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PALEOETHNOBOTANICAL EVIDENCE FOR DEFORESTATION IN ANCIENT IRAN: A CASE STUDY OF URBAN MALYAN

NAOMI F. MILLER
Department of Anthropology
Washington University
St. Louis, MO 63130

ABSTRACT.–Plant remains from archaeological sites can provide information about the ancient environment. However, these remains should be considered archaeological artifacts, "filtered" through human culture. Adequate interpretation is only possible, and is indeed enriched, by taking the cultural practices of human populations into account. This approach is applied to archaeobotanical materials from Malyan, a fourth to second millennium B.C. site in Fars province, Iran, where there is archaeological evidence for population increase, growing complexity of settlement organization, and technological changes. Clearance of the ancient woodland in the vicinity of Malyan, and concomitant changes in the choice of fuel woods, can account for the observed changes in the proportions of woody taxa found during excavation. In particular, it appears that as the local poplar and juniper were removed, wood of the more distant oak forest was used. Deforestation was a result of a growing population's fuel demands for domestic and technological–especially metallurgical–purposes.

INTRODUCTION

Iran has had sedentary communities for about 10,000 years. The beginning of this period marks the transition to an agricultural way of life. By the fourth millennium B.C., the great urban civilizations of antiquity were developing in Mesopotamia and Iran. Human populations have therefore had both the social organization and the technology to maintain themselves at relatively high densities for thousands of years–densities great enough to result in substantial changes in the natural environment.

Changes in the prehistoric environment have been documented by archaeologists based upon settlement pattern studies (Jacobsen and Adams 1958; Gibson 1974), by the study of botanical remains from excavations (Conrad and Koeppen 1972; Willcox 1974; Helbaek 1960; Minnis 1978; cf. Western 1971), and by analysis of ancient texts (Hughes 1983; Wertime 1983).

The site of Malyan in the Zagros Mountains of southwestern Iran, about 46 km northwest of Shiraz (Figures 1, 2), lies at an elevation of about 1700 m on the northwest end of the broad, flat Kur River basin. The major Near Eastern domesticates (wheat, barley, sheep, goat and cattle) were and continue to be the basis of the agricultural economy.

Although the plain has been occupied by settled populations since the seventh millennium B.C., the major occupation of Malyan began during the Banesh period, ca. 3400-2800 B.C.[1] Population estimates of 100 to 200 people/ha of occupied settlement suggest that the Banesh population in the valley was 5650 to 11,300 (Alden 1979; Sumner 1972). Most of the people were concentrated at Malyan itself, which had a population of 4500-9000. The remainder of the population lived in villages of less than 3.5 ha. By the time Malyan reached its maximum extent during the subsequent Kaftari period (ca. 2200-1600 B.C.), the city had grown from about 45 ha to 130 ha, with total occupied settlement area in the Kur basin of 288 ha (Sumner 1972). Thus the population of Malyan was between 13,000 and 26,000, and the total settled population was about 30,000 to 60,000.[2]

In addition to regional population increase, the organization of settlement also

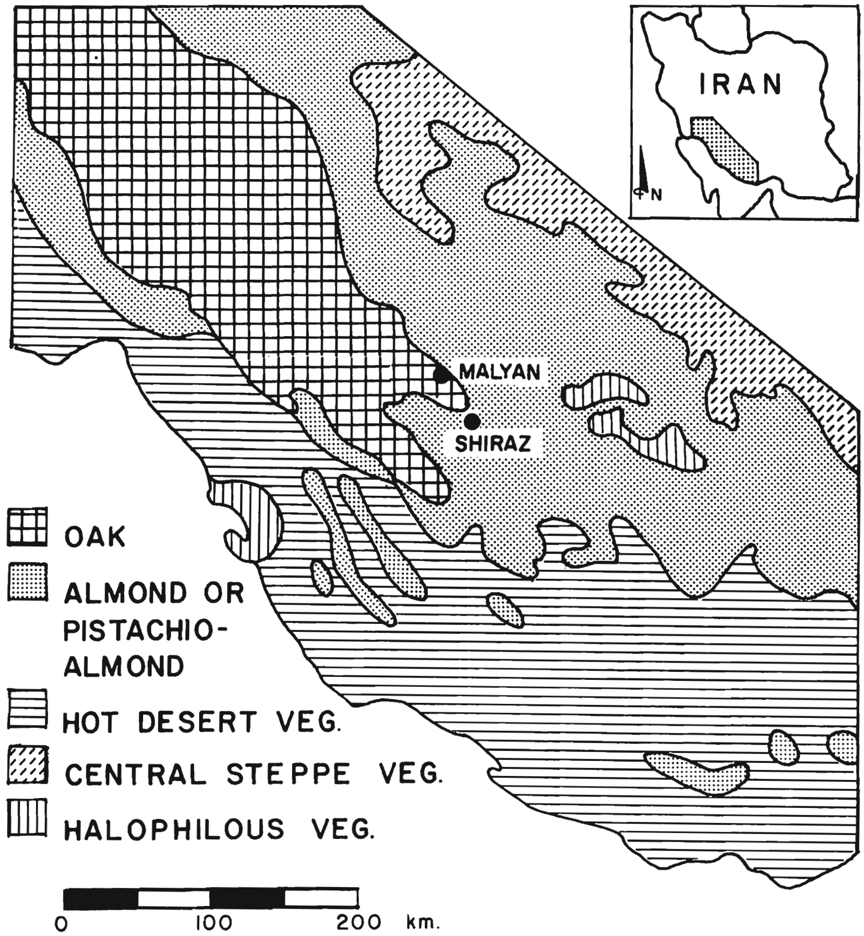

FIGURE 1.—Vegetation of southwestern Iran (after Zohary 1963).

changed. During the Kaftari period, only about one half of the population lived in Malyan, while the remainder were scattered in numerous villages and towns (0.5 ha to 10 ha) to the south and east (Sumner 1972, 1980).

Other important changes were taking place as well. Kaftari period Malyan is known in ancient texts as Anshan (Hansman 1972; Reiner 1974; Stolper 1976). Royal titles demonstrate a political link between Anshan, the highland capital of the Elamite polity, and Susa, the lowland capital during the Elamite period (Amiet 1979), roughly contemporary with the Kaftari deposits at Malyan. Malyan became increasingly involved in a broader economic and political network. A greater quantity of exotic goods is found at Malyan (Sumner 1974: 173). The third millennium saw an increase in bronze metallurgy throughout the Near East (Mallowan 1971:239-240, 305-306; cf. Lloyd 1978:82, 127; cf. Moorey 1982). At Malyan, copper-bronze slag indicative of smelting is more widesprad in the Kaftari period deposits.

The way in which a population exploits a given territory depends in part on its density, the way it is distributed over the landscape, its economic activities, and the resources available to it. These factors changed during the third millennium B.C. in the Kur basin. Excavations at Malyan provide evidence for the impact of human economic activities on the environment during the late fourth/early third and late third/early second millennia B.C. This report will show how ethnobotanical evidence can be used to monitor some of

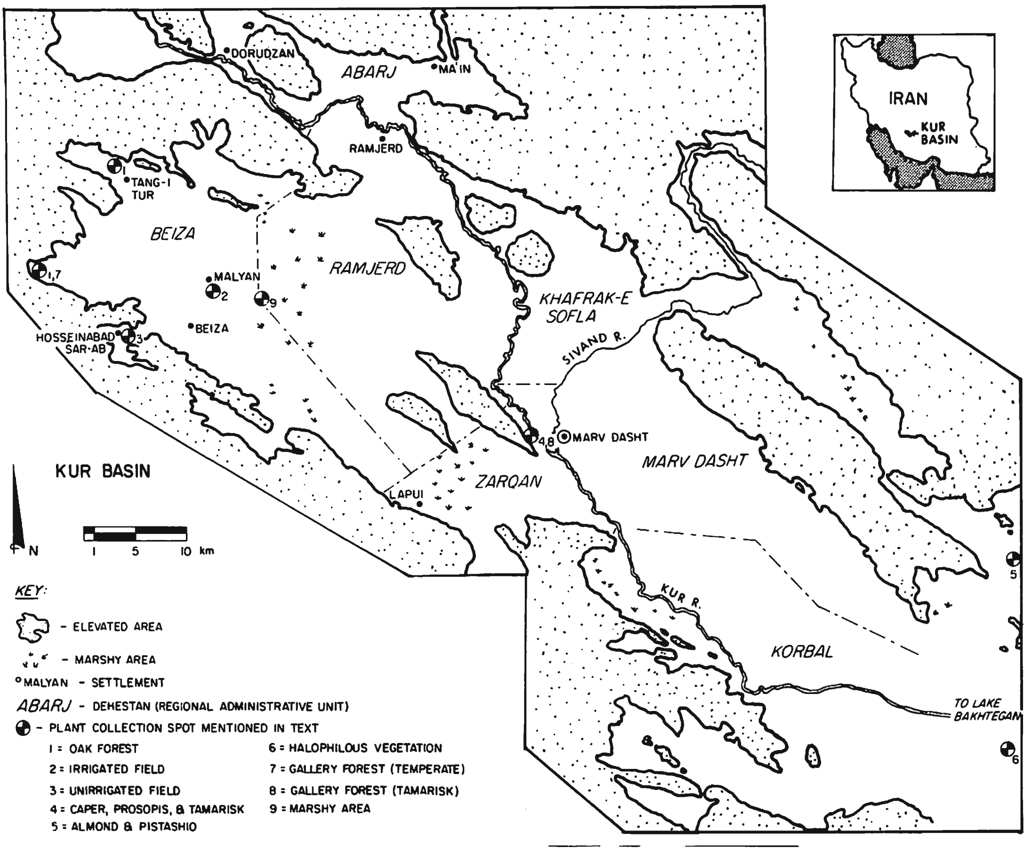

FIGURE 2.—Kur River basin.

these changes. The evidence is in the form of wood charcoal, recovered from Malyan during the 1974, 1976, and 1978 field seasons.

THE CHARCOAL ANALYSIS

Archaeobotanical evidence for the use of wood resources at Malyan consists of charcoal. Generic identifications of the charcoal were made by comparison with known, freshly carbonized woods collected during the 1976 and 1978 seasons. A variable power microscope with magnification of 7 - 30 x was used.[3] The modern comparative material was identified at the Royal Botanic Garden at Kew, England.

Charcoal pieces were broken manually so that the transverse section would be visible. With the help of Scanning Electron Microscopy (SEM) photographs of modern charred specimens (Miller 1982) and direct visual comparison with identified specimens[4], features such as the distribution of pores within the annual growth ring, ray thickness, and presence/absence of gum were noted. Fortunately, the major genera of the southern Zagros forests are anatomically distinctive relative to one another, so it was not necessary to examine each specimen at a higher magnification. Pieces with less than a complete growth ring, and those that crumbled beyond recognition were not included in the analysis; large pieces that had indeterminate anatomical features, as well as unfamiliar woods, are included in the category "unknown." Total identified pieces for each taxon in each sample were then weighed. Up to 20 pieces per excavation unit were identified when available. Although the pieces were not randomly selected, both small and large pieces were chosen. Some archaeological features were excavated in several units. Thus, more than 20 pieces of charcoal were identified from some of the larger and charcoal-rich features.

Although only 0.2% of the 130 ha site has been excavated to date, both Banesh and Kaftari deposits have been sampled extensively (Sumner 1980; Nicholas 1980; Nickerson 1983). A large number of sediment samples (ca. 10 l each) was taken for flotation (Table 1), and charcoal visible in the site matrix was collected on the site by the workmen. Some of the charcoal was submitted for radiocarbon dating and is unavailable for the paleoethnobotanical analysis. The charcoal from the Banesh and Kaftari periods at Malyan comes from a variety of residential contexts—hearths, pits, rooms, jar fill—burials, and other sediment matrix.

TABLE 1.—*Flotation sample summary from Malyan.*

Period	No. Deposits Sampled	No. liters floated	Charcoal Total Wt. (g)	Seeds Total Wt. (g)	Carb. Material
Banesh	97[1]	1303	426.49	3.11	429.60
Kaftari	89	1301	438.25	38.18	476.43

[1]Sediment volume of two jar samples could not be determined, so they are not included in this table.

The charcoal comes from two types of sample. The first consists of large pieces (generally about 1 to 3 cm in diameter) collected by hand during excavation[5]; the second consists of smaller pieces, well under 1 cm in diameter, recovered by flotation of sediment samples at the field laboratory.[6] Identification of the larger, hand-picked pieces is somewhat more certain, because it is generally easier to identify larger pieces. Also, the hand-picked pieces represent a greater quantity of wood per sample.[7]

For both time periods, information from numerous samples is combined, enabling comparison of the two. The initial justification for this step was that for both Banesh and Kaftari periods there is no evidence of burned structures. It is therefore assumed that the bulk of the charcoal represents wood or charcoal intentionally burned as fuel, regardless of whether it is found in primary hearth or secondary trashy deposits. No assumptions are made about the purpose of the fires, which could have been for cooking and other food processing, for heating, ceramic manufacture, and smelting, or for ritual activities. Some of the hearths and ovens have relatively high densities of charcoal (Miller 1982, Table B.1).

Although the amount of charcoal recovered does not necessarily reflect the amount of wood burned, one might expect charcoal weight to be the most appropriate measure of the relative importance of different taxa. The number of pieces of wood put into a fire, or the number of pieces of charcoal left when that fire is extinguished, would seem to bear a less direct relationship to the quantity of wood burned than does the amount (by weight) of charcoal left when that fire is extinguished. In addition, fragmentation rates may vary among different wood types. It is therefore intuitively appealing to measure charcoal quantities by weight to compare the relative importance of different taxa. Unfortunately, many of the small pieces from the flotation samples are too light (less than .02g) to weigh accurately. The charcoal fragments frequently have mineral or clay encrustations, further distorting the very low weights. Therefore, the use of charcoal counts is more practical.

In order to see whether an analysis by counts would differ from an analysis by weights, a correlation analysis of weights and counts for flotation and hand-picked samples was carried out. Counts and weights are highly correlated (Table 2). I have chosen to emphasize the number of charcoal pieces or count for the rest of this analysis better to compare flotation and hand-picked charcoal (Table 3). As a supplement to the

TABLE 2.—*Correlation of charcoal counts and weights of the major taxa.*

Taxon	No. Samples	Corr. coeff. (r)[1]
Juniper	29	.73
Almond	40	.80
Maple	18	.94
Pistachio	35	.81
Oak	33	.88
Poplar	19	.72
Elm family	25	.76

[1]Correlation coefficients significant at $p < .01$.

use of count and weight, relative frequency of the taxa can be used to identify types that may have a consistent but low level of occurrence (cf. Hubbard 1980). Weight and frequency measures are therefore useful checks on the data based on count (Tables 4 and 5). It is not possible to report densities for the hand-picked charcoal; although excavated volume of the various loci and features were calculated by the excavators, not all charcoal was collected. Pieces sent for radiocarbon dating were not available for this analysis.

Increase or decrease in the proportions of a taxon may be affected by a number of factors. First, because of the large size of the site, a sample of 10m x 10m squares was chosen for excavation, and not all areas were sampled equally.[8] Within the excavated areas, differences among hearths, pits, and other deposit types could conceivably account for some of the differences among samples (Table 6). Although it is inappropriate to use inferential statistics in the analysis, a representative group of deposits was sampled. Examination of a large number and variety of deposits, sampled by flotation and visual inspection, and measured in several ways (i.e., count, weight, and frequency) increases confidence that the observed patterning in the data accurately reflects the distribution of material on the site. Consistency among the various measures then provides the means to assess the reality of changes in the archaeobotanical record.

Differential distribution of charcoal within the site is assumed not to interfere with the broad comparison of taxon composition by time period because: (1) Overall charcoal densities in the flotation samples were of similar magnitude for each time period; (2) Both periods are represented by shallow and deep deposits; (3) A variety of contexts was sampled for both periods, and differences among deposit types were less pronounced than between time periods; (4) Banesh and Kaftari charcoal is assumed to have been from fuel because there are no burned structures.

CHARACTERISTICS OF THE MODERN VEGETATION

Today, the natural vegetation of the region is greatly disturbed by human activities. On the plain, lands not in cultivation are used for pasture, and the limestone hillsides surrounding the plain are largely denuded of vegetation. Reconstruction of the natural vegetation is based upon remnant forests of less populous areas. The vegetation is an open woodland. Presently forested areas are discontinuous, so boundaries between vegetation zones cannot be drawn exactly. Malyan lies at the southeastern limits of the Zagros oak forest, near the pistachio-almond steppe forest (Figure 1; Zohary 1963). Remnants of these forest types still exist in the area (Figure 2). At the northwest end of

TABLE 3.—*Charcoal counts from Malyan.*

	Hand-picked Samples				Flotation Samples			
	Banesh		Kaftari		Banesh		Kaftari	
No. of deposits (N)	(N=35)		(N=40)		(N=99)		(N=89)	
Taxon:	#	%	#	%	#	%	#	%
Dry Forest								
Juniperus excelsa[1]	243	32	45	5	118	14	4	+
Amygdalus sp.	101	13	159	17	372	43	322	30
Acer monspessulanum[1]	21	3	130	14	24	3	121	12
Almond/ Maple	—	—	1	+	—	—	—	—
Pistacia sp.	65	9	199	21	148	17	141	13
Quercus aegilops[1]	45	6	235	25	55	6	269	26
Humid								
Populus sp.	162	22	10	1	48	6	24	2
Fraxinus sp.	—	—	13	1	3	+	2	+
Platanus orientalis[1]	—	—	—	—	—	—	1	+
Vitex sp.	—	—	18	2	—	—	—	—
Distant Vegetation								
Capparis spinosa[1]	—	—	8	1	—	—	—	—
Prosopis sp.	—	—	1	+	—	—	2	+
Miscellaneous								
Vitis vinifera[1]	—	—	23	2	—	—	2	+
Daphne acuminata[1]	1	+	—	—	—	—	1	+
Rhamnus sp.	—	—	—	—	4	+	—	—
Ulmaceae	80	11	46	5	23	3	24	2
Diffuse Porous	—	—	—	—	14	2	39	4
Unknown	33	4	70	7	60	7	99	9
Totals[2]	751	100	958	101	869	101	1051	98

[1]Identifications to species are based on phytogeographic grounds, not morphology (cf. Sabeti 1966).

[2]Based on data presented in Miller (1982).

TABLE 4.—*Charcoal weights of hand-picked samples from Malyan.*

	Banesh		Kaftari	
No. of deposits (N):	(N=35)		(N=40)	
	Wt. (g.)	%	Wt. (g.)	%
Taxon:				
Juniperus excelsa	123.88	38	35.65	10
Amygdalus sp.	21.56	7	58.63	17
Acer monspessulanum	3.94	1	42.10	12
Almond/Maple	–	–	.07	+
Pistacia sp.	32.37	10	84.44	25
Quercus aegilops	14.29	4	73.37	21
Populus sp.	93.21	29	1.32	+
Fraxinus sp.	–	–	7.81	2
Vitex sp.	–	–	1.04	+
Capparis spinosa	–	–	6.19	2
Prosopis sp.	–	–	.06	+
Vitis vinifera	–	–	8.42	2
Daphne acuminata	.12	+	–	–
Ulmaceae	14.26	4	11.04	3
Diffuse Porous	4.51	1	–	–
Unknown	13.67	4	12.64	4
Total	321.81	98	343.78	98

the Kur River basin is an area of oak forest[9] which includes some pistachio. Almond grows on the lower and south-facing slopes. Several other species of trees and shrubs, such as maple and wild fig, are less common. At the southeast end of the plain is a fairly extensive stretch of somewhat degraded pistachio-almond forest. The pistachio-almond forest is more xerophytic than the oak forest, though they share some genera, such as maple. Juniper, which is present in the archaeological samples, is today fairly rare in the mountains of southwestern Iran. Bobek (1951) considers *Juniperus excelsa* "characteristic" of the transition zone between the dry southern Zagros oak forest and the pistachio-almond steppe forest of Fars province, but it is less common in the former. It grows well on calcareous soils and has an elevational altitudinal range of 1500 to 3400 m (Pabot 1960), so Malyan is near the presumed lower limit of its range. The one juniper specimen

TABLE 5.—*Frequency of charcoal.*

	Hand-picked Samples				Flotation Samples			
	Banesh		Kaftari		Banesh		Kaftari	
No. of deposits (N):	(N=35)		(N=40)		(N=99)		(N=89)	
	#	%	#	%	#	%	#	%
Taxon:								
Juniperus excelsa	26	65	3	9	34	34	11	12
Amygdalus sp.	21	53	17	49	57	57	58	65
Acer monspessulanum	4	10	14	40	12	12	35	39
Pistacia sp.	18	45	17	49	33	33	37	42
Quercus aegilops	9	23	24	69	19	19	55	62
Populus sp.	14	35	5	14	18	18	13	15
Fraxinus sp.	—	—	1	3	3	3	2	2
Platanus orientalis	—	—	—	—	—	—	1	1
Vitex sp.	—	—	1	3	—	—	—	—
Capparis spinosa	—	—	3	9	—	—	—	—
Prosopis sp.	—	—	1	3	—	—	1	1
Vitis vinifera	—	—	4	11	—	—	2	2
Daphne acuminata	1	3	—	—	—	—	1	1
Rhamnus sp.	—	—	—	—	2	2	—	—
Ulmaceae	16	40	9	26	13	13	11	12
Diffuse Porous	—	—	—	—	10	10	12	13
Unknown	11	27	15	43	21	21	34	38

found in the oak forest near Malyan is probably *Juniperus excelsa* M.B., a xerophytic species.

On the plain itself, most trees are cultivated, and groves typically consist of poplar (*Populus alba* L., *P. nigra* L.), willow (*Salix excelsa* G.M. Gmel.), ash (*Fraxinus syriaca* Boiss.), or fruit trees. In the central part of the plain near the city of Marv Dasht and toward the southeast, there are several species that prefer a warmer climate or that tolerate more saline conditions. Tamarisk (*Tamarix* sp.), which here grows as a shrubby tree, and caper (*Capparis spinosa* L.) and *Prosopis* (*P. farcta* L.), both shrubs, are relevant to the present discussion. They were never seen growing at the northwest end of the plain and were unfamiliar to a couple of Malyan boys with whom I visited this area.

TABLE 6.—*Density of charred material.*

	Banesh		Kaftari	
Deposit type	N	Mean	N	Mean
Fireplaces[1]	18	17.86	4	1.71
Pits	16	4.64	28	4.37
Rooms	49	1.45	32	3.18
Burials	3	2.79	—	—
Jars	4	1.33	3	1.22
Matrix[2]	7	2.64	22	4.86
Total	97[3]		89	

[1] Fireplaces: hearths, ovens

[2] Matrix: soil matrix not found in association with architecture

[3] Sediment volume of two jar samples could not be determined, so they are not included in this table.

CHARACTERISTICS OF MODERN WOOD USE

The effect of human activity on vegetation largely depends on the uses to which particular plants are put. First, wood is brought to a settlement for a variety of purposes, such as construction and fuel, and trees of both forests and gardens are cut and used differentially. Most woods are suitable as fuel, but variability in heat production, smokiness, and sparking will affect their desirability for particular tasks. Second, wood is a bulky commodity. If it is the primary fuel for cooking and heating, supplies must be replenished regularly. For example, estimates for fuel use in traditional Middle Eastern societies averaged over a year are 1.5-2 kg/person/day (Thalen 1979; Horne 1982a). Transport costs are therefore a significant factor in choice of wood (Chisholm 1967; Forest Research Institute 1972), and one would expect that, other things being equal, trees closest to home will be utilized first. Cultural preferences for particular wood resources are frequently determined by purpose and availability (e.g. Heizer 1963; Metzger and Williams 1966), which depend to some extent on the different physical and biological properties of trees. Knowledge of these properties can therefore be used to help interpret variation in the relative proportions of different species on an archaeological site.

Most of the major woods available today are suitable for fuel. Present-day villagers used to travel with donkeys and on foot to the mountains 15 or 20 km away in winter for wood; they mention almond (*Amygdalus* sp.), oak (*Quercus aegilops* L. ssp. *persica* (J. & S.) Blakelock), pistachio (*Pistacia* cf. *eurycarpa* Yalt.), and maple (*Acer monspessulanum* L.) as having been important. Poplar (*Populus alba* L. and *P. nigra* L.), grown for use as roof beams, is available in the village and sometimes is used to supplement dung-cake fuel. Juniper, found archaeologically, is quite rare nowadays.

The physical properties of these woods differ. Generally, oak burns hotter than maple and juniper (Graves 1919), although juniper[10] "is an excellent fuel and said to yield good charcoal" (Townsend and Guest 1966: 92). Pistachio, a resinous wood, may be a preferred fuel (cf. Mikesell 1961: 26). Almond is probably a good fuel wood too, but information about its burning qualities is hard to come by. Poplar is quite porous and burns rather quickly so is somewhat less desirable. Dung is also readily available for fuel, since most households own at least a few cattle, sheep, or goats. Wood, although preferred over dung cake fuel, is relatively expensive, and, at least in 1978, there were legal restrictions against fuel cutting in the forest.

The biological characteristics of the trees will affect their availability. *Juniperus excelsa*, for example, is a fairly slow-growing, xerophytic tree (Pabot 1960), and is adversely affected by a combination of fuel cutting and grazing (cf. Thalen 1979). Since it does not compete well with oak (Pabot 1960), it would not be able to renew itself if over-exploited for fuel. In contrast to juniper, poplar is fast-growing, and, when cut, readily puts up new shoots. Unlike juniper, it has a high water requirement, and in the arid climate of southwestern Iran, is restricted to stream sides, irrigated groves, and other areas with a high water table. Because it is always in demand for roof beams, it is cultivated and protected. Fuel is merely a by-product of its use in construction in the region today, and it is therefore always available, at least in small quantities.

FOREST UTILIZATION IN ANCIENT TIMES

The major genera found archaeologically at Malyan are juniper, oak, almond, pistachio, maple, and poplar. Perhaps the most striking difference between the Banesh and Kaftari levels is the inverse relationship between juniper and poplar on the one hand and oak and maple on the other (Tables 3, 4, 5). This relationship obtains regardless of analytical method (Table 7). During these time periods, almond and pistachio percentages remain fairly constant. The very small quantities of caper and *Prosopis* do not appear until the end of the sequence. In addition to these changes in the use of wood and charcoal fuel, there is indirect evidence for an increase in the use of dung fuel relative to wood and charcoal (Miller and Smart 1984).

Wood found on an archaeological site has been selected by people, so the composition of the charcoal assemblage is not directly analogous to the ancient vegetation. A change in wood use might represent a change in the relative availability of the economi-

TABLE 7.—*Consistency of results for the major wood taxa (changes between Banesh and Kaftari periods).*

	Hand-Picked			Flotation	
Taxon	Counts	Weights	Frequency	Counts	Frequency
Juniper	decline	decline	decline	decline	decline
Almond	slight increase	increase	slight increase	slight increase	slight increase
Maple	increase	increase	increase	increase	increase
Pistachio	increase	increase	slight increase	slight decline	increase
Oak	increase	increase	increase	increase	increase
Poplar	decline	decline	decline	slight decline	slight decline
Elm family	decline	slight decline	decline	slight decline	slight decline

cally important species. Changes in availability may be associated with climatic change, or, as is more likely in this case, with human interference with natural forest growth.

Before changes in wood use can be assessed, Post-Pleistocene climate and vegetation changes must first be considered. Ancient climatic conditions can be inferred from pollen analysis if suitable sediments are available for testing. Information thus obtained is complementary to ethnobotanical data from archaeological sites. Samples taken by H. E. Wright from a salt lake near Shiraz unfortunately yielded insufficient quantities of pollen to be useful for environmental reconstruction (1985, personal communication). Summarizing the available pollen evidence, Wright (1977) and van Zeist and Bottema (1982) infer that the Pleistocene environment over much of the Near East was a cold dry steppe. The species typical of the Zagros oak forest would have spread in a southeasterly direction from Syria and southeastern Turkey at the end of the Pleistocene (van Zeist and Bottema 1977). Conceivably this expansion of the oak forest in the post-glacial period did not reach the southern Zagros until the third millennium B.C., and it replaced a more xerophytic mixed forest of pistachio, almond, maple, and perhaps juniper. This reconstruction is not likely for two reasons. First, data from Lake Zeribar in the central Zagros indicate that the modern climate in that region became established by 5500 B.P. (van Zeist and Bottema 1982). Using the MASCA radiocarbon correction, this date is equivalent to about 4250 B.C. (Ralph et al. 1973), well before the Malyan samples. Second, although climate and vegetation history are important determinants of the presence, absence, or relative abundance of particular species, the proportions of different species is also influenced by people. The disjunct but widely dispersed occurrence of juniper in southern Iran today suggests that were it not for herding and fuel-cutting activities the area could support more juniper than it does at present.

Alternatively, a change in local availability of various tree species could be affected by factors other than climate. The use of wood by human populations determines which taxa will be brought to a site, and in the absence of accidental fires, which taxa will be preserved as charcoal. Wood cutting by human populations can alter the composition of the forest as well as its extent. Probable activities involving tree use are based on general and specific ethnographic analogy, and are partially corroborated by some of the archaeological evidence (Table 8). It is also possible to assess the amount of wood involved in various activities.

Fuel.—Wood may be used directly as fuel, or it may first be transformed into charcoal. Although trees may be pruned rather than felled for wood and charcoal, continuous demands for fuel by settled populations, especially in semi-arid climates, can lead to forest depletion.[11] Most structures excavated at Malyan represent domestic architecture. Given the cold winters of the Kur River basin, heating would have been necessary for part of the year. Various hearths and ovens suggest that food preparation and heating fires were set in built-in facilities within structures.

Fire was also used for industrial activities at Malyan. Copper-bronze slag, found throughout the site, provides evidence for metallurgy. Metal is widespread in the Kaftari levels. Nickerson (1983) has suggested that small-scale metal refining took place at the household level during Kaftari times. It is noteworthy that charcoal rather than wood is used in smelting, and some woods must be cut green in order to make charcoal (Horne 1982a). Forbes (1964:106) quotes the ancient Greek author, Theophrastus: "The wood of older trees is inferior to that of younger, for the same reason that of really old trees is especially bad. For it is very dry, wherefore it sputters as it burns; whereas wood for charcoal should contain sap."

Horne (1982a) specifically mentions juniper, pistachio, almond, and oak as having the characteristics mentioned by Theophrastus. Although charcoal has a higher caloric value than wood, its manufacture by primitive methods is a very inefficient use of wood fuel (Horne 1982a, b). It cannot be proved that charcoal manufacture increased during the third millennium. However, evidence for smelting is common in both Banesh and Kaftari deposits (W.M. Sumner, p.c.), and even in the absence of a per capita increase in metal use the larger Kaftari population would have required greater quantities of metal. It therefore seems likely that more charcoal would have been produced and burned for smelting.

There is evidence for pottery manufacture at Malyan. The pottery kilns, filled with kiln wasters and probable dung ash post-date the Kaftari occupation of the site, however.

TABLE 8.—*Possible uses of woody taxa at ancient Malyan.*

Taxon	Wood	Leaves/ Branches	Fruits
Juniper	fuel[1] timber[3]	fodder	medicine[3]
Almond	fuel[1,2,3] timber	fodder[2]	fodder[2] food[1,2]
Maple	fuel[1,2,3] timber[3]		
Pistachio	fuel[1,2] timber[3]	fodder[2]	food[2,3] (presume[1])
Oak	fuel[1,2] timber[3]	fodder[2]	fodder[2] food[3]
Poplar (largely cultivated now)	fuel[1,2] timber[1,2,3]		
Ash	fuel timber[3]		
Plane (some cultivated today)	fuel timber[3]		
Vitex	fuel		
Caper	fuel		food[3]
Prosopis	fuel		fodder[3] food[3]
Grape (cultivated only)	fuel[2]	food[3]	food[1,2,3]
Daphne	fuel		
Rhamnaceae	fuel		
Ulmaceae	fuel[1] timber[3]		

[1]Archaeological evidence from in situ oven/hearth/kiln (fuel) and latrine (food) deposits, including post-Kaftari deposits.

[2]Ethnographic observations and discussion with villagers.

[3]Published references for Near East (e.g. Wulff 1966, Townsend and Guest 1966, et. al.).

Alden (1982) has found several Banesh pottery manufacturing sites near the mountains and suggests their location may be due in part to their proximity to fuel. The few pieces of charcoal recovered from one of these sites neither support nor refute this proposition (Miller 1980).

Lime production would also have used up large quantities of fuel, considering the substantial evidence at Malyan for the use of plaster for walls, floors, and containers (Blackman 1982). It is appropriate to point out that Malyan, as the center of an urban system, could well have drawn finished products (notably lime and pottery) from its hinterland; direct evidence of fuel use for these manufacturing activities would therefore not appear at the site, even if deforestation may be inferred on the basis of the charcoal assemblage from the ancient city.

Construction.—Contemporary construction techniques are similar to those found archaeologically; for descriptions and discussion of traditional techniques in use, see Wulff (1966), Watson (1979) and Kramer (1982). Both present-day and ancient structures are made of sun-dried mud brick. The former, and presumably the latter, have wooden roof beams covered with mats, brush, and a layer of hard-packed mud. Today, poplar and willow are the primary woods used for roof beams. A large burnt public building, dating to about 400 years after the Kaftari period, had an abundance of poplar charcoal. The large chunks found in association with other roofing material (grass or reed stem, from matting) suggest that by 1200 B.C. poplar was used for beams. Juniper (*J. excelsa* M.B.) may grow to a height of 20 m; its wood is "light and not particularly strong," but it could provide durable wood suitable for beams (Townsend and Guest 1966). Although none has been found to date in this context, the excavator has suggested that some Kaftari period rooms may be too wide to have been spanned by poplar beams, which have a maximum usable length of about 4 m (W.M. Sumner p.c.).

In any case, despite population increase in the valley, the cutting of trees for roof beams for local use would probably not be sufficient to cause deforestation. If long-distance trade in wood were important for construction material (the suggested reason for depletion of the Lebanese cedar forests, for example) or ships (for example, in the Mediterranean region during Classical times, Hughes 1983), this could be a factor in deforestation. Data are not available to assess this possibility.

Tool manufacture.—Although no wooden tools have been found, there is no reason to doubt that wood was used for utensils, tool handles, containers, ornaments, and other objects. The manufacture of wooden artifacts is not likely to put as great a stress on the forests as fuel use and construction.

Grazing.—The role of grazing in deforestation could be quite significant, especially if animals were brought to forests that were already under stress from fuel-cutting. Goats and camels can be observed today in the oak forest nibbling on oak, pistachio, and almond trees, and undoubtedly they browsed these species during ancient times.

Land clearance.—No forest remnants occur on the plain today, but this has not always been the case (Kortum 1976:84). New fields could have been prepared by removing the trees. If the trees were burned, no archaeological evidence would be left. If the wood was used as fuel, one might expect to find some charred remnants on the site.

The activities of human populations which are destructive to forests may be counteracted by tree planting. Whether or not some individual trees had been cultivated in antiquity cannot be determined, since the wood of cultivated trees cannot be distinguished from the same species growing wild. With the exception of grape, which is thought not to be endemic to southern Iran, the woody taxa found archaeologically all occur in the wild today and many are also cultivated. Although the pistachio and almond of commerce are not now grown in the area, nor are they found archaeologically, nuts of wild pistachio[12] and almond[13] are collected today by villagers and are also found archaeologically. Although contemporary use of acorns is widespread—goats enjoy them, they are used in tanning leader, and nomands used them for flour—acorns have not been found in archaeobotanical samples. Grape is the only woody plant with edible fruits or nuts that one can safely assume was planted at ancient Malyan. Wood of the grape would represent incidental use as fuel.

DEFORESTATION IN THE KUR BASIN

Initially, forest clearance close to Malyan may have been undertaken to provide agricultural land. Population estimates for earlier fourth millennium occupation exceed those of the Banesh period, and presumably some forest clearance in the Kur River basin was already underway. In the absence of climatic and archaeobotanical data, the degree of disturbance cannot be estimated. However, the Kaftari population increase could certainly have led to the clearing of primary or secondary forest.

Horne (1982a) has suggested that the vast amounts of wood required for charcoal used in metallurgy can also lead to rapid depletion of forests. This is certainly a possibility for later antiquity; Wertime (1983) considers that the "pyrotechnical industries" were the primary cause of Mediterranean deforestation. As mentioned earlier, the choice of slow-growing juniper as a fuel would deplete a nearly non-renewable resource, particularly if the trees were cut down rather than pruned. Note further that juniper would have grown on the well-drained part of the plain, on land otherwise suitable for agriculture, whereas poplar would not have interfered with cultivation. A complicating factor is the apparent increase in the use of metal at Malyan and elsewhere in the Near East during the third millennium. Juniper could have been a preferred fuel for this activity. As the Classical author Theophrastus commented (although not specifically in reference to bronze manufacture and juniper): "Smiths require charcoal of fir rather than of oak; it is indeed not so strong, but it blows better into a flame as it is apt to smoulder less; and the flame from these woods is fiercer." (quoted in Forbes, 1964:107)

The archaeological context of the finds, particularly the absence of any evidence of burned structures in the Banesh and Kaftari levels, suggests that most of the charcoal probably represents the remains of spent fuel. The deposits characterized by high densities of charcoal probably represent primary hearth deposits or secondary dumping of hearth debris. The charcoal from low-density deposits has been interpreted as dispersed refuse. Since a major limiting factor for the use of firewood is transport costs; charcoal is lighter than wood, and its manufacture is one way to reduce transport costs. Charcoal production sites by their nature are ephemeral (cf. Horne 1982b) and would be difficult if not impossible to discover archaeologically. Although it is not possible to determine whether wood or charcoal was the preferred fuel, one may still apply least effort considerations to the problem of fuel use. Those collecting areas nearest the site would be used first, especially in a time of non-mechanized transport. One might expect charcoal percentages to reflect species availability within the shorest radius from the site.

During Banesh times, the fairly high proportion of juniper in the archaeological samples suggests that it may have been a major component of the pistachio–almond steppe forest that extended from the lower slopes down onto the plain. If this were the case, the juniper population seems to have been nearly completely removed from the environment between Banesh and Kaftari times. Textual support for depletion of juniper in southern Iran is provided by Hansman (1976), who has suggested that the ancient territory of Elam, east of Sumer, is "the land of the cut-down ERIN-trees" referred to in the Gilgamesh epic. During the third millennium, the Sumerian epic hero Gilgamesh must travel through this territory in order to obtain ERIN wood, which Hanseman suggests is *Juniperus excelsa* on epigraphic and phytogeographical grounds.

Poplar probably grew in the poorly drained marshy area to the east of the site and is unlikely to have been a preferred fuel. Like juniper, the importance of poplar for fuel seems to decrease between Banesh and Kaftari times. It may have grown naturally on marsh land that today is completely treeless and used for pasture. Unlike juniper, which is virtually absent in the area today, poplar did not disappear from the environment, because it is intentionally grown and protected by people. The decline of poplar charcoal in the archaeological samples from the Kaftari period may be due to a change in its primary use, from fuel (or construction and fuel) to construction.

During Kaftari times, the major woods used for fuel were those characteristic of the modern oak forest. Today, the plain seems to be at the southeastern limit of oak forest, so it is likely that the oak in the archaeological samples grew at high elevations. Some juniper could have grown on the plain or within the oak forest. There are at least two explanations which can account for the increase in the percentage of oak charcoal at the expense of juniper at Malyan. First, juniper could have been a preferred fuel wood, and a component of the oak forest in Banesh times, especially if charcoal manufacture for smelting was a significant factor. After the depletion of juniper from the forest, it would have been replaced by the more competitive oak. Note, however, that both juniper and oak yield charcoal that is suitable for smelting. Second, juniper could have been primarily a tree of the pistachio-almond forest near the site. This would accord better with the modern distribution of juniper. Whether or not juniper was preferred, it seems to have been removed first. Since oak would not have grown near the site, the increase in oak charcoal suggests that an increase radius of procurement was necessary to provide fuel for the city. The increased use of dung as an alternative fuel also suggests a decrease in local supplies of wood for fuel.

The other major genera found archaeologically (almond, pistachio, and maple) all interdigitate with oak in this part of Iran, depending on local climatic conditions. As these genera are dominant in plant associations of the warmer and drier climes to the south and east, they may have been associated with juniper on the plain during Banesh times, and possibly continuing into Kaftari times. They may have spread at the expense of juniper during the Kaftari period, but, due to fuel cutting and agricultural expansion, were eventually restricted to the more distant mountains, where they are found today.

Finally, there are only minute amounts of wood that may have come from the center of the plain, *Prosopis* and caper. Both of these shrubs provide edible fruit but are quite different in their properties. *Prosopis* provides high-quality fuel (Isely 1982), but it has only been seen growing to a height of less than 20 cm. Caper is extremely thorny and painful to collect; it is difficult to account for the presence of its charcoal for any purpose. One would not expect wood from these shrubs, particularly caper, to have been used regularly as fuel, especially if there were a closer source of wood. In keeping with our knowledge of the settlement pattern, the few pieces of caper and *Prosopis* charcoal (as well as three and a half *Prosopis* seeds) which would have come from at least 30 km away were recovered from the later levels, when settlement on the plain does seem to be more oriented toward the southwest.

CONCLUSIONS

Results of the analysis of charcoal from Malyan suggest that the economic activities of the ancient population caused long-term vegetation changes. The non-marsh vegetation of the Kur River basin, hypothesized as a pistachio-almond-maple-juniper association was either deforested or reduced to a pistachio-almond-maple association. In addition, the radius for fuel procurement seems to have expanded along with the expanding demand of the growing urban population for fuel and land—to include the areas of oak forest in the mountains.

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NOTES

[1]The chronology is based on MASCA corrected (Ralph et. al. 1973) radiocarbon dates from Malyan.

[2]The population estimates may be revised upward as the analysis of the settlement data continues (W. M. Sumner, p.c.).

[3]Poplar (*Populus* sp.), indistinguishable from willow (*Salix* sp.) at these magnifications, was examined under higher magnification.

[4]Collection in possession of author; duplicate material at the University of Michigan Ethnobotanical Laboratory, Ann Arbor. It is unfortunate that few wood atlases are available which include the major trees of Iran. Greguss (1959) has some of the useful fruit and timber trees, and Hajazi (1965) has poorly reproduced photographs of woods from trees of the northern Zagros and Caspian forests. For those who are interested in the documentation of the modern wood specimens, descriptions and SEM photographs (transverse, 50x; tangential, 100x; radial, 100x and 300x) are available (Miller 1982).

[5]Hand-picked samples come from 35 Banesh and 40 Kaftari deposits. Banesh: 5 hearths, 1 pits, 21 rooms, 8 matrix. Kaftari: 10 pits, 16 rooms, 14 matrix.

NOTES (continued)

[6]Flotation samples come from 99 Banesh and 89 Kaftari deposits. Banesh: 18 hearths, 16 pits, 49 rooms, 3 burials, 6 jars, 7 matrix. Kaftari: 4 hearths, 28 pits, 32 rooms, 3 jars, 22 matrix.

[7]The completed analysis of the materials appears in Miller (1982) and includes a consideration of charcoal weight, density per volume of soil, and differential distribution of charcoal within the site. The complete data set is presented sample by sample for those who wish to use it.

[8]The excavation areas were chosen to answer certain archaeological questions about stratigraphy, the extent of settlement, and the range of variability on the site (Sumner 1980).

[9]*Quercus aegilops* L. ssp. *persica* (J. & S.) Blakelock.

[10]*Juniperus polycarpos* C. Koch = *J. excelsa* M. B. (Riedl 1968).

[11]Cf. Day (1953): "So important was firewood in Indian economy that the Naragansetts of Rhode Island thought the English had come to America because they lacked firewood at home," and they even lived in the tempe^r^atre forest zone!

[12]*Pistacia* cf. *eurycarpa* Yalt.

[13]*Prunus* cf. *scoparia* (Spach) C. K. Schneider = *Amygdalus scoparia* Spach; *Prunus* cf. *kotschyi* (Boiss. & Hohen.) Nab. = *A. kotschyi* Boiss. & Hohen.