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Spatial and Temporal Variation in Mesopotamian Agricultural Practices in the Khabur Basin, Syrian Jazira

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While archaeologists have long recognized the value of regional analysis to define economic systems, relatively few archaeological data sets—principally settlement patterns, ceramics and lithics—have been used to assess regional-scale spatial variation and temporal change. As with other archaeological data sets, resolution of archaeobotanical data at a regional scale poses some formidable challenges. A new approach in the Near East uses archaeobotanical remains from multiple sites. The data have been drawn from midden assemblages that exhibit high variability between assemblages, requiring the use of random effects logistic regression models that can accommodate high variability. Our approach detects changes over time and over geographical region and tests the statistical significance of these changes. Results show a significant rise in crop-processing wastes, most probably from a specialized focus on barley processing at settlement and storage sites during the 3rd millennium BC (Ninevite 5 and Early Jazira Periods). This shift to a greater representation of barley-processing by-products represented in middens can most probably be linked with an emerging specialization in pastoral production and re-settlement in arid regions of the northern Mesopotamian steppe in the 3rd millennium BC.

Keywords: ARCHAEOBOTANY, REGIONAL ANALYSIS, RANDOM-EFFECTS LOGISTIC REGRESSION, NORTHERN MESOPOTAMIA, BRONZE AGE, EARLY AGRICULTURE, MIDDENS.

Introduction

Spatial variation has long been acknowledged as an important component of many archaeological data sets. In archaeobotanical analysis, spatial variation plays a major role in differentiating contemporaneous activity areas within sites, but it is less seldom effectively employed on an inter-site scale to consider regional variability and regional trends in agricultural production. Most Near Eastern settlement sites contain an extremely rich and diverse abundance of archaeobotanical material. Once considerable taphonomic influences in assemblage accumulation have been considered (Jones, 1991), charred plant remains may yield critical clues to food production and discard processes at agricultural sites (Hillman, 1984*a*; Jones, 1984; Hastorf, 1988; van der Veen, 1992; Miller, 1984, 1991). This rich record encourages analysts to focus on a single site (or less often, on 2–3 sites) from any given region or period (e.g., Miller, 1997*a*; Moens & Wetterstrom, 1988; de Moulins, 1997; van Zeist & Bakker-Heeres, 1985; Harris *et al*., 1993) to develop a regional model for agricultural production and change. This site-based approach poorly detects regional variation in agricultural strategies and risks missing instances of regional integration and exchange by over-emphasizing temporal explanations for site-wide shifts in assemblages. To address these issues and specific questions about shifts in agricultural production, this regional-scale archaeobotanical analysis uses midden-deposited plant remains from 16 archaeological sites spanning several steppe zones and 6000 years of prehistory in Northern Mesopotamia.

The Khabur Basin Project sampled plant remains from 16 sites occupied during an era of early village life. Preliminary studies from the Khabur (McCorriston, 1995) and models elsewhere in the northern Mesopotamian steppe (e.g., Miller, 1997*a*) suggest that barley emerged as a major crop for fodder after an initial phase when other crops, including wheats, played larger roles in food production. Epigraphic evidence from southern Mesopotamia may

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indicate a similar shift well after the emergence of city states there (Jacobsen & Adams, 1981; cf. Powell, 1985). Although archaeologists can guess at the socio-economic implications of such a change in crop base, it is critical first to ascertain whether the phenomenon merely reflects site-specific changes (e.g., highly localized intensification and soil degradation). Do crops and weeds represented at different sites indicate a regional pattern? Do changes in crops, such as an increase in barley, indicate steppe-wide participation in new regional social and settlement configurations? The regional-scale archaeobotanical analysis reported here provides data to address these questions using exploratory statistical techniques at a supra-site scale compatible both in scope and resolution with settlement surveys and other regional approaches.

The Khabur Basin

The Khabur river drains a substantial portion, most of it steppe, of the Syrian Jazira between the Tigris and Euphrates rivers. Annual precipitation declines both in amount and reliability as one travels southwards through a predominantly Irano-Turanian sub-continental flora. Steppe vegetation follows this precipitation and edaphic gradient. In the northern open parkland and isolated mountain spurs grow important sub-Mediterranean arboreal and shrub species including wild pistachio (*Pistacia khinjuk*), bitter almond (*Amygdalus orientalis*) and hawthorn (*Crataegus azarolus*). Wetter steppe areas in the north can also include sub-Mediterranean trees and shrubs (*Pistacia khinjuk*, *Phlomis* spp.) while southern steppes support sub-continental low scrub (such as chenopods and *Artemisia herba-alba*) (Frey & Kürchner, 1991; Pabot, 1957; Zohary, 1973; Handel-Mazzetti, 1914; Guest, 1961). Only in particularly wet years is cultivation successful south of Hasseke, which lies near the 250 mm rainfall isohyet. Archaeological surveys and excavations have documented farming villages in all steppe zones since at least 8000 years ago (Hole, 2001; Watkins, 1995; Matsutani, 1991; Wilkinson & Tucker, 1995; Suleiman & Nieuwenhuyse, 1999). Therefore, any modern reconstruction of potential vegetation must consider that humans have modified their environments since the mid-Holocene, when climate conditions for potential vegetation changed substantially (Gremmen & Bottema, 1991). Probably there never was a "natural" environment under the climate now prevalent in the Khabur basin, and farming, burning, coppicing, grazing, and clearing were variable factors always important in vegetative association formation, most especially in the vicinity of settlements. Introduction of new technologies and crops, such as threshing sledges 5000 years ago (Anderson & Inizan, 1994; Chabot, 1998), or wool-bearing sheep even earlier (McCorriston, 1997; Zeder, 1994) must have entailed changes in labour requirements, scheduling, socially-mediated access to land and other resources. Such changes would have profoundly affected communities in their interaction with the steppe environment.

In the mid 1980s, Frank Hole initiated a program of midden-sampling in the Khabur river drainage where dozens of mounds left by hundreds of years of mudbrick-village life line the riverbanks (Monchambert, 1993, 1994; Röllig & Kühne, 1983, 1977/1978). Recent salvage excavations have offered other opportunities to collect rich, midden-derived assemblages of charred plants and other cultural remains from early farming villages and thus to develop a regional perspective on agriculture, plant use, and cultural change. While it was impossible to sample every site, sampling over 11 years has yielded unprecedented regional breadth. A substantial proportion of midden assemblages (77%) come from 5th and 3rd millennium BC sites in the arid steppe zone south of Hasseke, while sites in the northern, better watered steppe (north of the 250 mm isohyet) include the earliest (mid 7th millennium BC) and latest (1st centuries BC) sites (Figure 1). The earliest evidence for settlement in the southern steppe is Halafian Umm Qseir, whose architectural and ceramic traditions closely link it with Halafian villages to the north (e.g., Tell Aqab), but whose economic strategies indicate that these settlers were colonists prepared to exploit a wide array of wild and domesticated resources (Zeder, 1994). Settlement continued largely uninterrupted in the most northern agricultural plains (e.g., Wilkinson, 2000; Figure 2b), but in both northern and southern steppe, a 4th millennium hiatus in small settlements appears to have been only broken by the distinctive but brief occupations of Uruk culture (Hole, 2001). By the early 3rd millennium, small (1–2 ha) walled communities with special storage facilities emerge on new riverbank sites in the southern steppe, and these new communities flourished through the expansion of urban settlements such as Leilan, Mozan, and Beydar in the most northern plains. For this study, all midden assemblages have been obtained from small, mostly steppe settlement sites ranging from <1 ha to 3 ha at the time of occupation. The sites, sampling, dating, and archaeological remains have been described in detail elsewhere (Hole, 2001, in press *a*, 1993/1994; Hole & Kouchoukos, in press; McCorriston, 1998; Zeder, 1994; Thuesen, 1993–1994, 1994; Matsutani, 1991; Fortin, 1998, 1995, 1984; Schwartz 1994, 1993/1994; Saghieh, 1991; Pfälzner, 1986–1987, 1997).

Materials and Methods

Recovery and sorting

Stratigraphic criteria and artifacts associations served to identify four critical contexts—middens, granaries, pits, and hearths—for systematic flotation. Middens, evident as in-filling between wall stumps or as layers between building phases, usually contained visible

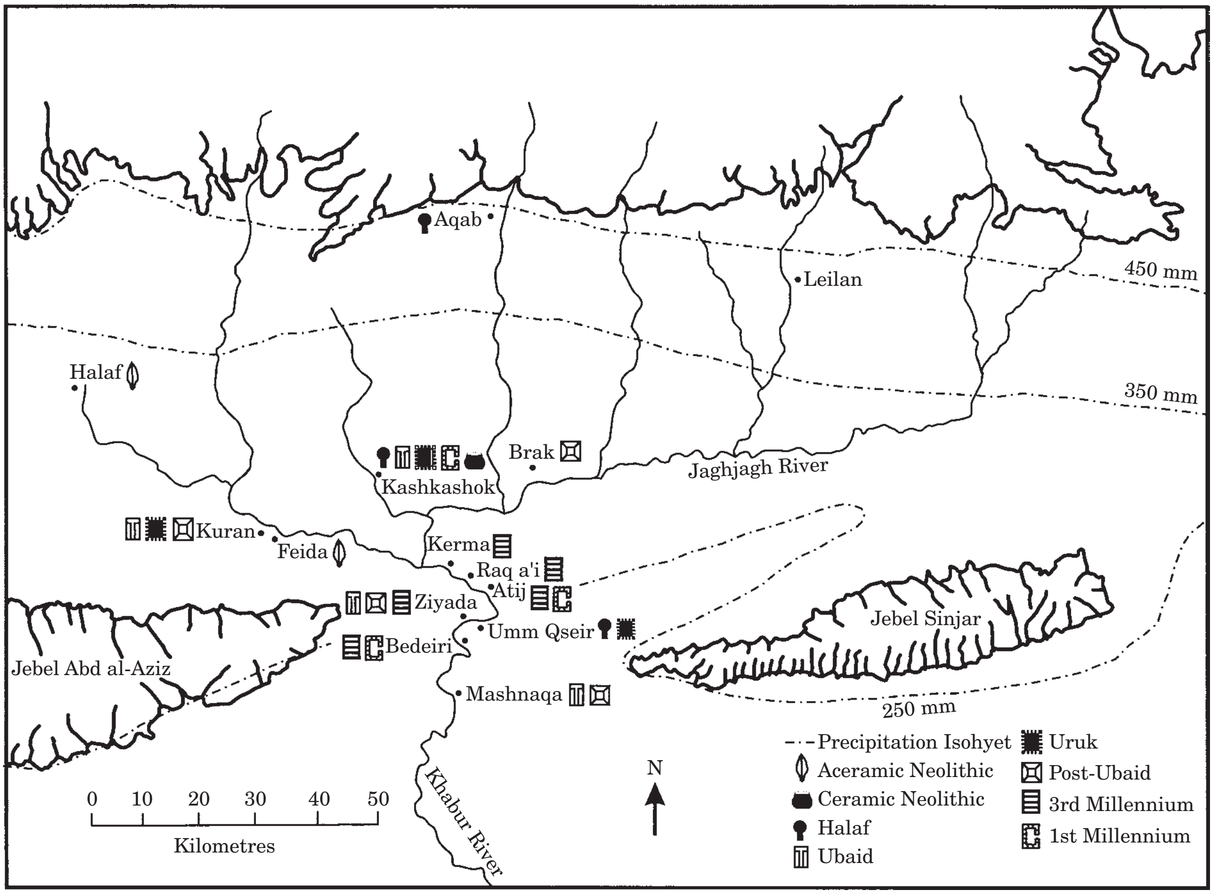

Figure 1. Map of Khabur Basin sites and periods of occupation. Modern vegetation boundary between northern steppe (with vestigial sub-Mediterranean trees and shrubs) and southern sub-continental scrub steppe lies between the 250 and 350 mm isohyets.

quantities of ash and charred fragments as well as relatively high quantities of bone and ceramic debris. In rare cases, granaries and their contents burned in antiquity, and such conflagrations can be distinguished both visually on site and confirmed in analysis (Jones *et al*., 1986; McCorriston, 1995). For example at Tell Kerma, granary deposits (Trench B) had burned while stocked with cereal and legume crops intended for consumption (Saghieh, 1991; Al Azm, 1992; McCorriston, 1995). At some sites, excavators identified former granaries (Davidson & Watkins, 1981; Fortin, 1998; Schwartz, 1994; Hole, 1991; Hole & Artz, 1998; cf., Hole, 1999) but their excavated contents were midden deposits, as were the fill of pits (McCorriston, 1995). Hearths, (which include the ubiquitous Near Eastern clay-skinned *tannur*) contain the ashes of one or several final burning events. Whether burning fuels primarily for cooking, heating, disposal of floor sweepings and food-processing debris, or a combination of these activities, hearth ashes require daily removal and disposal in middens. The contents of an abandoned hearth most probably reflect one or few events in the life of a site and thus typically include a less rich array of taxa than does a midden.

Other contexts seldom warrant sampling. Earthen floors typically contain un-identifiable charred fragments ground into earth (Hastorf, 1990). Floor deposit samples are necessarily of limited size (which tends to increase sampling error) and have relatively large spatial variability (Lennstrom & Hastorf, 1992; Matthews, 1995; Rainville, 2000). Deposits directly on floor surfaces most likely contain the earliest post-occupation accumulations on abandoned living surfaces and should thus be considered secondary (midden) rather than primary refuse (cf., Joyce & Johannessen, 1993). Tells develop through the decomposition of mudbrick, so most archaeological sediment is either wall stumps or decayed mudbrick fill. Such sediments may yield re-deposited charred plant remains derived in antiquity from even older mudbrick. Such recycled material offers little insight into past human activities and human-plant interactions (Hubbard & Clapham, 1992).

Most charred plant remains were recovered with a modified Ankara water-pressure flotation system (French, 1971). A typical soil sample was 20 l with a range between 2 and 80 l. Such samples routinely yielded charred material exceeding 100 cc, which in this region contain sufficient remains to represent an assemblage (Van der Veen & Fieller, 1982). Laboratory analysts used a riffle-splitter and incremental sorting at 7–10 × (e.g., Fasham & Monk, 1978). All flot less than 30 cc in volume (e.g., hearths) was sorted. "Assemblage size" henceforth refers to the number of identified seeds and non-woody plant fragments analysed after sorting (van der Veen & Fieller, 1982). Identifications relied upon herbarium-vouchered modern reference material from McCorriston's Near Eastern botanical and ecological fieldwork and will be detailed elsewhere. Where a species designation is used (e.g., *Anthemis* cf. *wettsteiniana*), a sufficiently wide collection of con-generic material was examined for species-level identification.

Analysed archaeobotanical assemblages ($n=216$) from the Khabur Basin are extremely rich with 228 identifiable plant genera, species, and types of plant parts. Some types are different parts of the same taxon, such as the chaff and grain of a glume wheat or capsules and seeds of *Scrophularia* sp. Nevertheless in most cases, distinct types represent altogether different plant species. The richest assemblages contain more than 40 different taxa and types while others contain fewer than a dozen. Number of samples (=items) per assemblage ranges from only a few to over 4000 identified specimens (Table 1).

Random-effects Logistic Regression Analysis

A data set this complex can pose formidable analytical challenges. Because of the large number of species (228) relative to the number of assemblages (177), statistical methods applied to the full data are of very low power, and are unlikely to show any clear differences. To increase power, the authors decided to follow recent practices of dropping and combining variables (van der Veen, 1992; Colledge, 1994; Jones, 1991; Hillman, Colledge & Harris, 1989; de Moulins, 1997). This allowed us to explore changes in the most frequently encountered (ubiquitous) taxa in the 177 assemblages. More than 15% of the samples had an AMS C^{14} date on an associated seed, seeds, or charcoal while other samples were dated through relative methods using ceramics and stratigraphy (Hole, 2001). For each sample, the analysis assumes a single date—either the median of the calibrated BC 2 sigma range in the case of C^{14} dates or the median of a relative date range.

The analysis used random effects logistic regression models (see Agresti *et al.*, 2000, for other examples of the use of this method, which is a special case of generalized linear mixed models). Briefly, suppose that p^s_{atl} is true, unknown proportion of samples in assemblage a collected at time in location l, where $l=0$ for assemblages collected in the South, and $l=1$ for assemblages collected in the North. Logistic regression (see, for example, Cook & Weisberg, 1999) assumes that the logarithm of the odds, $\log(p^s_{atl}/(1-p^s_{atl}))$, can be written as a linear combination of various effects; we have used

$$\log(p^s_{atl}/(1-p^s_{atl}))=b_0+b_1t+b_2l+b_3tl$$

Depending on the values of the bs, we can have time trends ($b_1\neq 0$), differences in overall level between North and South ($b_2\neq 0$), or difference in time trends between North and South ($b_3\neq 0$). Because of the extreme variation between assemblages, the ordinary logistic regression model cannot be used. To account for this variation, we have used a random effect logistic regression model, given by

$$\log(p^s_{atl}/(1-p^s_{atl}))=b_0+c_a+b_1t+b_2l+b_3tl$$

which differs from the usual logistic regression model only by the addition of a random intercept b_0+c_a *for each assemblage. As is usual in this type of analysis, we assume that the* c_a are a random sample from a normal distribution with mean zero and unknown positive variance. The program for fitting this model, Proc Nlmixed in SAS (SAS, 2000), will estimate this variance along with the bs, and provide tests of hypotheses concerning the bs, and hence about the changes in the prevalence of the various species over time and location.

Independent random-efffects logistic regressions were fitted in analyses of each of 66 response variables. The 66 variables (Table 1 caption) were the taxa or types occurring in greater than 10% of all 177 samples after combining related taxa and types. Crops and Other Plants were explored as two separate groups so that the frequency of relatively low representation of many non-crop taxa would be compared only to other non-crop taxa.

The high numbers of samples from 5th and 3rd millennium BC and relatively few samples from the 4th millennium force the regression to show a single long-term trend (decline, increase, or no change) regardless of 4th millennium activities that are poorly represented. (Indeed from the archaeological record, it is clear that few if any people were occupying most of the Khabur Basin during the 4th millennium BC). Assemblages from the northern steppe and southern steppe were grouped separately to detect any regional variation in agriculture related to rainfall, soils, and local vegetation, which differ very slightly. It should be cautioned that a trend fitted to northern or southern assemblages, while detecting pattern in otherwise complex data, by design removes peaks and valleys, leaving only a smooth trend. Nevertheless the analysis assesses statistical significance of apparent trends, an approach not usually followed with percentages (e.g., McCorriston, 1992; de Moulins, 1997; Hillman, Colledge & Harris, 1989; Willcox, 1996; Miller, 1997*a*). Perhaps the most evident characteristic of the midden assemblages from the Khabur Basin sites (apart from the later 4th millennium gap) is their high variability.

Table 1. Summary of sites, dates, assemblages, and samples

				Assemblages				Samples (=item count)									
								Crops (middens+pits) summary count				Other plants (middens+pits) summary count					All
Period	Site	N/S	Cal. year BC	n	M	H	G	Wheat	Barley	Cereal	Pulse	Weed	Steppe	Fall	River	Mixed	Total
Aceramic Neolithic	Feyda	N	7042–6378	2	2	0	0	24	34	27	24	0	0	1	1	4	115
Aceramic Neolithic	Halaf	N	6692–6423	2	2	0	0	38	0	27	23	1	9	4	4	18	124
Ceramic Neolithic	Kashkashok II	N	6300–6100	5	5	0	0	228	20	6	47	2	4	0	15	27	349
Halafian	Umm Qseir	S	5845–5630	12	12	0	0	963	845	309	202	21	109	2	0	223	2674
Halafian	Tell Aqab	N	5579–5350	3	3	0	0	223	63	59	62	4	8	0	0	348	767
Halaf-Ubaid Transitional	Tell Aqab	N	5266–4995	2	2	0	0	261	138	144	190	3	26	0	17	39	818
Halaf-Ubaid Transitional	Kashkashok I	N	5300–5000	4	4	0	0	66	6	45	19	31	52	1	0	837	1057
Earlier Ubaid	Tell Ziyada	S	5000–4750	22	18	4	0	2091	174	207	74	38	1590	137	50	1972	6333
Ubaid	Tell Mashnaqa	S	5200–4800	10	7	3	0	83	130	52	19	8	121	135	185	296	1029
Ubaid	Tell Kuran	N	4841–4546	8	8	0	0	1217	258	122	149	23	355	11	51	529	2715
Later Ubaid	Tell Ziyada	S	4750–4500	11	4	7	0	2423	178	282	30	28	603	2	23	1591	5160
Later Ubaid	Kashkashok III	N	4750–4500	1	1	0	0	121	62	44	40	0	202	6	0	422	897
Post Ubaid	Tell Mashnaqa	S	4521–4250	9	9	0	0	325	64	116	31	20	1988	2	86	1981	4613
Post Ubaid	Tell Ziyada	S	4500–4000	18	18	0	0	4394	911	652	90	86	5415	49	97	5854	17,548
Post Ubaid	Tell Kuran	N	4500–4000	1	1	0	0	0	8	0	0	0	3	0	0	12	23
Late 5th millennium	Brak Ditch	N	4544–4316	1	1	0	0	4	0	2	7	0	0	0	5	18	
Late Chalcolithic	Umm Qseir	S	4316–3822	4	4	0	0	16	25	5	8	1	3	0	4	283	345
Late Chalcolithic	Kashkashok II	N	3800–3500	2	2	0	0	20	8	8	28	33	7	0	1	12	117
Late Uruk	Tell Kuran	N	3626–3227	5	5	0	0	118	23	54	2	39	646	5	68	506	1461
Ninevite 5-Early Jezireh I-II	Tell Ziyada	S	3320–2906	9	7	2	0	123	88	327	39	28	4940	42	61	1421	7069
Ninevite 5	Tell Kerma	S	2900–2482	16	1	2	13	18	407	20	0	16	43	1	0	101	606
Ninevite 5/Early	Tell Raqa'i	S	2950–2650	21	19	1	0	464	1611	885	52	353	3691	236	44	5257	12,593
Ninevite 5/Early	Tell 'Atij	S	2950–2650	18	14	4	0	632	3039	547	41	204	4556	183	201	5340	14,743
Ninevite 5/Late	Tell Raqa'i	S	2650–2350	10	9	1	0	217	955	385	52	99	1571	184	29	2958	6450
Ninevite 5/Late	Tell 'Atij	S	2650–2350	4	4	0	0	310	981	397	25	71	825	95	12	753	3469
Leilan III/Akkadian	Tell Bdeiri	S	2400–2300	9	9	0	0	183	502	847	27	119	2688	124	43	1361	5894
Hellenistic	Kashkashok IVB	N	395–153	5	5	0	0	32	157	145	123	9	153	2	13	287	921
Hellenistic	Tell 'Atij	S	300–100	1	1	0	0	10	87	39	2	5	14	4	1	87	249
Totals				216	177	24	13										98,157

n=number of assemblages sampled; M=middens; H=hearths & pits; G=burnt granary. Summarized taxa and types are as follows: **Wheats**=*Triticum* sp. grains; *T. dicoccum* spikelet fork; glume wheats glumes & rachis (spikelet forks); glume wheat glume bases; terminal wheat spikelet fork; free-threshing wheat rachis; wheat glumes indeterminate; wheat rachis indeterminate. **Barley**=*Hordeum* sp. grains; *Hordeum* sp. rachis. **Cereal**=cereal grain indeterminate; cereal rachis indeterminate; basal cereal culm fragments; cereal culm. **Pulse**=Lens culinaris; large crop legumes indeterminate; large legume fragments indeterminate. (Dry Farming)**Weeds**=*Rumex* sp.; *Vaccaria* sp.; *Malva* sp.; *Buglossoides arvensis* (charred); *Asperula arvensis*; *Asperula/Galium* type; *Phalaris* sp. **Steppe** (Fallow/Disturbed/Grazed)=*Gypsophila pilosa*; *Gypsophila* sp.; *Silene* sp.; *Adonis dentata*; *Reseda* sp.; *Medicago radiata*; *Bupleurum lancifolium*; *Heliotropium* sp.; *Arnebia decumbens* (charred); *Crucianella exasperata*; *Eremopyrum bonaepartis*; *Hordeum* sp. wild grain; *Lolium* sp.; *Trigonella* sp.; *Helianthemum* sp.; *Lygia pubescens*; *Androsace maxima*; *Ziziphora* sp.; *Muscari/Ornithogalum*. **Fall** (Late-Fruiting Steppe Plants)=*Salsola/Noaea/Hammada* type; *Teucrium polium*; *Scrophularia* sp. River=*Atriplex leucoclada* fruit; *Atriplex* sp. seed; *Carex/Eleocharis* ; reed. **Mixed** (and other Ecological/Economic Associations)=*Astragalus* sp.; *Medicago* sp.; small wild legumes; *Galium* sp.; *Valerianella* types 1&2; *Anthemis* sp. receptacles; *Anthemis wettsteiniana* seeds; *Anthemis* sp.; *Artemisia* sp.; *Centaurea* sp.; *Aegilops* sp. grain; *Aegilops* sp. glume/spikelet; *Bromus* sp.; wild *Hordeum/Bromus* type; wild grass indeterminate; mouse dung. (Full data set forthcoming with Khabur Basin Project reports).

Table 2. Ubiquity of most abundant taxa and types in tannurs and middens+pits

	Middens & Pits		Tannurs	
	#(N=177)	%	#(N=24)	%
Weeds				
Trigonella sp.	140	79	24	100
SWL	150	84	22	92
Wild grasses	143	81	20	83
Astragalus sp.	86	<50	17	71
Aegilops grain	90	51	13	54
Aegilops Spikelet-fork	132	75	15	63
Crops				
Hordeum rachis	117	66	19	79
Hordeum grain	128	72	14	58
Cereal grain	119	67	14	58
Triticum grain	121	68	12	50
Large legumes	95	54	12	50
Glume wheat Glume-bases	94	53	11	<50
Glume wheat Glumes & rachis	90	51	13	54

All 53 other taxa and types at <50% ubiquity.

Table 3. T-test of 3rd and 5th millennium means [% wood (in grams) of total fuels (grams) divided by sorted assemblage volume (in l)]. Only 23 tannurs are included because one tannur from Mashnaqa had no wood, vessicular cereal, or dung fragments

Period	Site	Hearth or Tannur	N	% wood	Mean	S.D.
3rd mill.	Ziyada	#730		0·64		
3rd mill.	Ziyada	#735		0·67		
3rd mill.	Raqa'i	#507		0·09		
3rd mill.	Raqa'i	#518		0·88		
3rd mill.	Atij	#302		1·00		
3rd mill.	Atij	#310		0·87		
3rd mill.	Atij	#342		0·86		
3rd mill.	Atij	#336		0·75		
3rd mill.	Kerma	#455		0·78		
3rd mill.	Kerma	#464		0·90		
3rd mill.			10		0·825	0·113
5th mill.	Mashnaqa	#50		0·40		
5th mill.	Mashnaqa	#51		0·00		
5th mill.	Ziyada	#606		0·67		
5th mill.	Ziyada	#607		0·85		
5th mill.	Ziyada	#614		0·74		
5th mill.	Ziyada	#701		1·00		
5th mill.	Ziyada	#708		0·05		
5th mill.	Ziyada	#724		0·60		
5th mill.	Ziyada	#751		0·82		
5th mill.	Ziyada	#752		0·79		
5th mill.	Ziyada	#785		0·22		
5th mill.	Ziyada	#725		0·55		
5th mill.	Ziyada	#695		0·03		
5th mill.			13		0·517	0·344

Results

A. Calibration studies: hearths, middens, and site formation processes

To use midden remains as proxies for human activities taking place at different sites and periods, one must understand the taphonomic processes forming middens, especially the deposition of hearth ashes. Ethnoarchaeological research (Anderson & Ertug-Yaras, 1998; Reddy, 1998; Watson, 1971; Bottema, 1984; Miller, 1984; Horne, 1994) shows that hearths contain debris from burning dung and wood fuels, various parching accidents, and systematic discard of agricultural products and by-products. These activities have received intense scrutiny elsewhere (Miller, 1984; Miller & Smart, 1984; Miller, 1997*b*; Hillman, Legge & Rowley-Conwy, 1997; Bottema, 1984; Charles, 1988; Anderson & Ertug-Yaras, 1998; Reddy, 1998). In the Khabur archaeological assemblages, the most ubiquitous taxa in tannurs also are the most ubiquitous taxa in middens and pits, suggesting that tannurs were the primary source of charred material found in middens (Table 2). Since midden formation relied on people dumping ashes, variation in midden composition through time or regional variation should largely reflect variation in one or both of the following: (1) which debris people discard in middens and (2) the fuels and waste burned in tannurs.

Analysis drew upon 23 wood-and-dung-containing assemblages from tannurs in southern steppe middle Khabur sites. Ten assemblages come from 3rd millennium BC sites (Tell Ziyada, Tell Raqa'i, Tell 'Atij, and Tell Kerma) and 13 assemblages from 5th millennium BC sites (Tell Mashnaqa and Tell Ziyada). When compared, the percentages of wood as components of total fuels (wood+dung by sorted volume in g/l) differed significantly in the two periods with a higher percentage of wood recovered from the 3rd millennium BC than from the 5th millennium BC tannurs ($t=3{\cdot}03$, $P<0{\cdot}0085$, $df=15$) (Table 3). While it might be possible to interpret this as the effect of longer-term decay on wood in earlier deposits, the same decay would also have affected pieces of dung in earlier deposits. More likely is a greater use of wood fuel in 3rd millennium BC tannurs. Although it is not possible to eliminate the possibility that people dumped ashes according to different behavioural strategies (communal dumps? household dumps?) at various sites and times, there certainly were differences in the fuels in tannurs that would have also affected midden composition.

B. Chronological and spatial patterns in ancient midden composition

Logistic regression of midden assemblages shows several principal patterns for crops, weeds, and wild taxa. First, there are changes in midden composition through time: the relative abundance of some taxa increases significantly, some significantly decrease, and some conceivably remain essentially unchanged. Second, sometimes the rates of change differ at northern and southern sites, as may the percentages of taxa. Significance tests for differences in slopes with respect

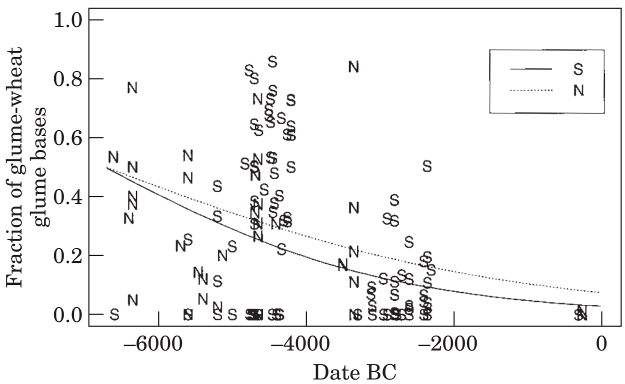

Figure 2. Glume-wheat glume bases (chaff derived by threshing wheats like emmer and einkorn with tightly adhering grain envelopes) show significant decline over time ($P=0{\cdot}0048$)

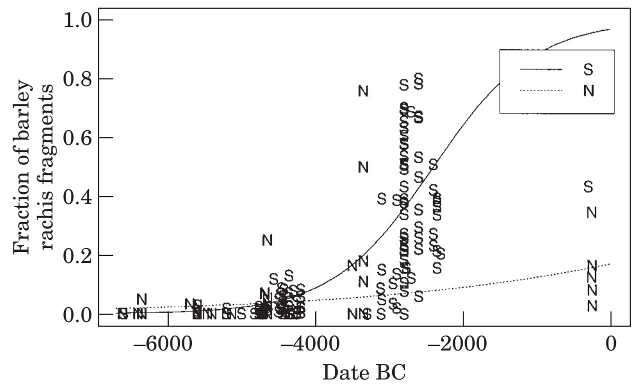

Figure 3. Barley rachis fragments, the chaff derived by threshing ears of *Hordeum* sp., show significant increase over time ($P=0{\cdot}0001$), higher percentages at southern sites ($P=0{\cdot}0001$), and a higher rate of increase in southern sites ($P=0{\cdot}0001$). Note that this latter may be skewed by the inclusion of a few late northern assemblages for which few comparable assemblages (1 from Tell Atij) exist in the southern area.

to time and differences in endpoints establish whether trends among northern sites differ significantly from southern site trends. The major trends are a greater representation of barley and cereal culm from crop processing during the 3rd millennium BC while wheats and crop legumes decline.

Crops

Several cereal crops, including wheats, show significant trends over time. On the one hand, Glume-Wheat Glume Bases—(GWGB) the chaff that in midden deposits marks processing of hulled wheats like emmer—show the same trend and same percentages in northern and southern sites (Figure 2). In both north and south, this glume-wheat processing debris (predominantly from emmer wheat, *Triticum dicoccum*) declines ($P=0{\cdot}005$). Wheat grains occur in greater proportions in southern sites ($P=0{\cdot}015$). In neither area do wheat grain percentages in middens change over time. There is no trend in the representation of spikelet forks (=glume-wheat glumes attached to rachis, which is also chaff from emmer wheat) as one might expect if earlier high percentages of GWGB had been generated from greater incidence of fracturing in older plant material. The pattern indicates a higher incidence of parching accidents in earlier times, possibly because of greater early period reliance on hulled wheats that needed parching to free the grain from the chaff.

If changes in GWGB reflect changes in agriculture, one might expect overall decline in glume wheats to be accompanied by a rise in a replacement crop. But certainly there is no evidence that another wheat, free-threshing *Triticum durum*, became more important over time in either northern or southern sites. Nor do percentages in the two areas differ with any statistical significance. Fractions of processing debris (*Triticum durum* rachis) in middens are tiny. For taphonomic reasons, one would not expect later percentages of free-threshing wheat chaff fragments comparable to earlier relatively high percentages of glume wheats had a replacement occurred. Unlike glume wheats, free-threshing wheats do not require routine parching during food-processing (Hillman, 1984*b*, 1985). In the rare instance of a burnt granary with its stored crop at Tell Kerma (ca. 2700 BC), free-threshing wheat constituted up to 56% of a mixed crop, indicating that it was once and may always have been far more significant than its presence in middens alone would suggest. But analysis detects no change over time and no significant variation across the wetter and drier steppe zones.

Barley does show a rise over time, primarily reflecting higher percentages from 3rd millennium special-function sites south of Hasseke. Overall, percentages of barley-processing debris (*Hordeum* rachis) are relatively high, with significant differences in trend between northern and southern sites ($P=0{\cdot}0001$) (Figure 3). This difference is perhaps mitigated by the relatively low percentages of barley in later northern sites at a time period for which only one comparable southern assemblage has been examined. (The later northern samples may drag down an otherwise greater increase in the 3rd millennium—one that would show up if 3rd millennium assemblages had been available from the north). Southern sites show a notable rise in barley-processing debris, while a slight rise in barley-processing debris is also evident in the northern sites. On the other hand, barley grain fractions show no statistically significant change due to time or location (Figure 4). The evidence suggests a real increase, perhaps especially in the south, in barley processing, or at least in charring and discard of barley-processing waste during the 3rd millennium BC. At the same time, relatively less barley grain (compared with barley chaff) was lost to middens. Perhaps discard behaviours and midden accumulation practices also changed? It seems that barley rachis and grain followed separate paths to become incorporated in the archaeological record.

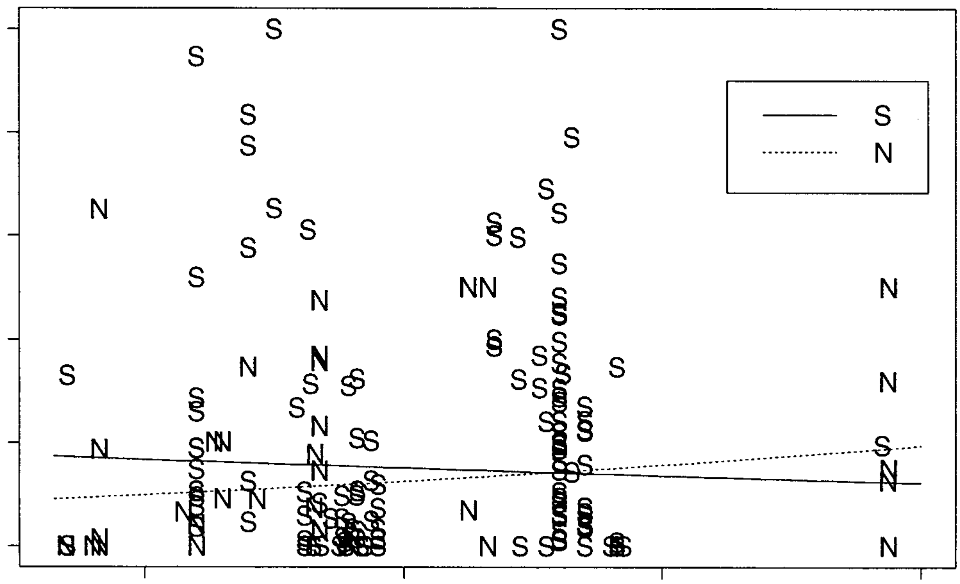

Figure 4. Barley grain (*Hordeum* sp.) shows no statistically significant time trend ($P=0{\cdot}37$) nor difference between northern and southern sites ($P=0{\cdot}61$).

Cereal culm, the unidentifiable straw fragments of wheat, barley or other robust grasses generated through cereal processing, also shows a statistically significant increase over time ($P=0{\cdot}005$). As with barley-processing debris, cereal culm percentages and rates of increase are significantly different (percentages $P=0{\cdot}0002$, rates $P=0{\cdot}004$) in the northern and southern sites, with greater representation and higher rate of increase in the south. Percentages of cereal grains (wheat, barley, and unidentified) show no temporal or regional trend. Yet a rise in both cereal straw and barley-processing waste strongly suggest that both arise from new practices of processing and discarding barley in the 3rd millennium sites.

Large-seeded legumes, despite their importance to Near Eastern farmers, neither preserve well in identifiable form as species (lentils, bitter vetches, peas, grass-peas, chickpeas, etc.) nor accumulate as relatively large percentages of midden assemblages. Their low representation in middens probably can be linked to lack of exposure to fires during processing rather than to their importance in agriculture or diet. Lentils show trends that differ with no trend in the north and a decline in the south ($P=0{\cdot}001$) while on average northern sites have fewer lentils than southern ones (Figure 5). For large legume fragments (some of which may be lentil), the same pattern appears, with a decline in the southern sites ($P=0{\cdot}001$) and no change in the north (Figure 6). One might hypothesize that the decline in large legume fragments reflects preservation: younger assemblages will contain more intact large crop legumes (identifiable to species), whereas older assemblages experience greater fragmentation. Yet there is no temporal increase in the (intact) large crop legumes (chickpeas, peas, and vetches). The trend for lentils (identified from largely intact cotyledons) and other crop legume data therefore suggest a decline over time.

A decline crop legumes may signal important changes in agricultural production. At the beginning of the 3rd millennium, the richness of crop legume types also declines, despite increasingly large sample sizes. Some taxa such as chickpea (*Cicer arietinum*) and bitter vetch (*Vicia ervilia*) disappear, narrowing represented crop types to lentils, grass-pea, and the occasional pea. In the assemblages from the Kerma granary, pulses never exceeded 9% by seed count of a stored crop and exceeded 1% in only three cases. Perhaps farmers began to focus on a barley crop, either dropping other crops from their agricultural base or from communal storage in granaries and a preparation process that left traces in middens.

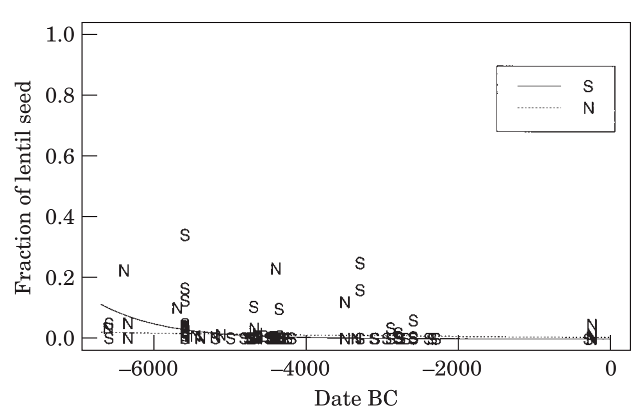

Figure 5. Lentil (*Lens culinaris* (L.) Medik.) seed shows a difference in averages between northern and southern sites, where they are better represented ($P=0{\cdot}0002$). There is no statistically significant trend in the north while lentils decline in the south ($P=0{\cdot}001$).

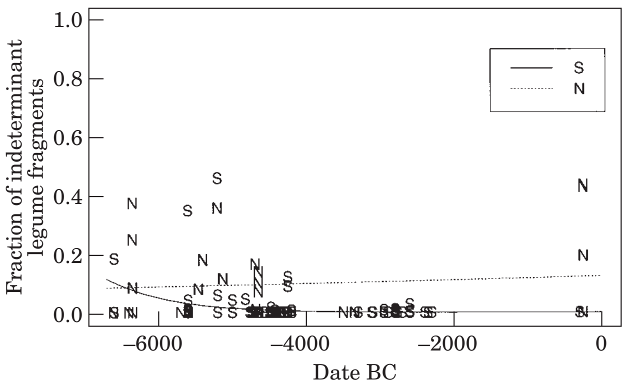

Figure 6. Indeterminate crop legume fragments decline in southern sites (P=0·001). These unidentifiable fragments could be from chick-peas, lentils, vetches, grass-peas, and peas, all of which have been found in the Khabur remains.

Other plants

Weeds and wild taxa potentially provide important insights into the development of agricultural economies, such as clues to shifts in land use, irrigation, and harvesting or processing patterns (Hillman, 1981; Jones, 1984). Combined non-crop taxa and types constitute a substantial component (often >50%) of each midden assemblage. In the present analysis, some individual taxa and types appear as small percentages (<1%) and often showed different temporal and spatial patterns from other taxa within the same broad ecological group. For example, among the Fallow/Disturbed/Grazed Plants, *Gypsophila pilosa*, *Reseda* sp., and *Medicago radiata* occur in higher average percentages in northern sites, while *Heliotropium* sp. has higher average percentages in southern sites, where it also declined over time. Other Fallow/Grazed/Disturbed taxa show no statistically significant differences in average percentage over time or space (Table 4).

Among the wild/weedy taxa, several interesting patterns deserve note here. *Heliotropium* sp. (heliotrope) and *Buglossoides arvensis* (bugloss) match the trend (higher percentages in south, decline in south) that characterizes lentils and unidentifiable crop legume fragments. Possibly gromwell and bugloss are associated with farming and processing practices that incorporated crop legumes and their weeds into middens. Hand harvest of green legumes would more easily incorporate these green weeds, whose foliage stands out in fields where cereals and most other weeds have dried before harvest. *Astragalus* sp. declines in both northern and southern assemblages. Regional *Astragalus* sp. distribution today includes mostly perennial and a few biennial species of lightly to little-grazed steppe, and an *Astragalus* sp. decline indicates either a decline in dung fuels of domestic herd animals or a decline in uprooted plants brought to ovens as tinder. In either case, the decline of Astragalus sp. may point to a concomitant loss of lightly-grazed land and perennial vegetation proximate to expanding settled populations in the 3rd millennium BC. Finally, *Eremopyrum bonaepartis*, a weedy grass in the wheat tribe, increased both in northern and southern sites. This plant is one of several that evolved into weeds particularly well-adapted to agricultural fields by the beginning of the Bronze Age, as field weeds continued to evolve throughout early agricultural history (Van Zeist, n.d.).

Discussion

The Khabur basin is the first region in which one can identify an increase in barley processing at a regional scale through the archaeobotanical record. Site-based economies showing an increase in barley have been recognized elsewhere, including late 3rd millennium Tell Sweihat, neolithic Gritille, and Tell Brak (Miller, 1997*a*; Colledge, 2000). But elsewhere, timing differs at various sites. Widespread cuneiform sources (Jacobsen & Adams, 1981; Powell, 1985; van Lerberghe, 1996) point to expanded barley production in Akkadian urban centres, yet the role of the rural steppe in agricultural development remains unclear. The pan-regional Khabur basin trend, despite great variability, suggests steppe-wide participation in new socio-economic configurations consistent with new regional settlement patterns early in the 3rd millennium BC (e.g., Stein & Wattenmaker, 1990; Hole & Kouchoukos, in press). As with regional ceramic data (on which settlement patterns are based), archaeobotanical data shows high variability among assemblages, reflecting (like surface ceramics) poor temporal resolution and mixing of many activities.

But the trend is nevertheless important. Across the northern and especially southern steppe regions along the Khabur river, barley assumed a much more visible role in crop production during the 3rd millennium BC. Were contemporaneous assemblages included from northern sites, the decidedly regional increase in barley in southern sites might be less pronounced.

The trend smoothes great variability, but its onset is tightly delimited by the 4th millennium BC gap in settled occupation (or assemblages) in the southern region. Once the region was re-settled, new farmers discarded more barley chaff and less glume wheat chaff and crop legumes in middens than had their Ubaid and Post-Ubaid (5th millennium) predecessors, whose household activities probably included daily, small-scale processing of a more diverse array of crops, especially legumes, than the 3rd millennium householders.

New processing and discard strategies probably best account for increased percentages of barley chaff. Bulk processing and community storage of pooled barley harvests may account for larger-scale charring accidents and for high-volume discard of spoiled wastes in communal dumps with a composition different

Table 4. Ecological groups of taxa and types with P-values for significant spatial and temporal patterns

Ecological group	Taxon/type	>% in N.	>% in S.	Decline N.	Decline S.	Increase N.	Increase S.
Dry-farming weeds	*Rumex* sp.	—	—	—	—	—	
	Vaccaria sp.	—	—	—	—	—	0·0418
	Malva sp.	—	—	—	—	—	—
	*Buglossoides arvensis**	—	0·0036	—	0·0028	—	—
	Asperula arvensis	—	—	—	—	—	—
	Asperula/*Galium* type	—	—	—	—	—	—
	Phalaris sp.	—	—	—	—	—	—
Fallow/Grazed/Disturbed	*Gypsophila pilosa*	0·0001	—	—	—	—	—
	Gypsophila sp.	—	—	—	—	—	—
	Silene sp.	—	—	—	—	—	—
	Adonis dentata	—	—	—	—	—	—
	Reseda sp.	0·0001	—	—	—	—	—
	Medicago radiata	0·0001	—	—	—	—	—
	Bupleurum lancifolium	—	—	—	—	—	—
	Heliotropium sp.	—	0·0152	—	0·0128	—	—
	*Arnebia decumbens**	—	—	—	—	—	—
	Crucianella exasperata	—	—	—	—	—	—
	Eremopyrum bonaepartis	—	—	—	—	0·0079	0·0079
	Hordeum sp. (wild grain)	—	—	—	—	—	—
	Lolium sp.	—	—	—	—	—	—
Spring Steppe	*Helianthemum* sp.	—	—	—	—	—	0·0296
	Lygia pubescens	—	—	—	—	—	—
	Androsace maxima	—	—	—	—	—	—
	Ziziphora sp.	—	—	—	—	—	—
	Muscari/*Ornithogalum*	—	—	—	—	—	—
Late Steppe	*Salsola*/*Noaea*/*Hammada* type	—	—	—	—	—	—
	Teucrium polium	—	—	—	—	—	0·0208
	Scrophularia sp.	0·0001	—	0·0001	—	—	0·0001
Riverine	*Atriplex leucoclada*	—	—	—	—	—	—
	Atriplex sp. (seed)	—	—	—	—	—	—
	Carex/*Eleocharis*	—	0·0079	—	—	—	—
	Reed	—	—	—	—	—	—
Mixed/Other	*Astragalus* sp.	—	—	0·0135	0·0135	—	—
	Medicago sp.	—	—	—	—	—	—
	Trigonella sp.	—	—	—	—	—	—
	Small wild legumes	—	—	—	—	—	—
	Galium sp.	—	—	—	—	—	—
	Valerianella types	—	—	—	—	—	—
	Anthemis sp. receptacles	0·0001	—	—	—	—	—
	Anthemis cf. *wettsteiniana*	0·0001	—	—	0·0002	0·0001	—
	Anthemis sp.	—	—	—	—	—	—
	Artemisia sp.	—	—	—	—	—	—
	Centaurea sp.	—	—	—	—	—	—
	Aegilops sp. grain	—	—	—	—	—	—
	Aegilops sp. glume/spikelet	—	—	—	—	—	—
	Bromus sp.	—	—	—	—	—	—
	Wild *Hordeum*/*Bromus* type	—	—	—	—	—	—
	Wild grass indeterminate	—	—	—	—	—	—
	Mouse dung	—	—	—	—	—	—

from household middens. New granary architecture appeared in 3rd millennium sites in the southern steppe (Hole, 1999, 1991; Fortin, 1998; Schwartz, 1993/1994), as did the use of new threshing technology (Anderson & Inizan, 1994; Chabot, 1998). Declining glume-wheat chaff and crop legumes probably reflects both a combination of reduced emphasis on their production and a difference in preservation with new processing and storage of crops in centralized storage facilities. Glume wheats are typically stored un-threshed and processed in small batches in each household just prior to consumption. This practice takes advantage of the protection from insect predation and mold afforded by husk-like glumes. Because barley glumes offer virtually no such protection, threshing an entire barley crop separates straw from grain without affecting grain storage. Bulk threshing prior to storage increases efficiency because animal labour and threshing sledges may be used to process large quantities.

Why was there an increased emphasis on communal storage of barley? Weed taxa show no changes clearly indicative of shifting cultivation strategies. Barley cultivation requires less water than emmer wheat; others have also noted its greater resistance to salinity

(Jacobsen & Adams, 1981) and tolerance of poor soils. Barley would become the more reliable crop with an onset of aridity, sharper seasonal contrasts in precipitation, and possibly greater interannual variability as occurred in the 4th millennium (Courty, 1994; Hole, in press *b*, 1997). That there was little 4th millennium settlement at all suggests that no one took up barley farming in response to aridity—instead people appear to have abandoned village life in the southern steppe. Barley would be the more tolerant crop if in the 3rd millennium, farmers crowded in closely-spaced sites along the river expanded cultivated land to include more of the poor quality, rain-fed steppe soils (McCorriston, 1998). Yet Dry Farming Weeds and other ecological groupings show no overall significant trend to indicate greater use of any particular land type. They show instead great variability from assemblage to assemblage, reflecting mixes from different crops, land types, harvests, and household production strategies.

Perhaps some of the mystery can be solved through contemplating uses of barley. Crop choices reflect not only agrarian conditions but also food preferences and economic exchange systems. Beer made from barley grain has long been a distinctive product particularly relished in Mesopotamia. Recent finds of 3rd millennium cuneiform texts from local Tell Beydar nevertheless point to another use—foddering herd animals with barley grain (Van Lerberghe, 1996: 121). Such foddering (including straw with rachis and culm) would allow steppe herders to exploit spring and summer flushes of annual and perennial vegetation with high numbers of herd animals (for surplus exchanges) later fed on barley stocked in riverside granaries (McCorriston, 1995). Conclusive evidence for this practice nevertheless rests with faunal evidence (Zeder, 1998) and with ongoing integrative studies of herding, farming, and husbandry (Zeder, McCorriston & McCormick, 2000) over a wide regional area.

Although the archaeobotanical record at present shows little clear evidence for steppe vegetation changes over time, low percentages of plant remains probably do not indicate that the steppe resources such as land or plants were unimportant or infrequently used. Low percentages of steppe plant seeds reflect a low incidence of exposure to charring, perhaps because dung fuel from animals grazing steppe plants was not routinely used, as evident in the relatively high wood charcoal percentages in 3rd millennium tannurs.

Finally, some important strengths and weaknesses are evident in a regional approach using binomial logistic regression. As might be expected from a regional analysis with relatively coarse temporal and spatial resolution, the most notable aspect of middens is their high variation. Aarchaeologists have now developed stratigraphic and radiocarbon chronologies that greatly refine chronological assumptions made while selecting middens to sample during the 1980s–early 1990s. In addition to a 4th millennium gap, it has now become clear that northern assemblages lack a 3rd millennium component. Full data tabulation (forthcoming elsewhere) will mean that future assemblages—from a greater spatial range, from all periods, and from rural and urban sites—could be included for future refinement. That the approach nevertheless detects statistically significant differences in northern and southern steppe sites in very similar landscapes today suggests a promising future for this method.

Conclusions

A multi-site archaeobotanical analysis offers an unprecedented view of agricultural development in antiquity. Any evident temporal pattern must be set against a backdrop of spatial variation and coarse temporal resolution. These qualities alone serve as strong caution against using a single site to model regional trends. This can hardly surprise us, since spatial variation has been emerging as an important component of other multi-site archaeological data sets. Parallel ceramic assemblages seem to indicate coexistence of separate cultural traditions (Stein, 1999; Hole, 2001), gaps in site-distribution point to episodes of depopulation (Hole, in press *b*) and regional differences in occupational density and economic practices (Lyonnet, 1996; Wilkinson, 2000). A clear trend has emerged in the Khabur with a rise in barley, most notably in the southern steppe, during the 3rd millennium. Greater tolerance of barley for arid conditions may partially account for this discrepancy, but other practices, such as regional differences in wild resource availability and use (McCorriston, 1992; Zeder, 1994, 1998) might also explain greater barley representation. Most important is a shift in processing and storage conditions with indications from site architecture and crop remains that communities practiced new agricultural and storage strategies with new patterns of waste discard. With an enhanced, multi-site understanding of regional trends in crop production and land use, a better picture of regional socio-economic development during northern Mesopotamian state formation becomes possible.

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