Regional Climate, Local Paleoenvironment, and Early Cultivation at Pre-Pottery Neolithic A el-Hemmeh, Jordan

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Abstract

For several decades, researchers have sought to define a relationship between environmental change and initial human experimentation with food production in southwest Asia. Many models emphasize the role of the Younger Dryas, a Northern Hemisphere-wide cold and arid climatic period that lasted from approximately 12,900 cal B.P.—11,700 cal B.P., in providing the impetus for first human experimentation with cultivation in southwest Asia. In general, these models focus on macrolevel environmental patterns, discounting variability in the effects of the Younger Dryas at local scales. In so doing, these models elide the question of whether or not regional paleoenvironmental data provide spatial and chronological resolution adequate for the purposes of establishing and examining relationships between environmental change, resource stress, and nascent cultivation in southwest Asia. Here, we consider this problem of scale in the southern Levant through geoarchaeological analyses of stratified in-stream wetland deposits dating to the Late Pleistocene and Early Holocene, including the crucial Younger Dryas period, in the Wadi el-Hasa, Jordan. The evidence of local landscape morphology and conditions that this provides, in close proximity to the Pre-Pottery Neolithic A settlement of el-Hemmeh (where pre-domestication cultivation was practiced alongside gathering of wild food plants), provides an opportunity to closely examine the environmental contexts of early experimentation with agriculture in the southern Levant, particularly their change over time and the relationship of local to regional evidence.

Introduction

The transition from hunting and gathering to food production not only changed how people acquired food, but also revolutionized the cultural practices and social structures of human communities. Because this transition was so fundamental, much debate revolves around precisely what contributed to the emergence of food production over 10,000 years ago in southwest Asia. Demographic thresholds, resource stress, cognitive changes, and competitive feasting are frequently suggested as influential in the origins of agriculture (Cauvin 2000; Watkins 2005; Bocquet-Appel and Bar-Yosef 2008; Hayden 2009; 2011), but these factors are generally overshadowed by the explanatory role attributed to environmental change (e.g., Bar-Yosef 2011). From the early days of Pumpelly's (1908) "oasis theory," which posited that increasing aridity compelled hunter-gatherers, plants, and animals to concentrate in well-watered oases, stimulating plant and animal domestication, to more recent archaeological models invoking "environmental deterioration" as a prompt for the development of wholly new subsistence practices, environmental change has long been viewed as a potential driver of human subsistence innovations.

The idea that the Younger Dryas, generally understood as a period of intensely cold and arid conditions throughout the Northern Hemisphere that began abruptly at approximately 12,900 cal B.P. and lasted until approximately 11,700 cal B.P., was the primary forcing mechanism that prompted the "origins of agriculture" in southwest Asia still holds considerable sway (e.g., Moore and Hillman 1992; Wright 1993; Bar-Yosef 1998; 2001a; 2001b; 2009, 2011; Hillman et al. 2001; Mithen 2006; Cordova 2008). This model specifies that, under the cold and dry conditions of the Younger Dryas, the productivity of wild cereal stands declined and their distribution contracted significantly (Bar-Yosef 2001b); variants also suggest that the (hypothesized) natural decline in cereal availability may have been further exacerbated by resource overexploitation caused by hunter-gatherer groups (Bar-Yosef 1998). In response to this climate-induced resource stress, the model suggests, hunter-gatherers increased their mobility in some cases and, in others, developed a new subsistence strategy—plant cultivation—to compensate for the decreased availability of wild cereals (Bar-Yosef 2001a; Grosman and Belfer-Cohen 2002).

At the same time, while the idea that the Younger Dryas had a profound and irreversible impact on the hunter-gatherer populations remains pervasive, the role of this climatic perturbation as the impetus for cereal cultivation by foragers has been recently challenged. Buoyed by the recent increase in the number of well-contextualized archaeobotanical datasets from the Early Holocene, there has been a proliferation of new models detailing the complexity and regional variability in nascent plant cultivation strategies in the Near East (e.g., Willcox 1999; 2005; Savard et al. 2006; Allaby et al. 2008; Gustafson et al. 2008; Abbo et al. 2010; Fuller et al. 2011; Rosen and Rivera-Collazo 2012). These newer models focus on local developmental trajectories that minimize the particular role of the Younger Dryas in driving changes in human subsistence. For instance, addressing the potential "push" of climatic deterioration, Willcox (2005) has suggested that the effects of the Younger Dryas on the shift to cultivation have been overemphasized, arguing that it would have had only a minor impact on the availability and distribution of wild cereals. Complementary arguments suggest that Late Pleistocene hunter-gatherer subsistence strategies were highly
adaptive, so much so that any changes in plant resource distribution that may have resulted from marked climate change, such as that hypothesized for the Younger Dryas, would have entailed shifts in the focus of resource exploitation rather than the development of entirely novel subsistence strategies (Rosen 2012; Rosen and Rivera-Collazo 2012). The chronological correlation between environmental change and cereal cultivation has also been challenged by critics who suggest that archaeoecological chronologies are at best too uncertain and inconsiderate to suggest causality, and may in fact contradict models relating the Younger Dryas to emergent cultivation (e.g., Willcox 2005; Blockley and Pinhasi 2011; Maher et al. 2011). Moreover, alternative relationships have been posited based on slightly different chronologies, linking the emergence of cultivation to the climatic amelioration following the Younger Dryas rather than the deterioration putatively associated with it (e.g., Robinson et al. 2006; Stein et al. 2010).

In sum, there are a number of macroevolutionary models that link climate change to emergent agriculture, looking either to the supposed stress of the Younger Dryas or the supposed new possibilities afforded by the climatic changes that constituted the end of the Younger Dryas and the beginnings of the Holocene. The profusion of different suggested correlations is testament to chronological uncertainties, which combine with the small sample of known sites to create a situation in which even small shifts in the evidence can suggest or enable major reworkings of climate-culture hypotheses. The ubiquity and variety of these kinds of arguments is evidence that they are hypotheses at best, rather than empirically driven explanations, while the persistence of climate-culture hypotheses regardless of how specific or rearranged is evidence that the models are underdetermined. In the absence of a unitary and mechanistic relationship between environment and human behavior (i.e., climate x necessarily produces cultural response y), arguments about the interplay of culture and climate at the dawn of agriculture are limited in large part by the spatial scale and chronological resolution of the paleoclimatic and archaeological data mobilized to construct them. As a result, selection between these competing hypotheses cannot be made by simply adding more coarse (temporally, spatially, or both) data. Rather, what we need to understand are local conditions, ideally over spans of time relevant to human decision-making.

Both deterioration and amelioration models share an understanding of the effects of the Younger Dryas that is dependent on paleoenvironmental data derived from regional records, namely, that the cooler and dryer period observable at a hemispheric scale resulted in declines in resource abundance in the foraging catchments of Levantine communities. Disagreements are primarily over whether these effects were of magnitude sufficient to compromise subsistence systems, over what precisely that magnitude might be, and over the chronological relationship of the Younger Dryas to early experiments with cultivation—but both the deterioration model and most of its critics embrace the potential significance of the regional-local relationship. In other words, generalizations about climate that are regional in scale (e.g., a hemispheric cooling and drying) are matched to mechanisms of explanation (e.g., foraging returns and behavioral responses to their variability) that are local in scale. One question left largely unaddressed is the character of the regional-local link; i.e., how were such regional climatic shifts manifest at the local scales at which they would have intersected the subsistence activities of inhabitants of southwest Asia?

Relating Models to Evidence: Scalar and Chronological Challenges

The questions that archaeologists have generally asked of paleoclimate data are implicitly local and short term: e.g., did the environments available to foragers change with regard to the key parameters of resource availability (water and animal and plant foods), and if so, how much, how fast, and for how long? Faced with spatially coarse-grained paleoclimate data with which to address these questions, it has been common to rely on an implicit downscaling that has tacitly posited a 1:1 relationship between regional averages and the local conditions under discussion.

Research investigating the specifics of any relationship between the Younger Dryas and emergent cultivation has been hampered by several factors: (1) the relative scarcity of archaeological sites that span the period of the development of the first food production strategies, (2) imprecise and/or underdetermined archaeological and paleoenvironmental chronologies, (3) ambiguity in the interpretation of palaeoclimatic proxies for the period (cf. Rambeau 2010:5230–5233), and (4) a scalar mismatch between the relatively coarse temporal and spatial resolution offered by paleoenvironmental records available for the southern Levant and the spatial coverage and temporal precision of archaeological evidence. We summarize these challenges before turning to the local evidence from the Wadi el-Hasa.

Archaeological Patterns and Evidence

Sites dating to the Terminal Pleistocene and Early Holocene are widely distributed throughout the southern Levant, in many different ecozones, with their only common factor being an association with water sources. Major landscape changes since the Early Holocene, including both natural and anthropogenic, have likely both destroyed some sites and masked others. In addition, archaeological research has been very uneven over the region. These two factors combine to make it difficult to know whether spatial patterning of sites from the Early Holocene or earlier can be considered reliable. Nevertheless, as no single occupation spanning the entire archaeological sequence from Early Natufian to Pre-Pottery Neolithic A (see Table 4.1 for a sketch of the relevant cultural chronology of the region) is known, it is necessary to examine temporal changes in aggregate. As individual sites
represent different seasons of occupation, scales, and functions, such a process doubtless conflates some spatial and environmental diversity.

Intensive exploitation of cereals was not a phenomenon restricted to the Neolithic. Wild wheat and barley were staple food grasses during the Upper Paleolithic (ca. 23,000 cal B.P.) at Ohalo II, and the exploitation of low-ranked (i.e., having high collection and processing costs and low yields) small-grained grasses alongside larger-grained wild cereals suggests use of a broad spectrum gathering strategy that may have been instigated by low-level resource stress (Weiss et al. 2004). Such “broad spectrum” strategies, in which foragers incorporate a more diverse array of foodstuffs into their diets as high-ranked resources become more difficult to acquire (see summary in Codding and Bird 2015), are frequently invoked as forerunners of pre-domestication cultivation.

Against a background of such Late Pleistocene subsistence activity, the Early Natufian (15,000 to 13,000 cal B.P.) is key to understanding hunter-gatherer subsistence strategies on the eve of the Younger Dryas. This period is defined by substantial settlements that are largely limited in their distribution to the Galilee region (but see Richter 2014 and Jones et al., this volume) and noted for sizeable circular stone architecture, human interments, and the use of large groundstone mortars and sickle blades. Wild barley, goat-faced grass, lentils, lupines, and peas, as well as other plants and fruits, were collected during the Early Natufian (Hopf and Bar-Yosef 1987; Edwards et al. 2002), but the general absence of carbonized plant remains at most Early Natufian sites has challenged attempts to document the precise plant exploitation strategies in use during this critical period. The Late Natufian, which roughly coincides with the onset of the Younger Dryas, is generally understood as a mobile adaptation to the hypothesized colder and drier environmental conditions of the Younger Dryas. Late Natufian settlements were considerably smaller and occupied at lower intensities relative to their Early Natufian counterparts, and contained dwellings much reduced in scale. Interestingly, there is little evidence for faunal resource stress during the Late Natufian. Low-ranked small game were heavily exploited during the Early Natufian, but capture of higher-ranked small game actually increased during the Late Natufian, suggestive of a relaxation of hunting pressure due to increased mobility of forager groups. At the same time, the continued exploitation of juvenile gazelle suggests large game prey availability and hunting pressure remained unchanged during the Younger Dryas (Munro 2003).

First experimentation with pre-domestication cultivation is one of the defining characteristics of the subsequent Pre-Pottery Neolithic A (PPNA) period, beginning ca. 12000 cal B.P. The presence of large-sized barley (*Hordeum* sp. grains typical for cultivars, barley rachis internodes exhibiting a smooth abscission scar associated with wild types, and “weeds of cultivation” at PPNA settlements strongly suggests that humans actively cultivated barley, although gathering wild plant foods was still intensively pursued (Edwards et al. 2004; Meadows 2005; White and Makarewicz 2012). The emergence of the PPNA is generally thought to coincide with the onset of Early Holocene pluvial conditions, but this chronological relationship is as much based on the hypothesized relationship as constitutive of it (cf. Blockley and Pinhasi 2011; Maher et al. 2011). Uncertainties in archaeological chronologies (stemming from the scarcity of deep and extensive excavations in Natufian and PPNA sites, the potential problems of old wood effects on 14C dating in arid environments, and the inherent measurement uncertainty in 14C dates) are thus small enough to suggest broad contemporaneity and relationships where it is not actually possible with available data to assess their reality (e.g., Grosman 2013), and large enough to leave questions of particular causal relationships frustratingly difficult to address (if not impossible to assess on purely chronological grounds). In the southern Levant, for instance, the PPNA may have commenced before the end of the Younger Dryas (Finlayson et al. 2011).

**Paleoclimatic Data in the Southern Levant**

While the broad parameters of climate in the Northern Hemisphere following the Last Glacial Maximum are well understood, the reconstruction
of specific local climates for particular regions remains complex. In the case of the southern Levant, the use of climate modeling (e.g., Robinson et al. 2006; Brayshaw et al. 2011) is clarifying the relationships between the North Atlantic forcing factors of the Younger Dryas and the climate of the Eastern Mediterranean, and improving understandings of changes in (for instance) seasonality and inter-annual variability, but remains at a regional resolution (e.g., 50 km cells in the higher-resolution of the two examples cited above). The paleoclimate data available for the southern Levant specifically, primarily derived from the carbon and oxygen isotopic composition of speleothems (e.g., Verheyden et al. 2008; Bar-Matthews and Ayalon 2011), pollen spectra in sapropels and lake cores (e.g., Rossignol-Strick 1999; Bottema 2002; Yasuda et al. 2000), and Dead Sea and Lake Lisan lake level records (e.g., Frumkin and Elitzur 2002; Stein et al. 2010; Torfstein et al. 2013) are interpreted as regional records representative of spatially averaged southern Levantine environmental conditions. It is important to note, however, that there is sufficient variability in these records to suggest that impact of the Younger Dryas was not uniform across the southern Levant (Rosen 2007; Makarewicz 2012), and these records do not capture local expressions of climatic variability in the southern Levant, which is characterized by pronounced topographic diversity and, consequently, high variability in precipitation and temperature even over short distances. For example, although it involves an area only approximately 700 km on its long axis, the modern southern Levantine precipitation regime is characterized overall by decreasing precipitation levels along west-east and north-south gradients (Ben-Gai et al. 1998), and varying also according to altitude. This spatial variability, in conjunction with seasonal and interannual variability in temperature and precipitation levels, would have produced a mosaic of environments and attendant plant and animal resources available at any given moment in time in the southern Levant. As a result, climatic or environmental archives from one locale may not be reliable indicators of even nearby past climates and environments. Such spatial diversity, with its potentially differential responses to regional climatic patterns, underlies the error that Maher and colleagues describe as, “a tendency to assume that interstadials were universally welcome and that cooler periods, especially the Younger Dryas, were universally cold, dry, resource-poor and unpleasant” (2011: 20).

Scale and Resolution

As discussed above, any model of cultural impacts of climatic and environmental change is faced with the challenges of articulating paleoenvironmental generalizations that are generally regional and local archaeological datasets that address landscape scales. As we use the terms here, landscapes are anthropocentric units of analysis defined by combinations of landforms, hydrology, and biotic communities, which determine the type and distribution of plant, animal, and water resources available for human exploitation, and whose extent is commonly a function of behavior (i.e., a human resource catchment, defined from the bottom-up; they are also freighted with various layers of meaning and social significance, and their extents and characteristics are dynamic). Regions, conversely, are top-down, defined without reference to inhabitants, and as such constitute mosaics of multiple landscapes. The Younger Dryas climate stress model is based on paleoenvironmental generalizations about the southern Levant, a geographical region rather than a landscape, and one characterized by sharp changes in topography, precipitation levels, and temperature that together contribute to wide variation in environmental conditions and biotic diversity over short distances (Rambeau 2010:52,32).

In addition, relating patterns of archaeological data to paleoclimatic records remains a chronological challenge as well as a spatial one. Both archaeological and paleoclimatic datasets incorporate significant uncertainty (if not outright error; cf. Meadows 2005). Chronological data underpin arguments linking the Younger Dryas and early agriculture, but even setting aside uncertainties in paleoclimatic chronologies, the archaeological chronological data tends not to stand up to rigorous reexamination. For example, although it is still commonly referenced (e.g., Goring-Morris and Belfer-Cohen 2011; Grosman 2013), the model of the Late Natufian as a specialized adaptive response to the Younger Dryas is not particularly well supported by the chronological data, and rigorous approaches to 14C data highlight the imprecision in dating and vulnerability to sampling effects that make establishing correlation difficult. Specifically, reanalysis of radiocarbon dates from archaeological sites across the region and the Soreq Cave speleothem record suggests that the emergence of highly mobile Late Natufian lifeways did not coincide with the Younger Dryas, as previously believed, but appeared earlier during the latest portion of the Bolling-Allerød and persisted into the Younger Dryas (Blockley and Pinhasi 2011), while Maher and colleagues (2011) point out that various correlations of particular cultural changes in southwest Asia with climatic periods remain speculative at best, given the limited precision and quality of the chronological data on which they are based. Moreover, the sample on which such hypotheses are based is inevitably small, and the observed patterns are very sensitive to the addition of new data: in the Negev and southern Jordan, for instance, both material cultural and chronological evidence argue for a continuous local development from the Harifian variant of the Late Natufian to the early PPNA (Finlayson et al. 2011; Finlayson and Makarewicz, in press), undermining the chronological gap proposed by Blockley and Pinhasi (2011:106) between the onset of the PPNA at the beginning of the Holocene and end of the Late Natufian.

The sensitivity of Blockley and Pinhasi’s conclusions to the addition of small amounts of additional data suggests that hypotheses of broad climate-culture relationships are driven more by general chronological correlation than by particular data about specific links. Even as Blockley and
Pinhasi dismiss the association of agriculture and the Younger Dryas, they suggest (2011:106) that the emergence of the PPNA largely coincides with the onset of pluvial conditions during the Early Holocene, writing that “the hypothesis to be tested is that climate change was the direct driver of the cultural innovation of the adoption of agriculture in the Southern Levant.” The replacement of the Younger Dryas with the onset of the Holocene as a proposed environmental driver of early agriculture reflects the fact that these proposed relationships are based more on conviction that some relationship should exist than on specific evidence arguing for such a relationship.

One way to address these problems of explanation and scale is through the identification and exploration of paleoenvironmental archives that can be directly linked to human activity. Ultimately such an approach can enable finer-grained modeling of subsistence possibilities and local experiences of climatic change. The investigation of such an archive in the Middle Wadi el-Hasa, we argue here, challenges some of the basic assumptions about how the Younger Dryas impacted the lives of those inhabitants of the Hasa who first began experimenting with agriculture. The local character of environmental archives is often taken as a limitation, as researchers struggle to define and advocate the regional relevance and implications of their data. It can also, we suggest, be an advantage, capturing vital aspects of landscape-scale change that are otherwise lost to regional averaging.

El-Hemmeh and the Middle Wadi el-Hasa

Here, we investigate the impact of the Younger Dryas at a local scale through an analysis of Late Pleistocene and Early Holocene paludal sediments located in the Middle Wadi el-Hasa, Jordan, and closely associated with the Early Neolithic (Pre-Pottery Neolithic A) site of el-Hemmeh (see Figures 4.1 and 4.2). The settlement of el-Hemmeh, currently the subject of ongoing archaeological investigation directed by one of us (Makarewicz), consists of a series of free-standing and semi-subterranean circular, oval, and irregular structures (see Figure 4.2, inset) constructed of stone and pisé (a mix of clay, water, and plant temper). To date, 15 structures have been identified; stratigraphic relationships indicate that not all structures were contemporaneous in construction or occupation. Occasionally, architectural features contained within structures were remodeled and renewed, and earlier structures were often partially dismantled to allow subsequent construction. Floors within individual structures were regularly renewed, with new surfaces installed after brief periods of abandonment, perhaps seasonal or annual. After falling into disuse, some structures were used as middens while others were allowed to simply collapse. These structures were also associated with extramural spaces, which served as both middens and informal activity areas (Makarewicz and Rose 2011).
Animal exploitation strategies pursued at el-Hemmeh appear to have been broadly similar to those at many other southern Levantine PPNA settlements (e.g., Tchernov 1994; Horwitz 2010). Preliminary zooarchaeological analyses of the el-Hemmeh faunal assemblage indicate that a broad spectrum of animal resources native to a variety of biomes were exploited including wild goat, gazelle, aurochs, boar, and waterfowl. Initial paleobotanical analyses indicate wild plants including lentils, vetch, and fig were commonly exploited. Predomestication cultivation was also practiced at el-Hemmeh, evidenced by the presence of large barley grains, predominance of smooth abscission scars on barley rachis internodes, and a high abundance of weedy taxa commonly associated with cultivation plots (White and Makarewicz 2012).

A single radiocarbon determination obtained from a hearth located inside one of the circular stone structures suggests that el-Hemmeh was occupied during the later portion of the PPNA (ca. 8800–8600 cal B.P.) (Makarewicz et al. 2006); additional dates are forthcoming. Lithic technosтратigraphical analyses and architectural style further support a late PPNA occupation. The absence of el-Khiam points and Hagdud truncations, two tool types commonly found at occupations dating to the early half of the PPNA, and the presence of stone-built, above-ground architecture at el-Hemmeh both parallel developments observed in the occupations of Wadi Faynan 16 (Trench 3) and Zaharat adh-Dhra 2 (ZAD 2) to form what appears to be a distinct Late PPNA phase (Finlayson and Makarewicz in press; Smith et al. in press).

El-Hemmeh is located on a dissected alluvial fan above the modern-day floodplain of the Wadi el-Hasa, which today is a deeply incised watercourse draining the central Jordanian Plateau into the Dead Sea Basin. Modern precipitation levels throughout the Hasa are quite low and on average reach only 80 mm per annum (Attevill and Humphreys 1996). As a result, water levels and flow within the drainage vary markedly interannually and are strongly dependent on winter precipitation levels. The steep slopes of the Wadi el-Hasa are largely devoid of vegetation (see Figure 4.2), but this may owe something to overgrazing as well as to generally and conditions; in the absence of exclosures protecting wild vegetation from grazing sheep and goats, it is difficult to evaluate the precise impact of either.

Small in-stream wetlands supporting abundant Phragmites growth are scattered throughout the wadi bottom where sufficient perennial surface or underground water is available. The modern hydrologic regime is significantly altered by diversion of surface water and groundwater mining for small-scale agriculture throughout the Hasa, and by the Tanmur Dam, completed in 2001. The former certainly contributes to the present aridity of even the floodplain above the dam, while dam release has created stable and perennial (if low) flows below the dam, promoting formation of in-stream wetlands. During the Late Pleistocene and Early Holocene, the topography of the Wadi el-Hasa was significantly different from the modern deeply incised drainage. A series of studies have addressed the question of exactly how different, and investigated the alluvial history of the drainage, confronting the basic problem of defining the number of aggradation and incision events and determining their chronology. Vita-Finzi and Copeland (Vita-Finzi 1966; Copeland and Vita-Finzi 1978), in pioneering work on Late Quaternary alluvial history in the Mediterranean generally, proposed a chronosequence of alluvial fills in the Wadi el-Hasa dated on the basis of associations of alluvial fills with chronologically diagnostic material culture. Their scheme (summarized in Copeland and Vita-Finzi 1978:23 and Fig. 1) suggested the existence of four post-LGM fills, with three of them dating to the Holocene, and guided subsequent archaeological interpretations of the drainage (e.g., Schuldenrein and Clark 2003; Hill 2006). Schuldenrein (2007) subsequently suggested some revision of the sequence, arguing that the latter two fills (III and IV, in Copeland and Vita-Finzi’s scheme) both dated to the last ~4,500 years (rather than the last 6,000), and that Fill IV had accumulated over the last 1,000 years (rather than the last 2,000). As we have argued elsewhere (Contreras et al. 2014:41), evidence from the Middle Hasa shows that this significantly oversimplifies Late Holocene alluvial history. In addition, our recent work, along with that of Jason Rech and Emily Winer (Winer 2010; Contreras et al. 2014), is demonstrating that the Late Pleistocene and Holocene history of incision and aggradation was significantly more complicated than previously reported (e.g., Vita-Finzi 1966; Copeland and Vita-Finzi 1978; Hill 2006; Schuldenrein 2007). With regard to the Terminal Pleistocene and Early Holocene, Schuldenrein (2007:564) points out that “there is no evidence of Early Holocene or even Middle Holocene landforms in the alluvial bottoms of the Wadi Hasa.” As we discuss below, the description of an alluvial landform dating to this period demonstrates that Holocene erosion has effaced evidence of an additional cycle of aggradation and incision, described below.

The date of the initial incision of Fill I (Unit C in Winer’s scheme; i.e., the massive alluvial fill deposited in the Pleistocene), and the subsequent aggradation/incision dynamics of the Middle Hasa, are vital to understanding not only the ages and locations of eroded deposits (which structure site survival and inferred settlement patterns) and the ages of surfaces accessible to archaeological survey and research (which structure survey results), but also the environments available to past inhabitants of the Hasa. The paludal deposits described below, in addition to providing an archive of the local environment during and immediately following the Younger Dryas, provide critical evidence about the post-Unit C (Later Pleistocene) cut-and-fill activity of the Hasa.

Paludal Deposits in the Middle Wadi el-Hasa

A geoarchaeological survey beginning in 2010 identified an in-stream wetland deposit in the Wadi el-Hasa, located only 160 m SE of el-Hemmeh (see Figure 4.1, inset). Three 1 × 2 m exposures were excavated on what was determined to be an eroded fragment of a Late Pleistocene/Early Holocene alluvial terrace; the uppermost surface of these is ~10 m above the current watercourse, which is today incised approximately 6 m into limestone (the Late Cretaceous Karak Limestone formation, according to Tarawneh 1988).
bedrock approximately 60 m to the south. These descend down the eastern (eroded) flank of the deposit, overlapping to capture a combined ~5.5 m of stratigraphy (Figure 4.3). In spite of the repeated aggradation and incision within the Wadi el-Hasa, which has effaced much of the Late Pleistocene and Early Holocene stratigraphic record (see above), this preserved alluvial terrace fragment provides a stratigraphic record of the Hasa floodplain.

The alluvial sands and gravels characteristic of most of the modern, episodically inundated, floodplain are absent from these deposits, which instead consist of paludal material: greyish silts incorporated into organic-rich black mat deposits (cf. Quade et al. 1998; Pigati et al. 2014), tufa deposits accreted around organic matter (e.g., Phragmites), and marls, interspersed in strata ranging from sub-cm to ~20 cm thickness (see Figure 4.3). Throughout ~5.5 m of stratigraphy exposed in the three excavations, spanning an estimated 2,000-4,000 years, these strata are uninterrupted by alluvial, colluvial, or aeolian sediments, with the exception of one small colluvial wedge intruding into the easternmost, upslope exposure.

In addition to the black mats—stratigraphic indicators of organic matter deposited in anoxic conditions—macroscopic evidence of Phragmites in tufa casts and carbonized vegetation suggests that these deposits formed under wet and marshy conditions. Ostracod analyses of a selection of strata confirm that the depositional environment was a shallow wetland (see Contreras et al. in prep). A modern analogue of such depositional conditions can be found in stands of Phragmites situated in perennially wet and often subaqueous organic-rich sediments, located approximately 3 km downstream from the sample site.

The middle portion of this deposit is now securely dated to 13000-12000 cal B.P. (based on four 14C dates on carbonized organic matter from black mats or sealed in tufa accretions in intact deposits; see Figure 4.3). The extrapolated age-depth curve (see Figure 4.3 and Contreras et al. in preparation) suggests that deposition began ~14000 cal B.P. and continued until ~10500 cal B.P., suggesting the presence of in-stream wetlands before, during, and after the Younger Dryas—and likely overlapping the period of PPNA occupation at el-Hemmeh (as noted above, a series of 14C dates suggest that the site was occupied from ~10800 cal B.P. until ~10600 cal B.P.). The recovery of four lithic artifacts from strata estimated to date between 13000 and 11000 cal B.P. (see Figure 4.3) provides further evidence of the interaction of the Hasa's human inhabitants with this wetland environment, and the presence of waterfowl in the faunal assemblage from el-Hemmeh indicates exploitation of this environment as well.

These paludal deposits also provide a dated post-LGM sequence of aggradation in the middle Hasa, the key ingredient to describing a significantly more complex sequence of aggradation and incision than those previously proposed. This added complexity has important implications for understanding the environments and resources available to Terminal Pleistocene and Early Holocene inhabitants of the Middle Hasa and changes therein.
The consensus view (Copeland and Vita-Finzi 1978; Schuldenrein 2007; Winer 2010) is that Fill I/Unit C is the product of Pleistocene aggradation, while differences coalesce over the timing of the post-Unit C incision, and the number, magnitude, and timing of subsequent cut-and-fill cycles. While the broad parameters of the prior scenarios remain intact, three archaeologically significant revisions are salient: (1) the massive Late Pleistocene terrace that is preserved in select areas (Fill I according to Copeland and Vita-Finzi, and later Schuldenrein, and Unit C in Winer's scheme) had finished aggrading by something closer to 27 kya than 15 kya (Winer 2010:21), (2) Terminal Pleistocene and Early Holocene dynamics (post-Unit C) included incision to near-modern levels, approximately 10 m of aggradation, and renewed incision to near-modern levels, all by the Early Holocene, and (3) the generalized chronosequence masks considerable complexity in the later Holocene (see Contreras et al. 2014:41).

The most recent chronological information (Winer 2010:18–22), coupled with the dates described here (and in more detail in Contreras et al. in preparation), suggest aggradation (forming Unit C) until ~27 kya, followed by incision to near-modern levels before ~15 kya, and then aggradation of the paludal deposits described here, characterized by ~6–10 m of accumulation until incision began at an estimated 10500 B.P. (the least well-constrained of these dates). This incision beginning ~10500 B.P. may be contemporary with Fill II/Unit D or may predate it; all of the alluvial activity encompassed by Fills III and IV postdates this incision. This is reasonably compatible with Winer's (2010:22) implication that Holocene aggradation (of what she terms Unit E) began ~9200 B.P. (particularly as that date, on bulk sediment, is a terminus post quem).

Most important for archaeological interpretation of el-Hemmeh and the early Neolithic, this datum signaling an aggrading alluvial plain during the Terminal Pleistocene/Early Holocene in the Middle Hasa also testifies to the height of the valley floor when Hemmeh was occupied. Situated approximately 10 m above the modern valley floor, these paludal deposits imply a much broader watered floodplain during the Younger Dryas and Early Holocene relative to that seen today. They demonstrate that the modern landscape (see Figure 4.2), even discounting the reservoir, is actually a very poor guide to the Late Pleistocene/Early Holocene landscape: its aridity is the product in part of modern land-use practices, and its morphology has been significantly altered by Holocene incision. Using the elevation (relative to the modern watercourse) of the deposits described here as an indicator of the elevation of the Late Pleistocene/Early Holocene floodplain and a simple nearest neighbor interpolation to generate a surface at this elevation, reconstruction of a paleosurface DEM shows that within a 2-km radius of Hemmeh, such a change in valley topography is the difference between ~22 and ~130 ha of floodplain (see Figure 4.4).

**Figure 4.4** Contrasting modern (black) and reconstructed Early Holocene (white) floodplains. Hemmeh's location is indicated with the black arrow. The underlying aerial photograph is from the 1953 Hunting Aerial Survey, predating the flooding of the area by the Tannur Reservoir.

**Discussion**

The data presented here strongly suggest that either the aridity of the Younger Dryas in the southern Levant has been previously over-emphasized or, perhaps more likely, that aridity associated with the Younger Dryas was not necessarily uniform across the region (in fact the model of a cold and dry Younger Dryas itself has recently been questioned; cf. Enzel et al. 2008; Stein et al. 2010; Torfstein et al. 2013). The presence of a continuously wet floodplain in the Wadi el-Hasa throughout the Younger Dryas, as well as before and possibly after, strongly suggests consistent levels of at least some precipitation within the Hasa catchment throughout the Younger Dryas and into the early Holocene. More to the point with regard to archaeological interpretation, whatever increase in aridity was associated with the Younger Dryas, wetland environments remained accessible to the inhabitants of the Hasa throughout.

If, in the case of the Middle Hasa, wetland resources remained accessible, it may no longer be tenable to consider the emergence of cultivation as a subsistence strategy as a response to resource stress—at least at the local scale. If the Younger Dryas was a wet period (or at least wetter than regional
averages suggest) within certain areas such as the Wadi el-Hasa, the distinctions between the Bolling-Allerød, Younger Dryas, and the Early Holocene in those areas are severely eroded. The blurring of these environmental distinctions severely undermines models linking environmental deterioration with resource scarcity and subsequent development of plant cultivation. The evidence from the Middle Hasa argues that if environmental changes had an effect on subsistence strategies of particular human communities, it would have been through changes in regional patterning—e.g., increasingly spatially circumscribed resources, heightened patchiness—rather than through direct impacts on local resource returns. Whether the Younger Dryas had such effects on regional patterning and diversity remains to be explored and will require environmental reconstructions with high spatial and temporal resolution, as well as regional data on well-dated settlement pattern dynamics.

One vital and historically under-appreciated element may be the floodplains of incised wadi systems like the Hasa. As discussed above, the Hasa was not only wetter than expected; its topography was also significantly different. As subsequent cut-and-fill cycles have largely removed floodplain deposits from drainage systems like the Hasa, the remaining landforms with surfaces dating to the Terminal Pleistocene and Early Holocene are, in order of frequency, wadi slopes (above the range of cut/fill cycles), apices of alluvial fans, and (rarely) remnant alluvial terraces. That this preservation bias may skew reconstructions of settlement patterns has long been recognized (e.g., Maher 2011). We would suggest that, in tandem with an over-reliance on regional generalizations about paleoenvironments, this preservation bias has also structured reconstructions of the environments and resources available to inhabitants.

A broader and wetter Hasa floodplain would not only have provided fertile, well-watered land eminently suitable for experimentation with cultivation, but also an area that was less susceptible to arid conditions caused by either annual variation in precipitation or regional climatic shifts. In arid and semi-arid environments, floodplains can be vital resources for foragers and cultivators alike. The instability of floodplains is more than offset by their productivity, and they provide "high values for resource diversity, productivity, and reliability" (Nicholas 1998:720). For cultivators, floodplains offer locations in which viable and intensifiable agriculture may be carried out without infrastructural investments in irrigation or landscape modification (Doolittle 2006). Indeed, previous work has suggested the importance of floodplains as locations of early cultivation (e.g., Sherratt 1980; Bintliff et al. 2006; Roberts and Rosen 2009).

The prominence of in-stream (floodplain) wetlands easily accessible from el-Hemmeh throughout the Younger-Dryas and into the period in which the site's inhabitants began to experiment with cultivation demonstrates that there was no dramatic change in the local environment associated with the Younger Dryas, and shows that these experiments took place in the context of a floodplain approximately six times larger than the modern one.
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5 Human-Environment Interactions Through the Epipalaeolithic of Eastern Jordan

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Abstract

On- and off-site environmental archives relating to archaeological sites in the Azraq Basin, Jordan, are used to relate Epipalaeolithic human behavior to local, and then regional, records of palaeoenvironmental change. We review recent work from three sites: Ayn Qasiyya, Kharaneh IV, and Shubayqa. Human occupation of the basin was more or less continuous throughout the Epipalaeolithic but shifted from locality to locality, varying in density and type. The environmental data suggest that this was at least in part, due to a complex landscape of changing local environments. We use this example to discuss issues of scale in developing an understanding of human—climate—environment relationships.

Introduction

The Azraq Basin drains approximately 12,000 km² of northeast Jordan, southern Syria, and northwest Saudi Arabia (Figure 5.1). It has a long and complex history of human occupation, as outlined below, and over the last decade the multidisciplinary Epipalaeolithic Foragers in Azraq Project (EFAP) has been reconstructing the prehistoric landscapes of what is today the eastern desert of Jordan. Working at three separate locations, we have attempted to integrate archaeological sites and the local off-site stratigraphy, evaluating the evidence of the environment in which the sites exist today and existed in the past. This chapter discusses using on- and off-site environmental archives to address the challenges of relating prehistoric human behavior to global, regional, and local records of palaeoenvironmental change.

The Azraq Basin is an area where the impact of environmental change, driven partly by the activities of people themselves, is clearly evident. The unsustainable use of natural resources, such as water, has been one reason for changing settlement patterns and agricultural practices in recent times (e.g., Fariz and Hatough-Bouran 1998). A point often made in prehistory is the need for hunter-gatherer groups to intimately know their environment and carefully schedule and manage their activities around particular resources and their availability (e.g., Lee and Devore 1968; Binford 1980;...
The Archaeology of Human-Environment Interactions
Strategies for Investigating Anthropogenic Landscapes, Dynamic Environments, and Climate Change in the Human Past

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