Quaternary Research 74 (2010) 216–226

Contents lists available at ScienceDirect

Quaternary Research

journal homepage: www.elsevier.com/locate/yqres

Vegetation development in the Middle Euphrates and Upper Jazirah (Syria/Turkey) during the Bronze Age

Katleen Deckers [a,*], Hugues Pessin [b]

[a] University of Tübingen, Zentrum für Naturwissenschaftliche Archäologie, Rümelinstr. 23, 72070 Tübingen, Germany
[b] University of Sheffield, Department of Archaeology, Northgate House, West St., Sheffield S1 4ET, UK

ARTICLE INFO

Article history:
Received 11 November 2008
Available online 7 August 2010

Keywords:
Anthracology
Wood resources
Deforestation
Climatic impact on vegetation
Syria
Turkey

ABSTRACT

Vegetation changes are reconstructed based on more than 51,000 charcoal fragments of more than 380 samples from nine Bronze Age sites in northern Syria and southern Turkey. In addition to fragment proportions, special attention was paid to the frequency of *Pistacia* relative to *Quercus* and *Populus/Salix* relative to *Tamarix*, fruit-tree ubiquity, and riverine diversity in order to gain an improved understanding of the human versus climatic impact on the vegetation. The results indicate that human impacts first took place within the riverine forest. This phase was followed by land clearing within the woodland steppe, especially in the northern portion of the study area. In the south near Emar, the woodland steppe probably disappeared by the Late Bronze Age. It is uncertain whether this was caused by aridification and/or human clearing. The northward shift of the Pistacia-woodland steppe is very likely a result of climatic drying that occurred throughout the entire period under investigation. Although increased deforestation is evident through time, the small proportions of imported wood indicate that local resources were still available.

Introduction

It is well known that woodlands are vital for life, they protect the soil from erosion and retain water in the soil, and are home to a rich variety of species. Woodlands produce oxygen, store carbon dioxide and, therefore, impact climate. Woodlands are also vital for those living within their confines, as they provide shelter, food, and firewood. In the Mediterranean and Near East, most scholars believe that massive degradation, including deforestation, occurred (Zohary, 1973; McNeil, 1992; Brandt and Thornes, 1996; Moore et al., 2000). Today, hardly any woody vegetation is growing within the Upper Jazirah, apart from some Populetea remains along the Euphrates. Satellite analysis and observations in the field show that the nearest stands of woodland are located in Turkey, about 10 km north of Horum Höyük and about 14 km north of Tell Mozan (Fig. 1).

Studies on the remaining vegetation have indicated that northern Syria could potentially, under the absence of human impact, be covered by woodland (Moore et al., 2000). For the Middle Euphrates and Upper Jazirah, however, little until now was known about the vegetation history due to poor pollen preservation (Bottema, 1989). Only recently have several anthracological projects been undertaken in this area (Frey et al., 1991; Engel, 1993; Willcox, 2002; Deckers, 2005; Deckers and Riehl, 2007b; Pessin, 2004, 2007) that have allowed for a regional synopsis of vegetation development from the Early to Late Bronze Age, a period that covers about 1800 yr from ca. 3000 until 1200 BC. The Early Bronze Age generally lasted from about 3000–2000 BC, the Middle Bronze Age from 2000–1600 and the Late Bronze Age from 1600–1200 BC.

The Bronze Age is particularly interesting because at its start societies were quite rural, probably impacting the vegetation only minimally, but shortly after (ca. mid-third millennium BC) became urbanized. It is also the period when plow use and fruit-tree cultivation became increasingly applied, and increased specialization within the agrarian and pastoral sector occurred (Akkermans and Schwartz, 2003). It is also of interest that one of the Middle Bronze Age rulers claimed to have intensively cut cedars and pines from the mountains, hence imported wood from remote areas (Taraqji, 1997).

Another reason why studying the vegetation development of this period is so interesting is the fact that the Middle Bronze Age was most likely as dry as it is today in this area (Fig. 2), while the Early Bronze Age was generally more moist and the Late Bronze Age drier (Lemcke and Sturm, 1997; Wick et al., 2003). In this way, it is possible to understand what vegetation cover would likely occur in the absence of several millennia of human impact.

The Middle Euphrates and Upper Jazirah show a strong gradient in rainfall from north to south, with values of more than 450 mm in the north and as little as 150 mm in the south (Fig. 1). The northern part of this zone belongs to the Fertile Crescent, a narrow zone of land where rain-fed agriculture is possible. South of the 250-mm border, the land is progressively drier and rain-fed agriculture becomes difficult. The sharp gradient and the borderline location make it a sensitive area to observe changes in vegetation.

* Corresponding author.
E-mail addresses: katleen.deckers@uni-tuebingen.de (K. Deckers), huguespessin@hotmail.com (H. Pessin).

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doi:10.1016/j.yqres.2010.07.007

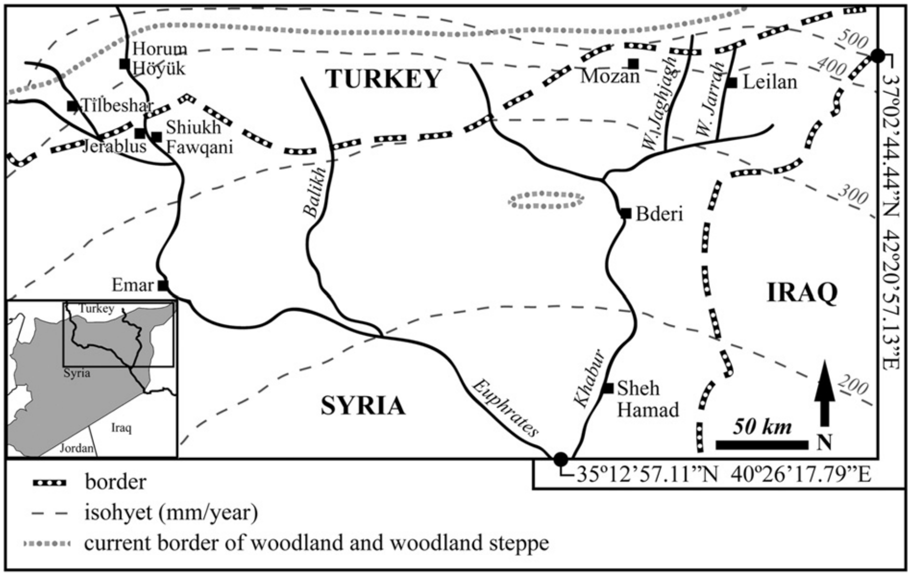

Figure 1. Map with location of sites. The present-day border of woodland (steppe) was delineated based on the analysis of satellite images and field observations.

In this article, we provide a reconstruction of vegetation changes based on anthracological analysis within this area for the duration of the Bronze Age (3000–1200 BC), evaluate causes for the observed changes and hint at the potential vegetation cover.

Studied material

This reconstruction of vegetation changes during the Bronze Age is based on charcoals from nine archaeological sites (Table 1). Most of the sites discussed have a riverine location, which was not always obvious upon first inspection. This is particularly true for Tell Leilan, where the Jarrah was dammed and runs dry. Tell Mozan is the only site included in this body of research that was not located along a permanent stream.

Table 1 depicts the number of samples and fragments for each site and shows details of fragment counts and ubiquity scores for all the sites and periods. In total, this summary contains more than 64,000 fragments from 329 samples, most of which were identified during our study. Published data from Tell Sheh Hamad (Frey et al., 1991) and Tell Bderi (Engel, 1993) have been included within this overview as well. Most data are derived from floated samples. Flotation samples from Tell Mozan, as well as large sediment samples from charcoal concentrations, have been investigated and should be representative of the local vegetation. A range of domestic contexts have also been analyzed (see, e.g., Deckers, 2005 for details of Emar), mostly deriving from secondary fill deposits. Charcoal samples from a few abandonment layers, hearths and construction wood have also been included here within the overview. The latter context is represented only in very few cases.

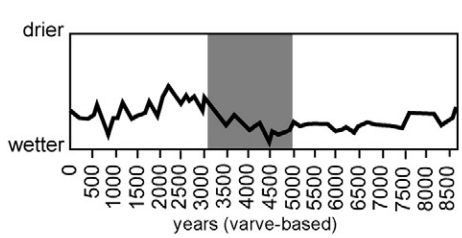

Figure 2. Van paleoclimatic proxy data based on stable oxygen isotopes; chronology based on varve counting (after Lemcke and Sturm, 1997).

Interpretation of the wood charcoal assemblages in relation to past habitats

Although other factors may have played a role in the representation of woody taxa at a site, it is often assumed that, especially in the case of firewood, they approximate the relative abundance of taxa in the vegetation of the area (Asouti and Austin, 2005). Based on this assumption, the amount of a charcoal taxon within samples and its ubiquity throughout the samples from a site are used as indicators of the relative abundance in the local vegetation (Smart and Hoffman, 1988). Since it has been demonstrated that weighing samples provides comparable results to counting (Miller, 1985; Chabal, 1991), and because fragments within this area were counted in previous studies, we only report results based on fragment counts. Considering the large number of data, fragment percentages were grouped into five vegetation categories, more precisely open park woodland, riverine forest, imported taxa, cultivated taxa, and a non-specifiable class.

Deciduous *Quercus*, *Pistacia*, *Amygdalus*, Pomoideae, *Prunus*, *Juniperus*, *Rhamnus*, *Lycium*, *Paliurus*, and *Ziziphus* were interpreted as belonging to open park woodland or woodland steppe (Zohary, 1973). Within this region, the main woody taxon of the open park woodland would consist of *Quercus*, whereas *Pistacia* would indicate woodland steppe (Moore et al. 2000). Overall, references within this paper to open park woodland imply a somewhat lusher woody vegetation than that assumed for woodland steppe. However, using charcoal identifications it remains difficult to draw a clear boundary between park woodland and woodland steppe, since they form a continuum. There is also a considerable species overlap between the two vegetation units, and it is difficult to reconstruct the density of the vegetation.

Salix/*Populus*, *Tamarix*, *Fraxinus*, *Phragmites*, *Alnus*, *Clematis*, *Platanus*, *Eleagnus Angustifolia*, and *Ulmus* were classified as taxa of the riverine forest (Zohary, 1973). There exist, however, some 24th century BC texts from southern Mesopotamia that indicate (if the words are translated correctly) that *Populus* and *Tamarix* were also planted, besides occurring naturally in the riverine woodland (Powell, 1992).

Furthermore, it is impossible to distinguish wild from cultivated fruit trees by means of basic wood anatomy. Although the present day natural distribution of *Vitis* and *Ficus* indicates some may have been growing wild in the local surroundings (see Zohary and Hopf, 2000), we classified them among the cultivated taxa. Seeds of these fruits

https://doi.org/10.1016/j.yqres.2010.07.007 Published online by Cambridge University Press

Table 1
Fragments and occurrence scores of taxa in the samples for each site and period. AF refers to absolute frequency and U to the ubiquity.

Site	Horum Höyük						Tilbeshar								Jerablus				Shiu kh Fawqani					
Period (BC)	3000–2800		2200–2000		2000–1700		3000–2700		2500–2200		2200–2000		1800–1600		3000–2700		2700–2200		3000–2800		2200–2000		1400–1200	
Frequency and ubiquity	AF	U	AF	U	AF	U	AF	U	AF	U	AF	U	AF	U	AF	U	AF	U	AF	U	AF	U	AF	U
Acer sp.					1	1											1	1						
Alnus sp.					3	2			3	2	5	1	2	1					8	3	11	3	68	4
Am vgdalus sp.			3	2	10	2	12	5	26	6	4	1	3	2			7	2						
Buxux sp.																								
Cedrus sp.																	14	1						
Chenopodiaceae					2	1	2	1			1	1												
Clematis sp.																	1	1						
Conifer sp.																								
Cupressus sp.																								
Eleagnus angustifolia																								
Ficus carica					25	1							1	1	8	1	26	6						
Fabaceae																	1	1	9	2	2	1		
Fraxinus sp.	3	2	8	2	227	2	305	10	100	7	32	2	33	4			105	7	95	11	2	1	69	2
Juglans sp.															70	1								
Juniperus sp.					3	2	2	1	18	3	3	1					4	2	2	2			3	1
Lycium sp.																								
Monocotyledon									2	1					8	3	29	5						
Morus alba																								
Olea europea			14	3	451	6	4	1	73	7	35	2	29	3			14	2						
Paliurus spina-christi					1	1	2	1											2	2	2	1		
Phoenix sp.																	45	3						
Phragmites autralis			1	1	1	1	29	9	11	5	2	1	1	1					59	9	6	2	67	8
Pinus brutia/halepensis			1	1	52	3	9	3	41	5	45	2	14	2							11	2	80	4
Pinus nigra/sylvestris					2	1	6	3									22	3	6	4				
Pistacia atlantica	7	1	6	1	9	3	12	5	29	7	6	1	31	3			16	2	3	2				
Pistacia sp.																	5	2						
Platanus orientalis			2	1	87	2	7	2	10	4	2	1	9	2			4	1	28	5	6	1	16	2
Platnus sp./*Fagus* sp.																	3	2						
Pomoideae	1	1			23	2	36	8	22	7	5	1	4	1					6	3			2	1
Prosopis farcta																								
Prunus sp.							143	4	10	4	1	1							6	3				
Quercus deciduous	329	7	138	3	1783	7	856	10	669	8	292	2	405	4	1	1	95	6	59	11	1	1	159	3
Quercus evergreen																								
Quercus sp.																	7	2						
Rhamnus sp.									1	1			1	1										
Salix sp./*Populus* sp.	11	3	4	2	129	6	59	8	13	5	8	1	7	4	810	6	1510	7	284	16	283	3	652	8
Tamarix sp.	1	1			12	2			4	3	1	1	3	1	1625	3	158	5	217	14	5	1	3	1
Ulmus sp.	1	1			27	4	48	7	3	1			1	1					13	1	58	3		
Vitis vinifera					7	3	6	4	20	4	8	1	6	2			10	1						
Ziziphus sp.																								
Zygophyllum sp.																								
Sum	353	7	177	4	2855	9	1538	11	1055	8	450	2	551	4	2522	6	2077	9	798	17	387	3	1119	8

Emar						Mozan						Leilan				Bderi	Sheh Hamad	
2200		2000–1600		1600–1200		2700–2200		2200–2000		2000–1800		2300–2200		1400–1200		2500–2200	13th century	
AF	U	AF	U	AF	U	AF	U	AF	U	AF	U	AF	U	AF	U	AF	AF	U
																1		
6	2																	
												4						
																	15	1
								2	1									
7	2			1	1	3	2	49	1							14	1	1
1	1			9	1			4	1									
2	2					1	1	1	1									
																2		
2	2			8	3	74	6	2	2	13	1					19		
4	2			19	1	273	15	40	10	14	2	155	5	22	2	170		
						3	1	3	2					5	1			
20	5	39	3	18	6											4	2	1
317	3	6	2	12	3	18	9	585	4	49	2	4	3	1	1	10		
																43		
3	2									474	5					1		
																5		
1	1			38	1											57		
1	1			14	3	4	1	6	2	85	1			1	1			
						20	7	0	0	1	1							
5	3	19	1									27	1	142	2	4		
8	4					37	7	39	8	43	2					5		
																	15	2
		1	1			25	6	22	5	35	2	6	1	326	2	12	5	2
				4	1	1	1	2	1									
8	1					3608	54	2411	51	332	26	79	6	33	2	83		
				1	1													
3	2					135	18	268	12			1	1					
																1		
17,504	11	1632	8	5272	17	206	28	117	17	125	9	83	8	261	2	1040	87	9
673	9	393	5	549	10	1	1									286	158	8
2	2	1	1	612	3	64	5	27	3	16	2	47	4	17	2	37	23	2
				1	1			2	1	14	2	1	1	26	2	6		
2	1																	
																1		
18,551	11	2091	8	6543	20	4101	59	2894	60	651	43	407	9	834	2	1801	321	17

were also found at these sites (e.g., Deckers and Riehl, 2007b; Riehl, 2010; Willcox, 2010) and some texts (especially for the Late Bronze Age) also confirm the presence of vineyards (Beckman, 1996; Westenholz, 2000). The find of *Olea* and *Phoenix* charcoal outside their natural distribution areas suggests their cultivation. In some cases, like at Horum Höyük, Tilbeshar and Emar, olive stones were found, supporting their origins as initiated through local cultivation (Deckers and Riehl, 2007b; Riehl, 2010; Willcox, 2010). However, this was not the case in Middle Bronze Age Mozan (Deckers and Riehl, 2007b), which may be due to the fact that olive oil production took place in pre-assigned areas with garbage deposition close by.

Based on the present geographical distribution of trees, the following were counted among the imported taxa: *Pinus nigra*/*sylvestris*, *Cedrus*, *Cupressus*, *Buxus*, and indeterminate conifers (Zohary, 1973). The real situation, however, may have been more complex, as suggested by a text from Mari concerning boxwood. Specifically, saplings of this tree species were imported to be planted (Michel, 1996: 389).

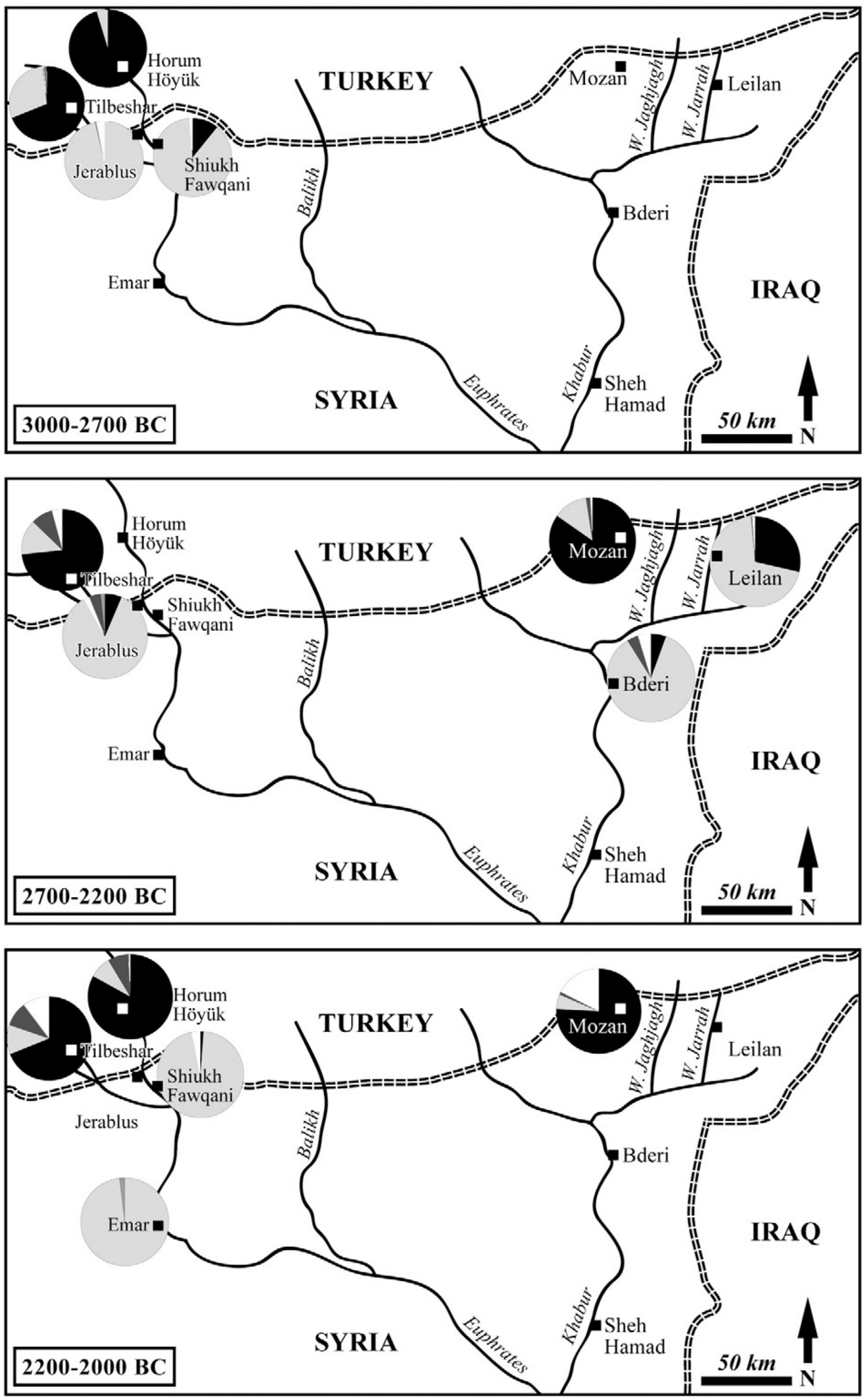

Figure 3. Pie chart summaries of charcoal fragment proportions for each period.

https://doi.org/10.1016/j.yqres.2010.07.007 Published online by Cambridge University Press

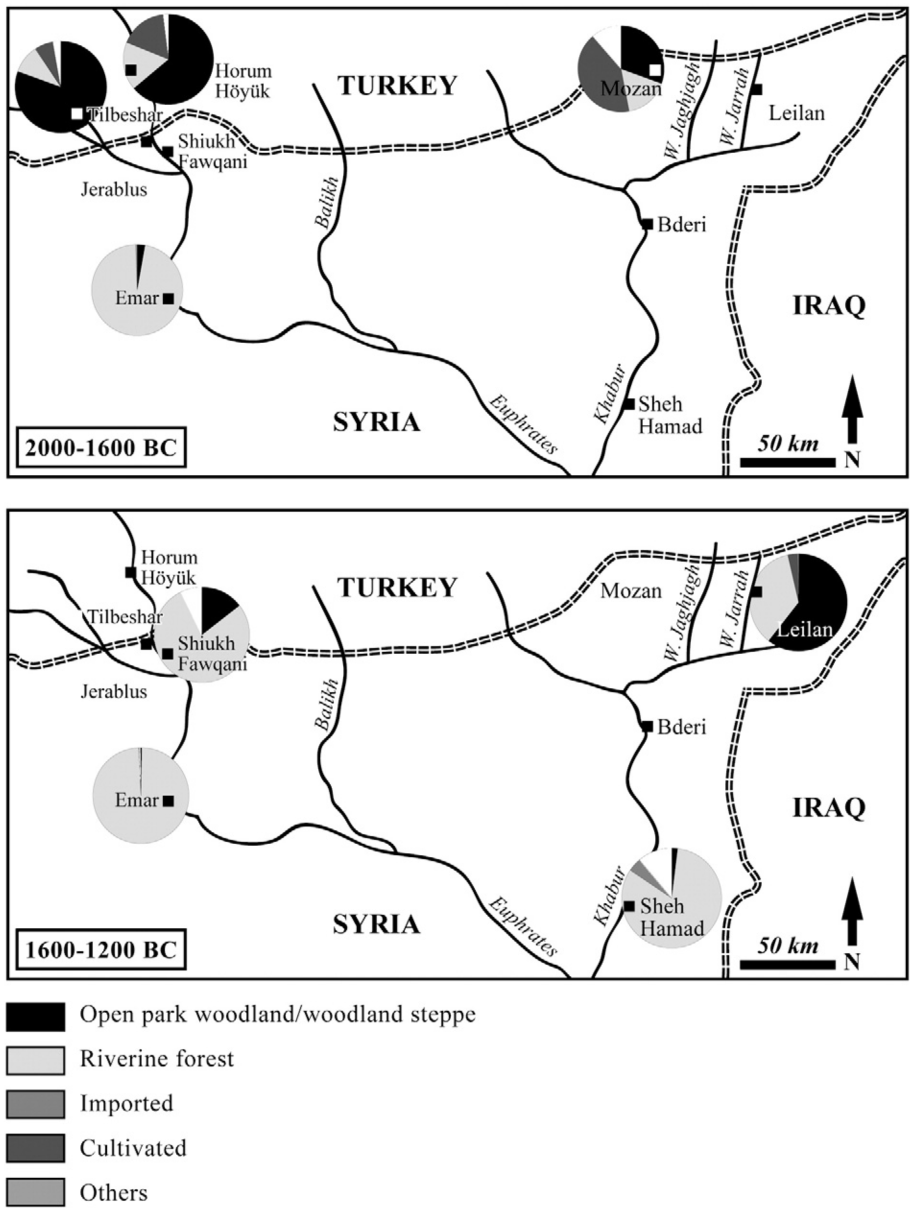

Figure 3 (*continued*).

In the unspecifiable group, we list *Pinus brutia*/*halepensis*, evergreen *Quercus*, *Morus*, *Prosopis*, monocotyledons, *Zygophyllum*, Chenopodiaceae, Fabaceae, *Juglans*, and *Acer* (Zohary, 1973). The imported status of the evergreen oak is somewhat debatable. This tree occurs today in scrub varieties within the Mediterranean zone and its wood, generally, only reaches small dimensions in growth; therefore, it is unlikely to have been imported. Additionally, Calabrian pine (*Pinus brutia*) could have been present here in the study area as a colonizer after fire clearance, or because Mediterranean vegetation may have extended to this area. Chenopodiaceae are mainly drought indicators but may equally have occurred in the woodland steppe as in the steppe. *Morus* may have been cultivated, though it more likely arose naturally. Furthermore, *Juglans* may have been either cultivated, or imported. *Prosopis* occurs on alluvial soils, among crops and on saline grounds and river banks, and may be an indicator of browsing. Its charcoal was only found at Bderi. *Zygophyllum* is a typical dwarf scrub that occurs in deserts and steppes, and similarly may be an indicator of human disturbance. The Fabaceae were also classified into the unspecifiable group since it is a large family and their species grow in many different environments. Finally, *Acer* could likewise be an indicator of riverine forest, as well as of woodland steppe or Mediterranean-type vegetation. Apart from *Pinus brutia*/*halepensis*, all these taxa occurred in rather small quantities and few samples.

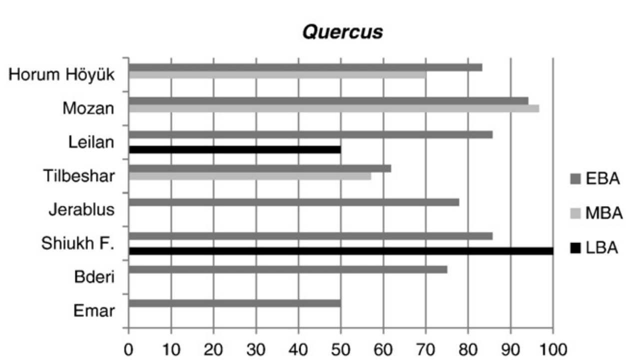

Figure 4. *Quercus* ubiquity percentages in proportion to *Pistacia*. Sites are listed from north to south (higher rainfall in the north). EBA, MBA and LBA refer respectively to Early, Middle and Late Bronze Age.

Criteria for the evaluation of climatic and human impact on the vegetation

In order to evaluate climatic and human impact on the vegetation, ubiquities and ubiquity ratios of some taxa were examined in more detail. Upon drying climatic conditions, the southern part of the oak park woodland/northern border of the *Pistacia*–*Amygdalus* woodland steppe would have retreated northwards towards wetter locations (see, e.g., in Moore et al., 2000). Therefore, the *Pistacia*–deciduous *Quercus* ubiquity ratio is a proxy for climatic change. It is understood that a diversity of species of the *Pistacia*–*Amygdalus* steppe could also occur within the oak Rosaceae park woodland, so their presence/absence does not demonstrate the location of the border between the two.

Additionally, fruit-tree charcoal ubiquity was used as a measure of the importance of cultivation in addition to fragment proportions. Fruit-tree wood remains primarily came into the archaeological record as the result of pruning, and fruit-tree wood was mainly used as firewood (Gale and Cutler, 2000: 173). Moreover, *Vitis* wood does not generally attain great dimensions. Therefore, the ubiquity of fruit trees provides a more appropriate picture of the impact of horticulture than fragment count percentages.

Another indicator for former human impact on the vegetation is the *Populus*/*Salix*-to-*Tamarix* ratio, which may indicate the impact of damming and irrigation on the vegetation. This is because under a pulse flood regime, most studies show that *Populus* and *Salix* outcompete *Tamarix*. However, when rivers are managed and dammed, *Tamarix* tends to expand at the expense of *Populus*/*Salix*. This is because *Tamarix* has a high drought/water-stress tolerance, whereas *Populus*/*Salix* does not. Increased proportions of *Tamarix* relative to mesophytic trees like *Populus*/*Salix* may therefore indicate human impact on the river systems, namely damming and irrigation, resulting in decreased pulse flood regimes (Glenn and Nagler, 2005). Additionally, *Tamarix* also has a high salt tolerance, whereas this is not the case for *Populus*/*Salix* (Glenn and Nagler, 2005). This means that climatically caused reductions in flooding may have had similar effects, making the floodplain drier and more saline and, in turn, favorable to *Tamarix*.

In addition to the *Populus*/*Salix*-to-*Tamarix* ratio, the general diversity of the riverine vegetation can also be used as a proxy for human impact on the vegetation. Since the Euphrates and Khabur rivers were perennial and dependent on distant, reliable water sources from the eastern Anatolian Mountains, their riparian vegetation, especially the diversity, would not be very sensitive to reduced rainfall. For this reason, a possible reduced diversity within the charcoal samples may be due to human impact on the riverine vegetation. The opposite, however, may also be argued—that a low diversity of riverine species within the samples may actually be indicative of the availability of abundant woody resources and, as a result, people were able to select those taxa they preferred most. If all riverine taxa were amply available and gaining good fuel wood was a main strategy[1] at the sites, one would, for example, expect *Fraxinus*, *Ulmus*, *Platanus*, and *Fagus* to be the dominant riverine species within the samples, while *Populus*, *Salix* and *Alnus* would be poorly represented. It will be demonstrated below that this is not the case.

Results

The proportions of the vegetation categories, as shown in Figure 3's pie charts, demonstrate the presence of a more southward distribution of park woodland during the Bronze Age in southern Turkey and northern Syria. In the north (Horum Höyük, Tilbeshar, Mozan, Leilan), the open park woodland was dominated by deciduous oak, while *Pistacia* dominated towards the south (Emar) (Fig. 4). However, woodland remains there were rather scarce in the late Early Bronze Age. In four of the six sites where samples could be studied diachronically, an increase in the ubiquity percentages of *Pistacia* relative to oak can be observed through time. Exceptions were found in Mozan, where a small decrease in *Pistacia* ubiquity percentages was observed from the Early to Middle Bronze Age; and in Tell Shiukh Fawqani, where oak occurs proportionally in more Late Bronze Age samples than Early Bronze Age samples. *Amygdalus* (Table 1) was more present within the northernmost-studied Euphrates sites, whereas it was hardly present at Emar.

One of the main trends observed in the park woodland proportions at the sites is that all the samples from the 2200–2000 BC phase have proportionally lower park woodland percentages compared to earlier periods. This is, for example, the case in Shiukh Fawqani, Tilbeshar, Horum Höyük, and Mozan. In Emar, where no earlier period samples could be investigated, the 2200–2000 BC samples have less park woodland percentages than those of the Middle Bronze Age. Ignoring the 2200–2000 BC phase at Shiukh Fawqani, Tilbeshar, Leilan, and Jerablus reveals an increase in the park woodland proportions over time. The only exception to this trend is Horum Höyük, where park woodland proportions diminish over time.

There is merely a small fruit tree proportion for the 3000–2700 BC phase. It is only from the 2700–2200 BC phase onwards that we observe a marked increase in the percentages of cultivated taxa within the samples, with culmination in the Middle Bronze Age and smaller proportions again in the Late Bronze Age (Fig. 3). In Horum Höyük, Tilbeshar and Mozan, ubiquities show the same trend of an increased presence of fruit trees in the samples from the Early to the Middle Bronze Age (Fig. 5). For Emar, however, no fruit tree charcoal fragments were found from the Middle Bronze Age strata, and ubiquities in the Early Bronze Age were equally high as in the Late Bronze Age.

The analysis of the diversity of riverine taxa within the samples indicates that at three of the five sites where vegetation changes can be studied diachronically, there was a clear reduction in riverine

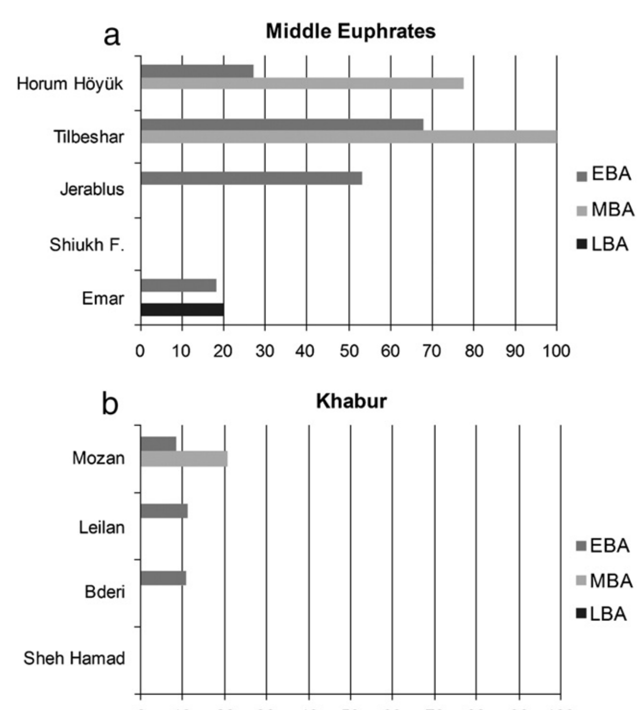

Figure 5. Ubiquity of fruit trees in: a. the Middle Euphrates and b. the Khabur Basin. EBA, MBA and LBA refer respectively to Early, Middle and Late Bronze Age.

[1] In Emar, for instance, it is obvious that the main riverine taxa present (*Populus*/*Salix* and *Tamarix*) were regularly used as fuel. This is obvious by their presence in oven contexts, but also by the high ubiquity of small twigs of these species within the charcoal assemblage (Deckers, 2010).

https://doi.org/10.1016/j.yqres.2010.07.007 Published online by Cambridge University Press

diversity within the samples over time (Fig. 6). In two northern Middle Euphrates sites, Horum Höyük and Tilbeshar, however, the opposite trend is visible.

As is seen from Figure 7, in three of the four cases (Tell Shiukh Fawqani, Emar and Tilbeshar) where diachronic data are available, *Tamarix* is represented in fewer samples as compared to *Populus*/*Salix*, although the trend is not very strong. The proportion of *Tamarix* to *Populus*/*Salix* is somewhat higher in the south than in the north.

The category with imported taxa is hardly present but is seen in its largest quantity at Sheh Hamad, making up about 4% of all identifications (Fig. 3).

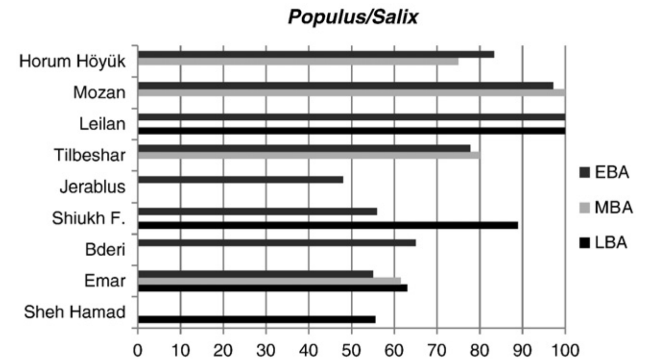

Figure 7. *Populus*/*Salix* ubiquity percentages in proportion to *Tamarix*. Sites are listed from north to south (higher rainfall in the north). EBA, MBA and LBA refer respectively to Early, Middle and Late Bronze Age.

Discussion

Distribution of open park woodland

The diagrams clearly show a more southward distribution of park woodland during the Bronze Age in southern Turkey and northern Syria. In the north, the open park woodland was dominated by deciduous oak, while *Pistacia* dominated towards the south (Fig. 4). Oak may have occurred as far south as Tell Bderi. It is of note that although fragment scores for *Amygdalus* are generally low, it occurs more in Middle Euphrates sites, where open park woodland is dominated by oak, than in *Pistacia* associations. *Amygdalus* is, for example, conspicuously absent in Bronze Age samples from Emar, while it was present during the Neolithic period in this area (Willcox and Roitel, 1998; Pessin, 2004, 2007). Its traces seem to have disappeared earlier than *Pistacia.* There is, however, more data needed from sites within the *Pistacia* (woodland) steppe to document the development of the *Pistacia* (woodland) steppe because Emar could have been located on its southern boundary and the other sites towards the north are clearly located within the oak park woodland.

The overall low fragment percentages for park woodland in Emar's Bronze Age samples may indicate that the woodland steppe in this region was strongly degraded compared to the early Holocene and, yet, rich in comparison to the vegetation cover there today. The presence of a richer (woodland) steppe in the neighborhood of Emar than is seen today is also underlined by the presence of gazelles and onager in the archaeozoological assemblages from Bronze Age Emar

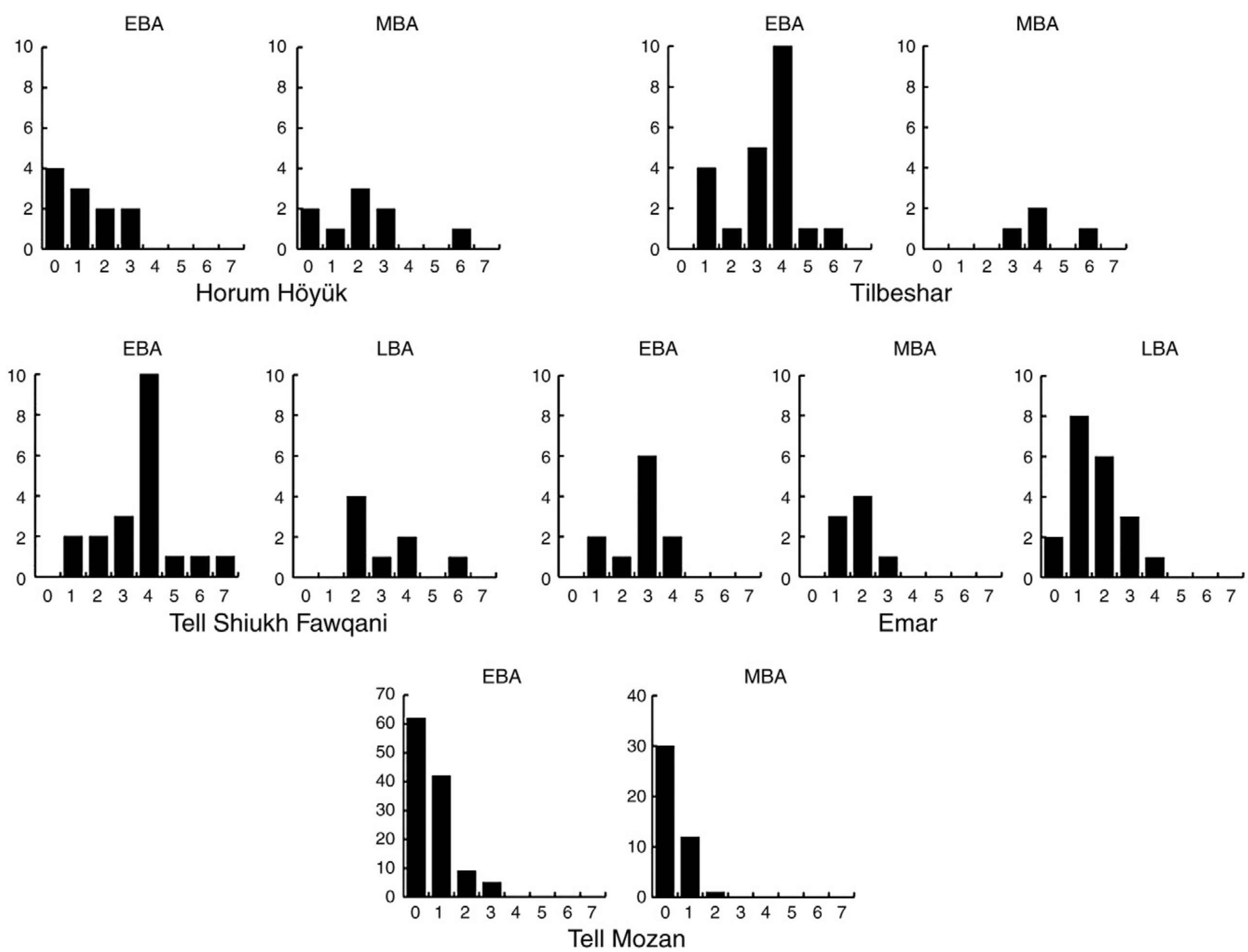

Figure 6. Riverine species diversity within the samples. The x-axis shows the number of species within a sample, while the y-axis shows the number of samples.

https://doi.org/10.1016/j.yqres.2010.07.007 Published online by Cambridge University Press

(Gündem and Uerpmann, 2003; Gündem, 2010). The reduced remains of woodland steppe in the late Early Bronze Age at Emar in relation to earlier periods (early Holocene) may be indicative of early deforestation or, likewise, may have been a result of drier climatic conditions. Interestingly, in most sites, an increase in the ubiquity percentages of *Pistacia* relative to oak can be observed through time; this may relate to aridification and retreat of the *Pistacia*-woodland steppe and open oak park woodland toward the north (Fig. 4). This aridification is also reflected in the settlement distribution in the southern Middle Euphrates, with a general decrease in the number of sites and areas occupied over time in the Sweyhat and upper Lake Assad region through the Bronze Age (Wilkinson, 2004). As mentioned above, however, no such increase in ubiquity of *Pistacia* to *Quercus* occurred at Tell Mozan or Tell Shiukh Fawqani.

Although the above arguments seem most plausible, the low values for woodland steppe at Emar could also be explained as an indication that the main zone of land use at this site was within the floodplain and that this was not the case at the other sites. Wilkinson (2004) observed that Emar's location, with its catchment mainly within the floodplain, is in marked contrast to most Bronze Age settlements farther to the north, which are located on the main Euphrates terrace.

The fact that open park woodland taxa were locally present in southern Turkey/northern Syria is signified by the small twigs of oak found at Tell Mozan, Jerablus, Horum Höyük, and Tilbeshar, as well as the acorns found at Tell Mozan. Small twigs of *Pistacia* were also found in the Late Bronze Age strata of Leilan and Emar, suggesting its local presence.[2] Moreover, the evidence reflected in the pie charts also seems to confirm the model we are using to interpret the charcoal data, i.e., that the charcoal proportions will mainly represent the local vegetation. All of our sites that are located along rivers have large amounts of riparian vegetation. The sites in the north have an additional measure of park woodland taxa, while those toward the south (e.g., Tell Sheh Hamad and Emar), where climatic conditions are drier, largely lack such vegetation elements.

The 2200–2000 BC reduction in fragment percentages of oak at the sites could perhaps be a result of the dry climatic peak between about 2300 and 2100 BC, as found at Lake Van (Wick et al., 2003), causing a reduction of park woodland vegetation. The general trend, nonetheless, of increased proportions of park woodland taxa at the expense of riverine taxa at four of the five riverine sites where diachronic data is available suggests that riverine environments were exploited and cleared first, and that only in subsequent phases was there an increased exploitation of the open park woodland zone. This pattern may have been driven by a strongly augmented population size in the northern Middle Euphrates region from the Early to Late Bronze Age (Algaze et al., 1994). This exploitation change, observed between Early and Late Bronze Age Leilan, may have been instigated by the Middle Bronze Age occupation peak within the western Upper Khabur (Risvet, 2005).

Riverine vegetation

Modern species diversity is low within the riverine woodland of the Euphrates and Khabur River. This is true to an even greater extent along the Upper Khabur Basin, where riverine woodland is no longer present, as is also the case for the Wadi Jarrah, along which Leilan is located. The anthracological data from the latter site indicated the presence of a gallery forest in the Bronze Age. Evidence has also been found for the (parallel flowing) Wadi Jaghjagh of a riverine gallery forest in the mid-Holocene (Deckers and Riehl, 2007a). Hence, these wadi environments must have looked different in the past compared to the present day. The archaeozoological data of the Khabur and Euphrates River further support the presence of reed jungles, brushes and trees along their benches, based on the beaver, elephant, fallow deer, auroch, and boar finds as far south as Tell Sheh Hamad and Emar (Gündem and Uerpmann, 2003; Becker, 2005). Numerous finds of small twigs from the most abundant taxa indicate that these riverine tree species were locally present.

The analysis of riverine taxa diversity within the samples indicates that there was a clear reduction in riverine diversity within the samples at three of the five sites over time (Fig. 6). Human impact on the riverine vegetation is also indicated by the fragment percentage results that signify the main zone of exploitation in the earlier phases of the site lay within the riverine gallery forest. Textual evidence from Emar, for example, occasionally refers to fields with their edges against the Euphrates River or even in the course of the river (Wilkinson, 2004: 38–40). Such fields are, therefore, indicative of local impact on the riverine vegetation.

In two northern Middle Euphrates sites, an increased species diversity of riverine taxa throughout time was nonetheless observed within the samples. As for the Horum Höyuk site, this may be related to the increased use of the riverine vegetation at that time. For Tilbeshar, it must be mentioned that the sampling could be unrepresentative because only four samples were investigated from the Middle Bronze Age. The southern Middle Euphrates site of Emar has lower riverine taxa diversity than seen in northern Middle Euphrates sites; this may be a consequence of the riverine forest already being degraded by the end of the Early Bronze Age.

There is, nevertheless, no indication of an increased impact from irrigation on the riverine vegetation through time. More precisely, there is no evidence of the consequences of reduced flooding and increased salinity on the vegetation. As is visible from Figure 7, in three of the four cases where diachronic data are available, there are *Tamarix* in fewer samples compared to *Populus*/*Salix*, although, the trend is not very strong. This may be due to the fact that although the climate became drier and overall discharge decreased, Euphrates discharge for the month of May would have increased, resulting in more extreme floods (Riehl et al., 2008; Fig. 1). *Populus*/*Salix* has a very high tolerance to flooding, while this is not the case for *Tamarix* (Glenn and Nagler, 2005). In spite of this, there are relatively higher ubiquities of *Tamarix* towards the south, which may either be an indicator of local irrigation or, alternatively, of its more arid location.

Regarding the possibility of local irrigation for sites in the south (with higher ubiquities of *Tamarix*), it is sometimes argued that the main Euphrates was too difficult to control and for this reason only smaller tributaries were used for irrigation (see Wilkinson, 2004; Hole, 2006). This was the case as indicated by texts for ancient Tutul (Tell Bi'a), but it is unclear whether all tells beyond the dry farming limit received irrigation in this way (Wilkinson, 2004). A possible Late Bronze Age irrigation canal along the Euphrates has been found roughly 20 km downstream of Emar (Wilkinson, 2004). Farther south and adjacent to our study area, texts indicate that in the 18th century BC three canals irrigated the Mari Kingdom, the remains of which have been discovered during regional surveys (Lafont, 2000). The canals can be traced back to the lower Khabur. For this region, Ergenzinger and Kühne (1991) undertook extensive work to reconstruct and date the observed canal system. It probably is a somewhat later system than the one from Mari, with the canal on the eastern Khabur bench being in use from the 13th century BC onwards. However, this canal was probably fed by the Wadi Jaghjagh and not by the Khabur, and as such would not have had a major impact on the Khabur riverine vegetation. Hence, although there is some evidence that irrigation was practiced, the present evidence does not seem to underline strong local water withdrawal from the Euphrates near Emar, and for the Khabur near Bderi or Sheh Hamad, that would have influenced the lower *Populus*/*Salix* to *Tamarix* ratio compared to sites located northwards. Therefore, the regional differences in the *Populus*/*Salix* to *Tamarix* ratio can be explained

[2] The *Pistacia* twig finds from Late Bronze Age Emar are not listed in Table 1, since these samples were only recently analyzed.

https://doi.org/10.1016/j.yqres.2010.07.007 Published online by Cambridge University Press

by different environmental conditions, causing higher salinity levels in the south.

Fruit-tree cultivation

The evaluated fragment proportions indicate that, initially in the Early Bronze Age, fruit tree cultivation in the investigated sites was hardly existent. It is only together with increased urbanization (in the 2700–2200 BC phase) that we observe a marked increase in cultivated taxa, with culmination in the Middle Bronze Age and smaller proportions again in the Late Bronze Age. In Horum Höyük, Tilbeshar and Mozan, ubiquities show the same trend of an increased presence of fruit trees in the samples from the Early to Middle Bronze Age (Fig. 5). On the other hand, for Emar, no fruit-tree charcoal fragments were found from the Middle Bronze Age strata, and ubiquities in the Early Bronze Age were equally high as in the Late Bronze Age. Overall, though, fruit tree cultivation seems to have been more important in sites located in areas with higher annual precipitation, in particular the Turkish Middle Euphrates sites. Still, textual sources indicate that fruit tree cultivation was more important in the southern Middle Euphrates (e.g., Mari) than one would believe from analyzing its geographical location (Michel, 1996; Lafont, 2000). Also, many texts have been found concerning the purchase of vineyards at Late Bronze Age Emar and its surroundings, which indicate that vineyards were present in an area that cannot support vineyards using rainfall alone (see, e.g., Beckman, 1996; Westenholz, 2000).

Imported taxa

Local woody resources were accessible at all the sites during the Bronze Age, as is visible from the general absence of large proportions of imported wood. Although the Middle Bronze Age king, Yahdun-Lim, claims he was the first to cut cedars and pines in the coastal mountains, no evidence has been found for increased import of pines and cedars during that period. If *Pinus halepensis*/*brutia* was an import product (although we classified it in the "others" category), it was already traded from the Early Bronze Age onward.

The low quantities of imported taxa, as revealed within this study, ultimately need to be differentiated. The samples detailed here are mainly from domestic contexts. Recent research at two Middle Bronze Age palaces has shown that distant woody resources were intensively used within palaces. For example, 40% of the fragments identified from the Mozan Palace consist of imported *Pinus* wood (Deckers, in press), while at Qatna (western Syria), the palace construction consisted mainly of *Cedrus* that must have been transported from relatively long distances (at least 60 km).

Conclusion

The Bronze Age vegetation in the area under investigation was generally much richer than the one observed today. The riverine vegetation was a great deal more diverse, and oak park woodland could still be found in northern Syria, probably as far as Bderi on the Khabur. *Pistacia* (woodland) steppe occurred as far south as Emar. Hence, the present data suggests that massive degradation, including deforestation, has occurred within our research area. There are some hints both for human and climatic impact on the vegetation through the Bronze Age but, still, by the end of this period, the region was much more covered in woody vegetation than today.

Regarding human impact on the vegetation in the Bronze Age, our trend analyses in some cases demonstrate a typical pattern for the exploitation of woody resources through time. Fields were probably preferentially located near the rivers, and the riverine forest was first cleared. After clearance of riverine vegetation took place, we can observe the next phase of increased exploitation as a consequence of the augmented demand for agricultural resources over time. This next phase is characterized by the increased use of land within the woodland steppe. We can especially observe this trend at Tilbeshar from the Early through Middle Bronze Age, at Tell Shiukh Fawqani from the Early till Late Bronze Age, at Jerablus from early phases of the Early Bronze Age until later phases of the Early Bronze Age, and at Leilan from the Early Bronze Age until the Late Bronze Age. In the case of Emar, the woodland steppe diminished in the Late Bronze Age. This may have been caused by a combination of aridification and prolonged human impact, albeit discerning between the two remains difficult. The *Pistacia* to *Quercus* ratio indicates a shift northward for the *Pistacia*-woodland steppe, due to more arid climatic conditions.

Acknowledgments

Many thanks are due to the excavation directors of Tell Mozan, Tell Jerablus, Emar, Tell Leilan, Horum Höyük, Tilbeshar, and Tell Shiukh Fawqani, respectively Peter Pfälzner, Eddie Peltenburg, Uwe Finkbeiner, Harvey Weiss, Catherine Marro, Christine Kepinski, and Luc Bachelot. We thank them for allowing us to investigate the botanical remains. Research was supported by the Deutsche Forschungsgemeinschaft, the Strukturfonds of the University of Tübingen, the Belgische Stichting Roeping, the Landesstiftung Baden-Württemberg, the European Commission (Marie Curie Fellowship), and the European Social Fonds in Baden-Württemberg. We are grateful to these agencies. We also would like to thank M. Deva Jebb for her help in preparing figures and editing the manuscript, and the reviewers and editor for their critical but helpful comments.

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