CHAPTER 6

Vegetation Proxy Data and Climate Reconstruction

Examples from West Asia

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"Climate" may be defined as a thirty-year average of the weather. Its influence on culture and culture change is important, but difficult to assess. In West Asia, climate change has most recently been implicated in both agricultural origins (Hillman et al. 2001; Moore and Hillman 1992) and a late third-millennium collapse of civilization (Weiss 1997, 2000; Weiss et al. 1993). To evaluate its significance, we need dates precise enough to determine that the proposed climate shift happened before the proposed cultural change. We also need to determine whether the climate shift was big enough to affect established, traditional cultural responses to normal annual and interannual variability in a positive or negative way. A variety of complementary techniques have been applied to these questions: dendroclimatology, oxygen isotope analysis, sedimentology, palynology, and archaeobotany.

Tree rings give precise dates and they reflect growing conditions well. Unfortunately, those data for West Asia are not yet good enough to be useful (Kuniholm 1990). Paleoclimatologists have many other ways of reconstructing climate with proxy data from natural sediments, though each technique has its own uncertainties. Some lines of evidence are relatively direct indicators of climate, such as oxygen isotope ratios.[1] Other materials give more direct evidence of vegetation and plant cover, which, at a subcontinental scale, reflects climate. For example, rapid sediment deposition in the Persian Gulf is evidence of erosion upstream, which implies

bare ground in the Tigris-Euphrates watershed, which, in turn, has been used to infer a late third-millennium drought (Aqrawi 2001; Cullen et al. 2000; see also deMenocal 2001). Pollen gives evidence of vegetation, but has its own interpretive issues that limit its direct application to climate reconstruction. There are two obvious ways a pollen assemblage is not a direct representation of vegetation cover and an even less precise indicator of climate: pollen production and dispersal vary among plant taxa. For example, wind-pollinated plants produce far more pollen than insect-pollinated plants, and some pollen is local to a lake, some washes in, and some blows in from a long distance (see Bottema 1997). Plant macroremains from archaeological sites complement pollen, because archaeological visibility is based on use and usefulness to people rather than on pollen production (Miller 1997).

On a broad scale of time and space, vegetation data are very good proxies for tracking climate changes. For example, pollen cores from Lake Zeribar in the central Zagros register the retreat of cold, dry steppe and the spread of pistachio and oak forest at the end of the last Glacial period (Van Zeist and Bottema 1977). But if you want to limit the time frame, specify a location, or consider individual species, ambiguities are unavoidable. One problem is that different plant taxa respond differently to climate shifts, sometimes depending on what is (or is not) already growing in a place.[2] In the Zagros, both pistachio and oak increase at the end of the Pleistocene, but at different rates. At what point does the pistachio-oak forest become the oak-pistachio forest? Whole categories of plants may respond at different rates to changed conditions. For example, grasses established themselves before trees. Archaeologists should remember that climate change does not alter whole ecosystems, but rather affects individual organisms and groups of organisms at different rates.

When one turns from geological to archaeological time, it becomes much more difficult to correlate the dates of the different lines of evidence. And the time scale at which climate variability occurs is important, because people respond to actual conditions in particular places, not theoretical or average ones. Even when some variables cannot be measured, analyses should not gloss over considerations such as the time scale and synchronicity of the presumed climate shift, its spatial scale, and its magnitude. Time, space, and degree all have bearing on the magnitude of presumed cultural shift. And reasonable archaeologists can and do disagree about what constitutes a major break in the archaeological record.

The Younger Dryas

Sometimes, botanical data are good proxies for climate. The Younger Dryas is characterized as a cold, dry period that occurred after the climate had begun to ameliorate at the end of the last Glacial period. In West Asia, its impact on vegetation has been documented from the Mediterranean to the Zagros (Baruch and Bottema 1999; Stevens et al. 2001), and appears to have occurred before human activities had significantly altered the vegetation (figure 6.1). Lemcke and Sturm (1997) see the Younger Dryas in the ∂18O/16O ratios of the Lake Van cores. At Lake Zeribar, in the central Zagros of Iran, Stevens, Wright, and Ito (2001, 753) see the Younger Dryas in enriched ∂18O comparable to Lake Van. It may not have taken long for climate to become a dependent variable, however: a paleoclimatologist, William F. Ruddiman (2003), has identified a nonnatural increase in the greenhouse gases methane and carbon dioxide as early as 7000 (cal) BC that he attributes to rice agriculture in South Asia[3] (for more in-depth discussion of rice cultivation in Asia, see chapters by Madella and by Sato in this volume). Neil Roberts (2002) proposes that human activities—burning in this case—could have slowed forest advance in West Asia at the end of the Pleistocene. And Yasuda, Kitagawa, and Nakagawa (2000) have identified forest clearance associated with early agriculture in a pollen core from Lake Ghab, Syria. So the question of causality seems to be getting more complicated.

Third-Millennium Drought

Ancient texts suggest that nomad invasions precipitated the collapse of the Akkadian empire of Mesopotamia at the end of the third millennium BC. Deteriorating climate across Eurasia could explain why nomads were moving and how agriculturally weakened polities of the rainfall agriculture zone might have been the first to succumb. Changing stream flows and weather patterns affecting the irrigation agriculture areas would have disrupted the economy and society of lower Mesopotamia (Weiss 1997, 2000; Weiss et al. 1993). In the past decade, evidence has been emerging that might support the argument that parts of West Asia experienced a sudden, severe, widespread drought at about 2200 BC (calendar years). On the other hand, based on critical reading of the epigraphic evidence and archaeological arguments for the ceramic dating, Richard Zettler (2003) questions the severity of the proposed collapse. Drought or not, he concludes that the evidence does not support arguments for radical settlement shifts in northern Mesopotamia at that time.

The scientific evidence for drought at 2200 BC includes isotope studies at Lake Van (Lemcke and Sturm 1997) and arguably at Lake Zeribar, where Stevens, Wright, and Ito (2001) see a Late Holocene dry spell between 4000 and 3500 BP (approximately 3350–3150 cal BC to 1775–1875 cal BC; extrapolated from Stuiver et al. 1998); they comment that

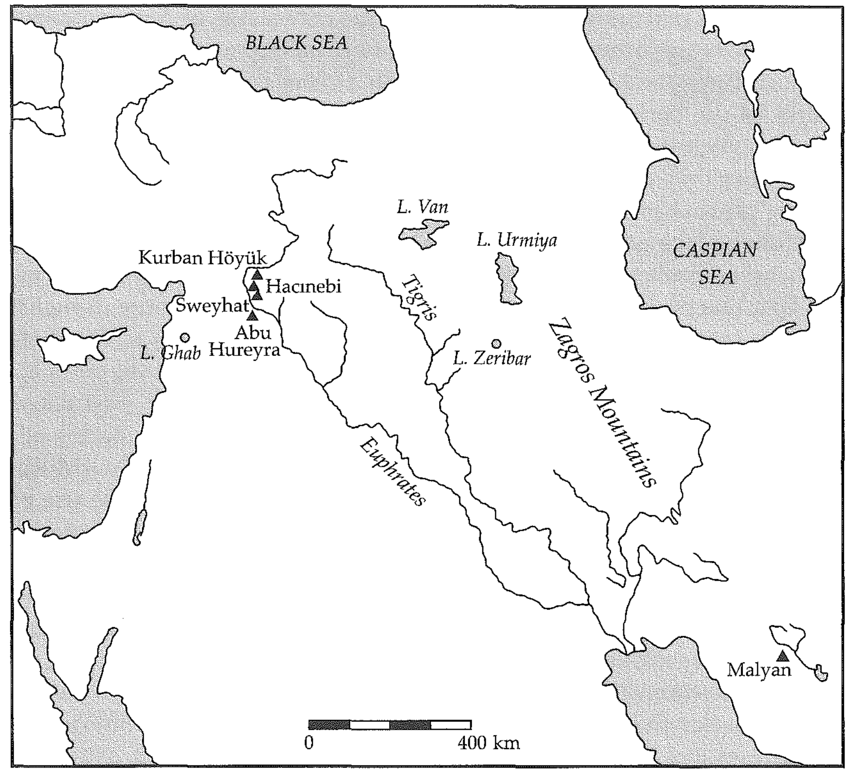

FIGURE 6.1. Map showing the location of places mentioned in the text.

the "timing of this event appears to be coeval with the abandonment of farming sites in northern Mesopotamia during the Akkadian empire . . . although the large errors associated with our dates preclude a more robust correlation" (753). As mentioned above, increased sedimentation rates in the Persian Gulf date to this time (see also Kay and Johnson 1981 for synthetic discussion of Tigris-Euphrates streamflow). For the eastern Mediterranean, Rosen (1995) discusses the social implications of drought in the region with an innovative study of phytoliths. Yet, Bottema and Cappers (2000) see no pollen evidence for a third-millennium drought in the Lake Ghab core from northern Syria, and Bottema (1997) reaches a similar conclusion in his discussion of the Zeribar core. Rather, they see vegetation responding to human activities. Archaeobotanical evidence could point to third-millennium deforestation in some places, if you accept the premise that the proportion of charred seeds to charred wood is an indicator of dung fuel to wood fuel (Miller 1997). But drought is not the only conceivable cause of deforestation.

The third millennium is the time of first city-states of Mesopotamia. Irrigation technology, attendant population increase, and the development of fuel-intensive technologies such as bronze metallurgy are hallmarks of the period. Ax-wielding people can cause deforestation; so, if people switch from wood fuel to dung, is it because the climate dried up or because they cut down the trees?

The climate of the rainfall agriculture zone of northern Mesopotamia follows "the general Mediterranean pattern, characterised by cool to mild, rainy winters and hot and dry summers" (Zohary 1973, 27). A farmer's first line of defense against drought would be to grow more drought-tolerant crops, like barley. As you go from the wetter north to the drier south, barley does become more important relative to wheat (figure 6.2).

The Kurban Höyük sequence spans the period of the postulated drought of 2200 BC. If anything, an increased emphasis on barley occurred in the mid-third millennium, before the great drought (Miller 1997).[4] Deforestation as indicated by an inferred increase in the use of dung fuel is also dated to the mid-third millennium (Miller 1997, figure 7.3). It is perhaps no accident that the mid-third millennium is also the time of maximum population and settlement in the region (Miller 1997, 129; Wilkinson 1990). In a nutshell, there are indeed widespread changes in vegetation, but they are not uniform in their causes or effects.

Both the timing and the severity of the proposed drought are also at issue (Charles and Bogaard 2001, 325–26; Miller 2004). Two alternative hypotheses may explain apparent vegetation changes at about 2200 BC. First: over a vast expanse of the Eurasian continent there was a period of drought severe enough to cause serious deforestation, loss of even herbaceous plant cover, and consequent erosion; the ramifications for people were movement of nomads to greener pastures and subsequent stress on urban civilization in Mesopotamia. Second: most of the changes in the environmental record can be explained by human activity. The truth probably lies somewhere in between. That is, there is some evidence for drought, but the resilience of local people and economies in northern Mesopotamia seems to have allowed them to adjust, at least at a scale that is archaeologically visible.

Malyan

The site of Malyan in the southern Zagros of Iran provides a comparison with northern Mesopotamia. At about 3000 BC Malyan was the largest site in the Kur River basin. The settlement covered about 45 ha, and survey estimates for the aggregate area of rural settlement in the valley are about 30 ha. Archaeological survey and excavation at Malyan show there

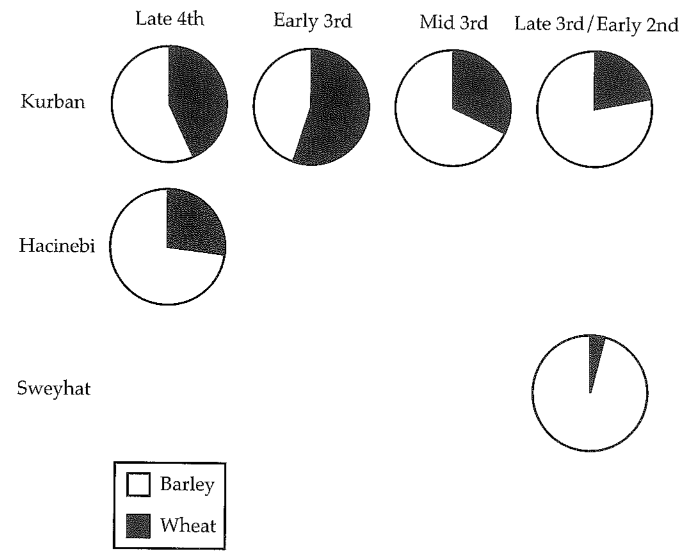

FIGURE 6.2. Proportions of wheat and barley in the rainfall agriculture zone of the Euphrates River. The total weight of identified cereal grains is low. Kurban Höyük: late 4th millennium—2.81 g; early 3rd—9.11 g; mid-3rd—6.03 g; late 3rd/early 2nd—0.18 g. Hacinebi: late 4th—2.77 g. Sweyhat: late 3rd/early 2nd—4.56 g. (Source: Miller 1997, fig. 7.6.)

was almost no settlement for about 400 years in the middle of the third millennium BC (Sumner 1989; 2003, 54–55). Then, at about 2200 BC, Malyan once again became the center of a much larger and more complex settlement system—with an estimated area of 130 ha for the city and 278 ha for the valley as a whole (Sumner 1990). The ceramics of the earlier and later periods are quite different from each other, but one small excavation unit has produced a few sherds consistent with a transitional assemblage that suggests there was some cultural continuity (Miller and Sumner 2004). Beyond the Kur River basin, a paucity of settlement sites in the middle of the third millennium BC extends across the southern and central Zagros generally. Archaeologically speaking, does absence of settlement mean absence of people here?

The presence of nomadic pastoralists is the most reasonable explanation for this pattern (Miroschedji 2003, 24). From historic times to the present, Qashqa'i nomads have passed through the valley on their way to summer pasture, though we do not know for certain how far back that pattern of transhumance goes. For the third millennium, the closest site of any significance is at Jalyan, about 200 km to the south of Malyan. It is one of few archaeological sites thought to have been left by nomads, but it was a cemetery, not a settlement (Miroschedji 1974). Thus, independent archaeological evidence points to a nomadic population occupying the region continuously during the third millennium. Archaeobotanical evidence can be used to address specific questions about landscape and climate as well as about the impact of the nomadic population on the vegetation in the region.

The climate regime of the Zagros Mountains of western Iran is similar in some respects to that of the mountains of the eastern Mediterranean, with a pattern of wet winters and dry summers, but it is more continental, with cooler winters (Zohary 1973, 37). As rainfall decreases (toward the south and at lower elevations), pistachio-almond forest replaces oak. The Kur River basin straddles the border between the oak forest to the north and west and the pistachio-almond forest to the south and east (figure 6.3; see Zohary 1973, map). The valley bottom, on which Malyan is located, is now largely cultivated. Remnant pistachio and almond grow on the edges at the north end of the valley. Two of the other woods, common in the archaeological samples but not in the present forest, are maple and juniper. Maple is a component of both forests. Juniper today occurs rarely in scattered locations in this part of Iran; it is also absent or rare in the pollen record of the central Zagros. The most likely species, *Juniperus excelsa* Bieb. (=*J. polycarpos* C. Koch), is probably a cold- and drought-resistant type (Sabeti 1966; Zohary 1973, 351) that is an "excellent fuel and said to yield good charcoal" (Townsend and Guest 1966, 93).

The distribution across time in the major forest wood types shows some patterning (table 6.1, figure 6.4). The data come from counts of about 1,500 identified pieces of the handpicked charcoal (Miller 1982). In general, the counts and weights of handpicked and flotation charcoal are correlated (Miller 1985). A plausible assumption essential to this analysis is that the main cost of wood fuel is transport, so all things being equal, trees growing closer to a settlement will be cut first for fuel.

A significant reduction in the proportion of juniper appears to have occurred between the Banesh and Kaftari settlement periods. The 400-year gap would have been long enough for any climate change to have an archaeologically observable effect on the vegetation. So, could the decline of drought-resistant juniper signify severe drought at that time? Judging from the increase in oak, which is a tree of the moister northern woodlands, probably not. Conversely, could the decline in juniper indicate a mid-third-millennium moisture increase so great that juniper could no longer compete with more moisture-loving plants? This, too, seems unlikely, because poplar/willow and hackberry, which grow in fairly moist places along streams in the Kur River basin, also decline in the later

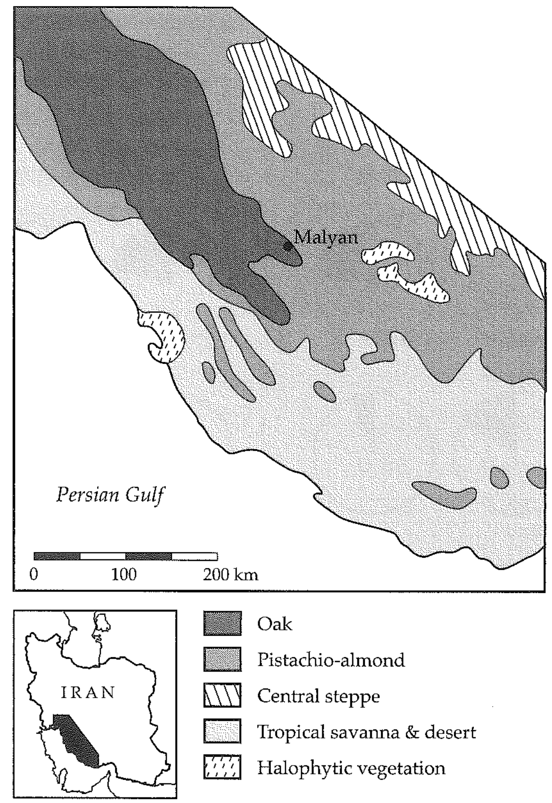

FIGURE 6.3. Vegetation zones of southwestern Iran. (Source: Zohary 1973.)

levels (table 6.1). In any case, no one has proposed climate change for the mid-third millennium.

If climate was not a factor in the juniper decline, perhaps people had something to do with it. Although absence of settlement characterizes the mid-third millennium in the region, archaeological traces of nomadic pastoralists are notoriously hard to find. Maybe what we are seeing here is the otherwise invisible impact of nomads on the landscape: juniper is slow growing, is unlikely to grow back from a stump, and is a good fuel; its fruits and shoots might be eaten by sheep and goats,[5] and it might have been preferentially cut. In contrast, the nut-producing trees (almond, pistachio, and oak) might have been protected by the herders, and in any case can grow from stumps if nibbled. But juniper, already under stress from fuel cutting, could not recover from grazing pressure.

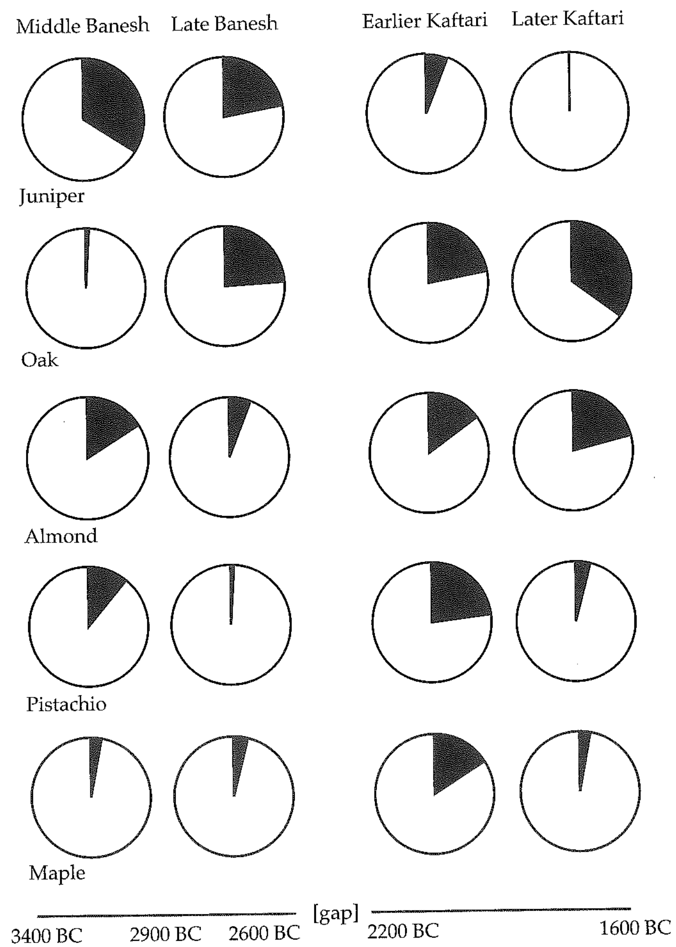

FIGURE 6.4. Major forest woods at Malyan.

Assuming the present-day woodland vegetation is an indicator of climatically established past distribution, the increase in oak during the Banesh period and contemporaneous decline of juniper, pistachio, and almond would represent an expanding radius of fuel procurement. Today, the boundary between the pistachio-almond and oak vegetation lies just at the northern edge of the valley. One could make the argument that, initially, juniper (along with pistachio and almond) grew on the valley bottom, but even the small urban system of the Banesh period put some pressure on wood resources.

TABLE 6.1. Identified charcoal from Malyan based on samples that can be assigned to phase

	Middle Banesh	Late Banesh	Earlier Kaftari	Later Kaftari
Number identified (1,491)	490	140	731	130
Number of samples (62)	24	9	19	10
Juniper (*Juniperus* sp.)	0.34	0.22	0.06	0
Oak (*Quercus* sp.)	0.01	0.24	0.22	0.35
Maple (*Acer* sp.)	0.03	0.04	0.16	0.03
Almond (*Prunus* sp.)	0.16	0.06	0.15	0.21
Pistachio (*Pistacia* sp.)	0.11	0.01	0.23	0.04
Poplar/willow (*Populus/Salix*)	0.27	0.06	0.01	0.02
Hackberry (cf. *Celtis* sp.)	0.05	0.33	0.05	0.04
Other	0.03	0.04	0.10	0.31

Source: Miller 1982.

Note: Banesh samples assigned to stratigraphically and ceramically defined subphases; temporal assignment of Kaftari samples based on relative stratigraphy (William M. Sumner, pers. comm., 5 March 2004). Measurements in the main body of the table are percentages expressed over 1 rather than 100.

The proportions of almond do not show much change over the long term; one imagines it to be a protected tree, or perhaps it can withstand trimming and browsing. The edible nuts have an intense almond flavor with a strongly bitter aftertaste. I have seen wild almond (probably *Prunus scoparia* [Spach] C.K. Schneid.) grow from unnoticeable to large shrubs within twenty-five years (between 1978 and 2003), just north of Shiraz; from the hillslopes down to the highway, there used to be a completely degraded landscape with no plant growing taller than about a half meter; wild almond is now thriving there, probably because roadside development has made it inaccessible to grazers.

The pistachio distribution is interesting, too. It looks like both the earlier and later urban systems stressed the trees, but that pistachio was able to regenerate during the 400-year gap in settlement.

I have no neat explanation for the apparent changes in the amounts of maple; perhaps it replaced juniper during the 400-year settlement gap and, having no use as food, was cleared during the more populous Kaftari period. As is true for all of these examples, one point is well worth remembering: whether influenced by climate or human activities, each species within an ecosystem has its own trajectory.

Conclusions

The interactions of people, plants, and climate are complex. Even though vegetation responds to changing climate conditions, individuals and taxa do so at different rates. Vegetation responds to human manipulation of the landscape, too; and one should also bear in mind that vegetation and human activities can influence climate. Several specific conclusions that apply to climate and landscape in the ancient Near East can be drawn from this assessment of vegetation data as a proxy for climate:

First, from an archaeological perspective, the most important result of the Malyan study is that the decline in juniper that seems to have occurred during the 400-year settlement gap in the Kur River basin was not caused by climate change. Rather, this evidence supports the idea that pastoral nomads were a significant presence in the mid-third-millennium Zagros. In particular, archaeobotanical data suggest that those populations had a major impact on the landscape.

More broadly, climate has short- and long-term fluctuations to which people must adapt. Farmers in West Asia have always dealt with uncertainty and year-to-year variability in the weather. In both the short and the long term, crop choice, irrigation, and mobility are how they deal with it. By the third millennium BC, people in the Near East were clearly having an impact on the vegetation.

Finally, from a paleoclimatological perspective, the comparison of the cultural sequence in southern Iran and northern Mesopotamia should raise at least some questions about the geographical extent of the great drought of 2200 BC. Even if there were some drying trend in northern Mesopotamia at that time, archaeologists and paleoclimatologists should probably maintain a healthy skepticism of each other's methods and explanatory schemes.

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Notes

1. The ^{18}O isotope is heavier than the more common oxygen, ^{16}O. Lighter isotopes evaporate first and fall in precipitation last, but condensation processes are affected by temperature. The ^{18}O-depleted sediments are associated with colder temperatures or winter rainfall (Stevens, Wright, and Ito 2001). Lemcke and Sturm (1997) use oxygen isotope ratios as proxies for humidity in their analysis of cores from Lake Van.

2. Lewin (1985) discusses a study by Kenneth Cole of packrat middens that suggested that the observed lag between climate change and vegetation is a result not just of the inherent immobility of plants but also of the fact that the existing vegetation may limit the spread of plants more suited in principle to the new climate—a phenomenon called "vegetational inertia." See also Von Holle, Delcourt, and Simberloff (2003).

3. He suggests an uncalibrated radiocarbon date of about 8000 BP (Ruddiman 2003, 273).

4. Charles and Bogaard (2001) reach a similar conclusion based on the continuing use of the relatively moisture-demanding free-threshing wheat throughout the sequence at Tell Brak, in northeastern Syria.

5. *Juniper* is probably not preferred if other plants are available. In Texas, where juniper control is a problem, a rancher reported that "not all goats will eat juniper . . . the first step in using goats as a cedar [i.e., *Juniperus*] control tool is to identify which animals in the herd have a taste for the juniper berry" (Briskin 2003). In a Texas rangeland study, Cory (1927) found that "the fruit of both species [*J. monosperma* and *J. utahensis*] is palatable to goats." In England, sheep eat the seedlings in winter, not summer (Fitter and Jennings 1975). The Kur River Basin is on the Qashqa'i migration route, closer to the summer pastures (Beck 1991, map 3), but William M. Sumner has seen winter camps about 14 km northeast of Malyan (W. M. Sumner, pers. comm., 18 March 2004). If the animals eat the fruit, that could limit the ability of juniper to reproduce. It is likely that the cones (juniper "berries") would have been ripe during the spring migration to the summer pastures.

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