botanical assemblages, the observed number or weight of seeds may not be a reflection of the actual utility of that species. As Birks and Birks (1980) note, the number of macrofossils produced by various plant taxa can vary greatly, based on differences in germination rate, dispersal rate, palatability, and preservation, all of which affect taxonomic representation in a seed assemblage. With these considerations in mind, this study emphasizes a variety of relative measures of charcoal and seed abundance within and between sites occupied in the Early and Middle Bronze Age.

While some seeds may be identified to species level, virtually all of the charred plant remains are divided into the following categories: orchard crops, cereals, cultivated legumes, wild/weedy seeds, charcoal and the remaining components of charred plants (e.g. rachis internodes and spikelets). The first three categories can be interpreted in terms of the production, processing and/or consumption of economic taxa (Hastorf, 1988). Orchard crops reflect long-term investment in marketable secondary products (Zohary and Hopf, 1988; Zohary, 1992), while cereal crops would have been cultivated for human and/or animal consumption (Miller, 1988). Arboriculture associated with our study sites featured olive (*Olea europea*), fig (*Ficus carica*), grape (*Vitis vinifera*), and pistachio (*Pistacia* sp.) (Fall et al., 2002). Cereal cultivation emphasized wheat (einkorn [*Triticum monococcum*], emmer [*Triticum trugidum* subsp. *dicoccum*] and bread wheat [*Triticum aestivum/T. compactum*]) and hulled two-row barley (*Hordeum vulgare* or *H. distichum*). Less prolific cereals include oats (*Avena* sp.) and rye (*Secale* sp.). Cereal crops were supplemented by cultivated legumes, including peas (*Pisum sativum),* lentils (*Lens culinaris),* chickpea (*Cicer*), horsebean (*Fava*) and grass pea (*Lathyrus*). Wild and weedy taxa include uncultivated grasses, legumes and weeds, many of which followed the clearance and cultivation of farmlands.

3.2. Interpretive methods

Individual plant taxa or larger botanical categories may be quantified in many ways to serve a variety of analytical purposes (e.g., see discussions in Hastorf, 1988; Pearsall, 1989; Cotton, 1996). In this study, most seeds from cultivated taxa are identified to genus level and then grouped into broader categories of orchard taxa, cereals and legumes. Seeds from non-cultigens are subdivided into categories of wild and weedy seeds. Relative frequencies of plant taxa or categories permit broad characterization of the mix of crop cultivation, animal management and land use strategies employed by our sample of communities in the ancient Near East and Cyprus. In addition, calculation of density ratios (e.g., the weight of charcoal or number of seeds per volume of sediment floated) permits assessment of relative rates of deposition, preservation and recovery of charred botanical remains (Miller, 1988), and provides a means of standardizing data for comparison between sites. This study quantifies seed densities based on seed weight or the number of plant fragments recovered per kiloliter of processed sediment. Charcoal density, which is often more subject to extreme fragmentation during use, deposition and recovery, is expressed as charcoal weight per kiloliter of sediment.

Several ratios derived from seed counts, seed weights and charcoal weights provide more detailed insights on Bronze Age crop and herd management, and environmental interaction. These ratios and their interpretation build on the argument that charred seeds from archaeological trash sediments tend to originate from burned dung fuel, whereas charcoal fragments represent the remains of burned fuel wood. One ratio utilized commonly in archaeobotanical analysis compares relative amounts of carbonized seeds to charcoal (e.g., Miller, 1988). Since carbonized seeds reflect a variety of land use strategies, this ratio is most valuable as a relative measure of fuel wood consumption and a proxy measure of tree cover (Schwartz et al., 2000, pp. 446–447). Such tree cover ratios commonly compare seed and charcoal weights. We also present tree cover ratios as seed counts relative to charcoal weight.

A second ratio comparing wild and weed taxa to charcoal provides a more selective measure of fuel use. In this instance, carbonized wild and weedy seeds (rather than seeds from cereals, legumes or orchard taxa), should result from burning of dung produced by animals grazing on uncultivated or fallow land. This ratio of wild and weedy seed count to charcoal weight estimates the relative mix of dung vs. wood fuel utilization, and therefore of open vs. woodland landscape (Schwartz et al., 2000, pp. 446–447). A closely-related third ratio of cereal seed count to charcoal weight provides a measure of subsistence crop cultivation relative to fuel wood consumption (Miller, 1997a, p. 101). In this ratio cereal seeds (as opposed to wild/weed seeds) should stem from burning of crop processing debris or of dung from animals feeding on crop stubble or fodder (rather than grazing on uncultivated land). A fourth ratio of seed counts for wild and weedy taxa vs. cereal taxa provides a relative measure of reliance on pastoralism vs. food crop cultivation (Schwartz et al., 2000, pp. 446–447).

4. Results

The botanical assemblages from our sample of five sites reveal relative seed frequencies for major taxonomic categories with clear similarities between Tell el-Hayyat and Tell Abu en-Ni'aj in the Jordan Rift, and between Tell es-Sweyhat and Tell Umm el-Marra in Syria (Fig. 2). All data used in this study come from Early and Middle Bronze Age deposits (see Appendix 1). Pronounced distinctions emerge between the preponderance of orchard crop remains at Politiko-*Troullia*, as compared to the greater abundance of cereals and pulses in the Rift villages, and the profusion of wild and weed seeds at the Syrian sites. In contrast to *Troullia*, orchard remains are moderate in relative frequency at Hayyat and Abu en-Ni 'aj, and nearly absent at Sweyhat and Umm el-Marra (Table 1). The remains of annual crops (pulses and especially cereals) provide the largest floral component at the Jordanian sites, but only minor contributions at the other three settlements. The plant assemblages from Sweyhat and Umm el-Marra are characterized by nearly 90% frequencies of wild and weed taxa. Interestingly, new data analyzed from eleven samples from Umm el-Marra (Schwartz and Miller, 2007; new data are summarized in Appendix 1) show similar patterns to the results presented here (Schwartz et al., 2000).

The site-by-site ranking for seed density runs nearly opposite the ranking for charcoal density. Seed remains range from the highest density at Tell Abu en-Ni'aj, followed by the Syrian sites and Tell el-Hayyat, to the lowest density at Politiko-*Troullia* (Table 2). Conversely, Tell el-Hayyat provides the highest charcoal concentration, followed by *Troullia* and Abu en-Ni'aj, and then trailed by Sweyhat and Umm el-Marra. Tell Abu en-Ni'aj and Umm el-Marra offer the highest seed to charcoal ratios according to seed weight and by seed count, followed by Tell es-Sweyhat, Hayyat and

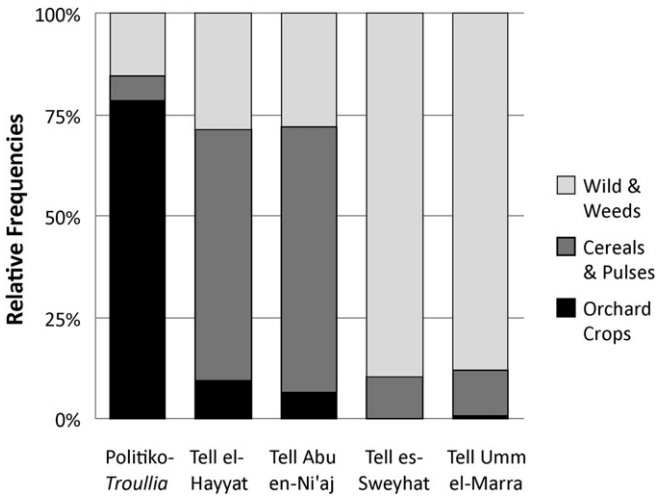

Fig. 2. Relative frequencies of seed categories by archaeological site. Data sources: Politiko-*Troullia* and Tell Abu en-Niaj unpublished previously; Tell el-Hayyat (Falconer and Fall, 2007); Tell es-Sweyhat (Miller, 1997a); Umm el-Marra (Schwartz et al., 2000).

Table 1
Seed counts from Early and Middle Bronze Age sites from the eastern Mediterranean.

Taxon	Politiko-*Troullia*[a]	Tell el-Hayyat[b]	Tell Abu en-Ni'aj[a]	Tell es-Sweyhat[c]	Umm el-Marra[d]
	$n=54$; 0.367kl	$n=15$; 0.074kl	$n=37$; 0.113kl	$n=17$; 0.126kl	$n=13$; 0.168kl
Charcoal (g)	178.8	210.25	54.84	23.56	4.57
Orchard					
Ficus	223	86	2006	1	19
Olea	33	47	19	0	4
Pistacia	26	0	8	0	0
Vitis	32	5	24	0	5
Total	314	138	2057	1	28
Cereals					
Avena	3	113	10	0	0
Hordeum	2	50	2463	618	337
Secale	2	89	38	0	0
Triticum	5	67	767	29	43
Cereal indet.	13	133	10,166	249	388
Total	25	452	13444	1035	629
Cultivated legumes					
Cicer	0	11	0	0	1
Fava	0	2	0	0	0
Lathyrus	0	4	0	2	2
Lens	0	29	2	4	6
Pisum	0	4	33	0	0
Pulse indet.	0	0	36	125	1
Total	0	50	71	131	10
Wild & weed seeds					
Wild legume	4	89	388	8199	1067
Wild grass	0	104	1444	728	2040
Other weed	21	368	2165	718	1195
Other wild	0	0	0	0	15
Unknown wild/weed	37	2	2227	356	595
Total	62	563	6224	10,001	4912
Total	401	1203	21,796	11,168	5579

[a] Data unpublished previously.
[b] Data from Falconer and Fall, 2007.
[c] Data from Miller, 1997a, Appendix 6.3.
[d] Data from Schwartz et al., 2000, Table 4.

Table 2
Ratios from Early and Middle Bronze Age sites from the eastern Mediterranean.

Taxon	Politiko-*Troullia*[a]	Tell el-Hayyat[b]	Tell Abu en-Ni'aj[a]	Tell es-Sweyhat[c]	Umm el-Marra[d]
	n = 54; 0.367kl	n = 15; 0.074kl	n = 37; 0.113kl	n = 17; 0.126kl	n = 13; 0.168kl
Charcoal (g)	178.8	210.25	54.84	23.56	4.57
Densities					
Charcoal (g/kl)	487	2842	485	187	27
Seed (#/kl)	1093	16,257	192,885	88,635	33,208
Ratios					
Sample means					
Seed:char (g:g)	0.35	0.97	2.37	1.27	2.42
Seed:char (#:g)	30.4	110.2	1733.1	866.0	1564.1
Wild:char (#:g)	15.5	19.8	376.4	717.4	1277.1
Cer:char (#:g)	7.42	6.62	1272.8	140.4	276.1
Wild:cer (#:#)	2.24	2.69	3.14	7.84	8.18

[a] Data unpublished previously.
[b] Data from Falconer and Fall, 2007.
[c] Data from Miller, 1997a, Appendix 6.3.
[d] Data from Schwartz et al., 2000, Table 4.

Politiko-*Troullia*. Furthermore, the higher seed to charcoal ratios are fueled by particularly large amounts of cereals at Abu en-Ni'aj, abundant wild/weed seeds at Sweyhat and el-Marra, and small charcoal weights at all three sites, especially Umm el-Marra. In contrast, lower seed to charcoal ratios at Tell el-Hayyat and Politiko-*Troullia* reflect very limited evidence of annual crops at *Troullia* and substantial charcoal weights at both sites.

Additional, more specific ratios tend to group the Syrian sites together, sometimes in conjunction with Tell Abu en-Ni'aj, whereas the ratios for Politiko-*Troullia* show similarities only to Tell el-Hayyat, or stand alone. Umm el-Marra and Sweyhat generate the highest ratios of wild and weedy seeds to charcoal weight, followed by Tell Abu en-Ni'aj, while Hayyat and *Troullia* produce starkly lower values. Among cereal to charcoal ratios, Abu en-Ni'aj emerges with an extremely high value, followed by much lower ratios for Umm el-Marra and Sweyhat. Again, Hayyat and *Troullia* make up the bottom end of the range, with very low ratios. The wild and weed to charcoal and cereal to charcoal ratios again reflect the abundance of cereals at Abu en-Ni'aj and of wild and weed seeds at Sweyhat, coupled with low charcoal densities at both sites, and especially at Umm el-Marra. The driving factor in the ratios for Tell el-Hayyat and Politiko-*Troullia* is their much higher relative abundance of charcoal. The ratios based on seed counts for wild and weed taxa versus cereals include comparably high values for the Syrian sites, and comparably lower values for the Jordan Rift settlements and Politiko-*Troullia*. These results reflect the modest amounts of cereals and the abundance of weeds at Umm el-Marra and Sweyhat, and the minimal evidence of wild and weedy species at the other three settlements, especially Politiko-*Troullia*.

5. Discussion

Analysis of charred botanical remains commonly leads to interpretation of crop production, processing and consumption (Hastorf, 1988). Accordingly, utilizes the density of charred botanical remains within an archaeological site as a measure of fire-intensive activities (ceramics, metallurgy, meal preparation) and, thereby, land use and land cover for a wide variety of landscapes, in the highlands of the Andes, the Tibetan Plateau, the various landscapes of the Near East among countless others. Many scholars (Miller, 1988; Sillar, 2000; Anderson and Ertug-Yaras, 1998; Rhode et al., 2007) discuss the potential sources of fire fuel particularly in areas of sparse tree cover, in which activities would necessitate a material other than preferred wood charcoal. In agrarian societies a particularly likely alternative is animal dung, which by nature is a representation of land cover by virtue of the charred material within the dung. Miller (e.g., 1988) has been particularly influential in the study of botanically derived seed and charcoal ratios as a means of inter- and intra-site comparisons regarding land cover and land use. Our application of this approach reveals variable expressions of Bronze Age land use and land cover as inferred from a sample of five data-rich excavated settlements in Jordan, Syria and Cyprus.

Following the rationale that seed to charcoal ratios primarily suggest relative availability and consumption of fuel wood, lower values imply substantially more tree cover on the landscapes surrounding Tell el-Hayyat, and especially Politiko-*Troullia*, than around Tell Abu en-Ni'aj, Tell es-Sweyhat and Umm el-Marra. This general pattern holds true whether using seed weight or count, particularly as it distinguishes the apparently wooded countryside around Politiko-*Troullia*. Intriguingly, Tell el-Hayyat and Tell Abu en-Ni'aj, located in very close proximity in the Jordan Valley, reveal clearly dissimilar seed to charcoal ratios. Abu en-Ni'aj's ratio based on seed count is more than 15 times larger than that at Hayyat. Further results, however, suggest differing land use strategies may explain this disjunction better. The differences between Tell Abu en-Ni'aj and Tell el-Hayyat reflect the cultural milieu in which each village was occupied. Villagers of Tell Abu en-Ni'aj lived during Early Bronze IV, an era of urban collapse, and practiced a mixture of subsistence agriculture and sheep/goat husbandry, possibly in cooperation with the non-sedentary pastoral populations, who are hypothesized as the major component of Early Bronze IV society. In contrast, the farmers of Tell el-Hayyat lived during the subsequent redevelopment of urbanism during the Middle Bronze Age, and intensified their production of marketable crops (e.g., olive oil), probably as part of more commonplace forest clearance for orchards.

As relative measures of open versus wooded landscapes, the wild and weed to charcoal ratios amplify the patterning seen in the seed to charcoal values. Much less wooded land cover is suggested by the higher values for Abu en-Ni'aj, Sweyhat and Umm el-Marra (in ascending order). The much lower values for *Troullia* and Hayyat (by more than an order of magnitude) suggest the distinction between their local woodlands and much more open vegetation around the other three settlements. Carbonized seed remains are recovered less commonly on Cyprus due largely to the relatively less frequent burning of animal dung, with its constituent plant remains, than on the Near Eastern mainland. Conversely, the apparent persistence of forests would have encouraged greater burning of fuel wood than in the Near East.

The cereal to charcoal ratios allude to distinctions in land use associated with these landscapes. Intensive cultivation of annual cereals and legumes emerges as the most likely primary factor behind the very high value for Tell Abu en-Ni'aj. Lesser values for Sweyhat and Umm el-Marra, in conjunction with high seed to charcoal and wild to charcoal ratios, suggest a relatively open landscape less dedicated to crop cultivation than the fields surrounding Tell Abu en-Ni'aj. As a further commentary on variable land use, the ascending ratios of wild and weed taxa suggest the increasing scale of pastoralism relative to crop cultivation from a low at Politiko-*Troullia* ascending to the Jordan Rift villages and, more substantially, to the towns of Syria. There are several factors that contributed to the more forested landscape of Cyprus and, hence, the great concentration of archaeological recovered charcoal fragments on the island. While the onset of urbanism appeared later than in ancient Jordan and Syria, the Cypriot Bronze Age, like that of the Near Eastern mainland, ushered in intensified cultivation of orchard crops, often involving deforestation to make way for

orchards. However, Cyprus was characterized by lower population density and more dispersed pre-urban settlement. The persistence of forest resources is reflected in substantial evidence of deer and wild goat hunting, which continues later on Cyprus than on the mainland.

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Appendix 1. Supplementary data

Supplementary data associated with this article can be found in the online version, at doi:10.1016/j.jas.2010.05.022.

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