Climate and Ancient Societies

Edited by Susanne Kerner, Rachael J. Dann and Pernille Bangsgaard

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Complex Society's Responses to Climatic Variation

Urban Adaptations to Climate Change in Northern Mesopotamia

Jason Ur

Abstract

Only in rare circumstances does climate change force a uniform response from human communities; adaptations can vary dramatically even between neighbouring settlements. This chapter considers variation in response to proposed climate changes in third millennium BC northern Mesopotamia. Using spatial data from surface collection, satellite remote sensing and landscape archaeology, it considers how urban-based farmers and pastoralists responded at three of the largest Early Bronze Age cities in northern Mesopotamia: Hamoukar, Tell Brak, and Tell Leilan. Despite their close proximity, the different adaptive responses at these three places resulted in three different settlement histories.

Introduction

Complex societies pose a particular problem to the study of climate and human responses, since their complexity often involves the development of cooperative technologies and social institutions designed to compensate for variable conditions. On the other hand, it may be that in the development of technologies and institutions, these societies overextend themselves, or develop to the point of losing resilience in the face of such variable conditions. In the process, they can impact their environments in ways that mimic, or are indistinguishable from, the effects of climate change. Ongoing debates about the causes of deforestation and soil erosion in the late Holocene attest to these difficulties (Roberts et al. 2011a; Roberts et al. 2011b).

The focus of this study is squarely on this second aspect: the responses of human communities to environmental change. In general, models for human-environment interaction have fallen along a continuum. On one end, environment has been seen as determining aspects of social change, including some of the most dramatic events of human history. At the most extreme, a sudden infilling of the Black Sea basin has been hypothesised (Ryan and Pitman 1998). According to this account, in a span of a few weeks, this event displaced members of a society that had emerged around a freshwater lake at the centre of the basin. They migrated out in all directions, eventually settling in Europe, the Eurasian Steppes and Mesopotamia, where they gave birth to the Linearbandkeramik culture, the Indo-Europeans and the Sumerians, respectively. This last civilisation was kind enough to preserve this event in the form of the Flood myth.

Equally implausible is the idea that human societies exist somehow independently of their environments, and all social change is the endogenous result of shifting relationships between individuals and groups. Such interpretations rarely make these assumptions explicit, but the social actors in such models exist in an abstract world without physical environments or cultural landscapes.

The intermediate position places humans within an ecosystemic context. The environment is a real factor in the decision making processes of individuals, whose actions are constrained by it, but whose adaptability can take advantage of certain elements (McIntosh, Tainter and McIntosh 2000b; Rosen and Rosen 2001; Rosen 2007). It is important to recognise that the human-environmental relationship is complex and non-linear, and that different societies, and indeed different individuals in a society, can respond to identical environmental changes in variable ways (Coombes and Barber 2005; Rosen and Rosen 2001). In only the most extreme cases is a single human response the only possible option.

In considering the human-environmental dynamic, and particularly the social response, there are several issues that are worth explicit discussion as we evaluate competing reconstructions. Of particular importance is the nature of what it is that responds. "Society" is a convenient expression for an amazingly complex, internally diverse system of individuals, institutions and the relationships between them. To say that a society "responds" to some event is to speak of an aggregate of individual actions, but never a uniformity. Societies, settlements and institutions should not be reified into decision making agents.

Closely related to this issue is the chronological scale of events. Are "abrupt" events those that occur in a day, a week, over a decade, or a century? Past societies could persevere for centuries or longer, but the decision making individuals of which they were comprised lived in a human timescale. A century-long process of aridification might seem abrupt in an ice core, but four or five generations would have witnessed this "event", if we can use that term. Human response is closely related to human perception and social memory (McIntosh, Tainter and McIntosh 2000a: 16–17). Our reconstructions of social responses must consider how individual members of past societies would have perceived environmental change, and how it fit within the understood normal range of climatic variation.

A frequently reconstructed human response to climate change, particularly to abrupt events, has been "collapse", but all too frequently there is no explicit discussion of what this term means. What is it that collapses? Do we mean a political collapse, where centralised administrative institutions lose their legitimacy, and society breaks down into smaller autonomous units? Do we mean economic collapse, where trade networks are disrupted, and agricultural or pastoral systems become non-viable? Or do we mean a demographic collapse, where conditions are so drastically altered that communities are reduced in number or must physically relocate themselves? A "collapse" could mean any or all of these things; they are related but not necessarily synchronous (Yoffee 1988; Schwartz 2007: 46–47).

Archaeologists frequently assume that social responses took the form of a shift from a high state of social complexity to a lower state. These shifts include the political fragmentation of states and empires, and the reduction or disappearance of settlement nucleation in the form of urbanism. It is important to recognise that in such cases, climatic or environmental variations may be stressing societies that have developed in particular ways which have reduced their resiliency (Wilkinson 1997). Such societies may not need dramatic events to impact them; something as simple as high floods, a long winter, or a run of dry years might be sufficient to set off a non-linear chain of responses whose ultimate result might be radical social transformation (Coombes and Barber 2005). In such cases, the ultimate causes are as much social as they are environmental.

Climate and society in the Early Bronze Age (EBA) Northern Fertile Crescent

One of the most discussed of the proposed abrupt climatic events is placed at 4.2 thousand years ago, or 2200 BC. Initially this event was used to explain settlement history at Tell Leilan in northeastern Syria but was expanded to address hypothesised regional settlement abandonment in northern Mesopotamia (Weiss and Courty 1993; Weiss et al. 1993) and later throughout the Old World at the end of the 3rd millennium BC (Weiss 1997; Weiss 2000b). The initial publications in 1993 were provocative, proposing previously unrecognised regional abandonments and mass population movements at the hands of environmental events. In the succeeding 20 years, much research energy has gone into identifying social responses to this proposed event elsewhere in northern Mesopotamia and throughout the ancient Near East (see, most recently, Kuzucuoğlu and Marro 2007; Rosen 2007; Wossink 2010; Danti 2010). The current state of research makes it an excellent case study in the complex relationship between climate and society, the difficulties of integrating paleoclimatic data, archaeology and ancient texts, and the variability of human responses and adaptations. Contrary to the expectations of the 4.2 kya abrupt climate event model, a close consideration of the settlement trajectories of three large cities reveals variable adaptations resulting in three different histories, rather than a single simultaneous response.

Early Bronze Age urbanism

Early Bronze Age cities emerged between 2600–2500 BC in an arc along the southern edge of the Taurus Mountains (fig. 1). Today, this is a Mediterranean climate, with cold wet winters and hot dry summers. Most of this region receives between 300 and 600 mm of rainfall per year, almost all of it between November and March. At the upper end of this range, rainfall is sufficient for successful dry farming, and those regions have witnessed nearly continuous sedentary agricultural communities since the Neolithic. At the lower end, toward the steppes of central Syria, settlement occurred only in certain periods, generally times of political stability under states and territorial empires (Geyer and Calvet 2001; Wilkinson et al. 2005), but earlier in the Holocene possibly because of more favourable rainfall conditions (Hole 1998; Bar-Matthews and Ayalon 2011).

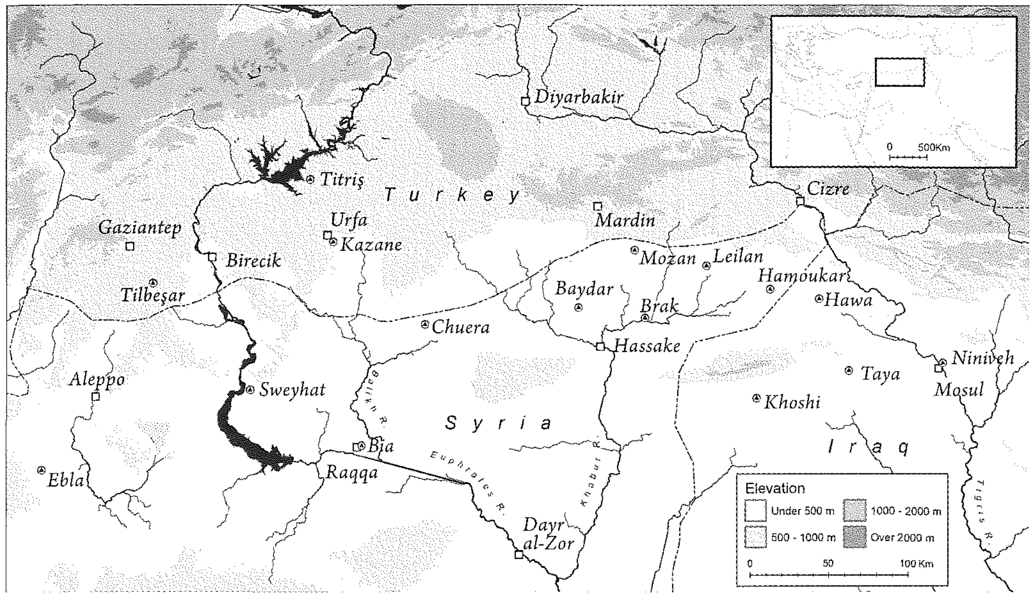

FIGURE 1. *Cities and towns in northern Mesopotamia in the Early Bronze Age (c. 2600–2000 BC).*

Even in areas that receive on average over 300 mm per year, the amount of rainfall fluctuates dramatically each year. For example, the rainfall station at Mosul in northern Iraq shows very high interannual variability in the 20th century AD. Such variability means that some areas might have one failed crop every three years, even if the long-term average is high enough for successful cultivation. We must consider the possibility that ancient societies were faced with such routine climatic variability as well.

In the early 3rd millennium, most settlements were small villages of 1–2 hectares, with a few larger settlements around 15 hectares. Beginning around 2600 BC, several of these settlements grew rapidly to sizes of 60 to 100 hectares. Even at the earliest stages of this expansion, they hosted large institutional households such as palaces and temples on monumental scales. Outside of these elite core areas, the expanding lower towns contained narrow streets and narrower alleys running between densely packed domestic residential neighbourhoods. The basics of political structure are beginning to emerge from scattered tablet finds at Ebla, Mari and Beydar. The major centres were Ebla (Tell Mardikh), Mari (Tell Hariri) and Nagar (Tell Brak), and their rulers engaged each other in a combination of diplomacy and warfare (Sallaberger 2007; Archi and Biga 2003; Eidem et al. 2001). Archaeological and textual evidence attests to mass production of ceramics and specialised production and exchange of metals and textiles (for recent reviews, see Akkermans and Schwartz 2003; Stein 2004; Ur 2010a).

The economic backbone of these cities and their hinterlands was, however, cereal agriculture and sheep and goat pastoralism (Weiss 1986; Wilkinson 1994; Deckers et al. 2010). Paleobotanical studies demonstrate the importance of barley and wheat (Charles and Bogaard 2001; Riehl 2009). Recovered animal bones are mostly sheep and goat, with lesser amounts of cattle and pig (Zeder 2003). Archaeologists give disproportionate attention to the manufacturing aspects of their economies, but at their base, these cities were overwhelmingly agro-pastoral in nature (Danti 2010), and as a result closely connected to their local ecologies.

Climatic events and variability in the later 3rd millennium BC

There is general agreement that the Near Eastern climate changed during the course of the 3rd millennium BC (see recent reviews in Roberts et al. 2011b; Bar-Matthews and Ayalon 2011). There is, however, considerable debate regarding its timing and duration (fig. 2). The earliest hypothesis, by Harvey Weiss and colleagues, proposed that an abrupt event changed the climate to a new arid state at 2200 BC, an event referred to as the 4.2k BP event. The empirical core of the initial hypothesis was micromorphological evidence for volcanic activity, found in layers covering the final occupation of Tell Leilan (Weiss and Courty 1993; Weiss et al. 1993; Courty and Weiss 1997). More recently, the micromorphological evidence has been disregarded in favour of changes in atmospheric circulation (Staubwasser and Weiss 2006). Although the cause of this event has evolved since its initial publication in 1993, the hypothesised human response has not: it is still considered to be a "collapse to less extractive political organisation, directed habitat-tracking to regions where agriculture was sustainable, and the abandonment of reduced-production cultivation for pastoralism" (Weiss 2000a: 88). It is thus proposed that urbanism collapsed at Leilan, almost all other sedentary settlement in northern Mesopotamia was abandoned, and the resulting displaced populations forced the fragmentation of the Akkadian empire. This same 4.2 kya event is now implicated in the demise of the Old Kingdom in Egypt and the end of the Harappan civilisation in the Indus (Weiss 2000b).

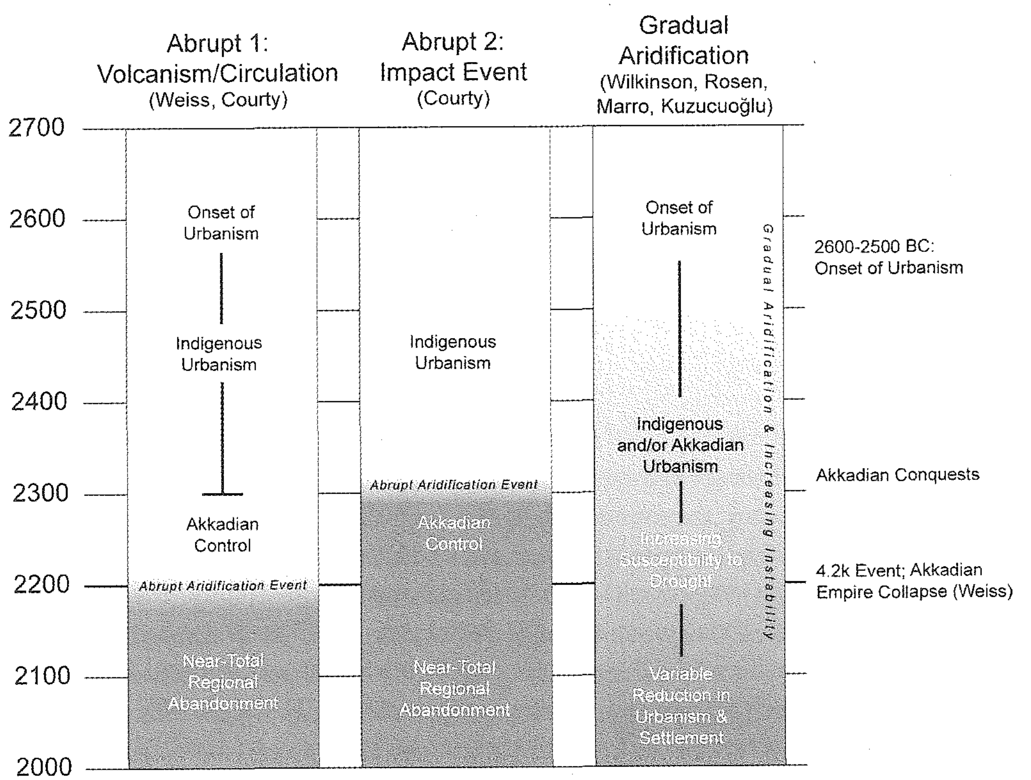

FIGURE 2. *Models of climate and social development in the later Early Bronze Age.*

The paleoclimatic reconstruction of Weiss and colleagues is not unchallenged, however. The same micromorphological tephra signature was found in layers at Tell Brak that could be as much as a century earlier (c. 2300 BC), and has been interpreted as the result of an extra-terrestrial impact event (Courty 1998; Courty 2001). The context of the Brak samples, in levels predating the fortress constructed by the Akkadian king Naram-Sin, places this event in the middle of the span of urban development, not at the time of its demise.

Others see a gradual climatic drying, based on a variety of proxy indicators. A mid-Holocene humid phase was replaced by more arid conditions throughout the 3rd millennium, reaching a driest phase around 2000 BC and remaining that way for the remainder of the Bronze Age (Wilkinson

1997; Hole 1997; Rosen 2007; Marro and Kuzucuoğlu 2007; Bar-Matthews and Ayalon 2011). These models also assume substantial interannual variability in temperature and rainfall, and a long-term human adaptation to such variability. Under this climatic model, 3rd millennium urbanism appeared and developed in the context of increasing aridity.

In conclusion, there is disagreement as to the nature and timing of climatic events in the late 3rd millennium BC. In one model, volcanoes, meteorites and atmospheric circulation shifts are blamed for sudden aridification on the scale of years or decades; in the other, climatic drying was a centuries-long process that may not have even been perceptible within the normal range of interannual variation.

The landscapes of EBA cities

Whether abrupt or gradual, aridification must have had an impact on the staple economy, the foundation upon which EBA urbanism was constructed. Fortunately, in approaching questions of settlement and economy, we have more than just sites with carbonised plants and animal bones. The landscape of northern Mesopotamia preserves an array of off-site features that demonstrate the extent and intensity of agricultural and pastoral activities at this time. Such features are crucial for approaching questions of human-environmental relationships and adaptation to climatic variability.

The first type of features is a set of shallow linear depressions that radiate outward from mounded sites. They are difficult to see on the ground, but under proper conditions, they are clear in remote sensing datasets. These features, called "hollow ways", represent the traces of past trackways. They were first mapped by Willem van Liere in the 1950s (van Liere and Lauffray 1954–55) and later by Tony Wilkinson in the 1980s (Wilkinson 1993). Using declassified intelligence satellite photographs, over 6,000 kilometres of hollow ways have been mapped across northeastern Syria and northern Iraq (Ur 2003, 2009, 2012a; Wilkinson et al. 2010). Hollow ways are mostly associated with sites of this 3rd millennium urban phase, both large cities and small villages; a smaller, morphologically distinct set can be associated with sites of the early Islamic period.

Hollow ways demonstrate routes of communication between settlements, but they also serve as a proxy for extensification of ancient agriculture and pastoralism (Wilkinson 1994: 492–493). The majority of traffic consisted of farmers and their plough animals moving to and from their fields adjacent

to the settlement, and herders and their flocks moving from the settlement to the pasture beyond those fields. Within the agricultural zone, their movement was constrained onto these paths by the growing crops; hence the disturbance that causes the paths to sink was also constrained, resulting in the formation of hollow ways. Beyond the edge of the agricultural zone, no such constraints existed, and movement would have dispersed; in this zone, no hollow ways formed. What survives for archaeology are the settlement, now in the form of a mound, and the former paths where constraint caused the deepest incision. With this model of hollow way formation in mind, we can reconstruct agricultural zones by connecting the terminal ends of hollow ways.

When viewed on a regional scale, the areas of densest settlement were nearly completely cultivated, since the reconstructed zones almost abut each other. By estimating settlement population and the productivity of their associated agricultural catchments, we find that most villages and small towns would have been self-sufficient or surplus-producing. However, larger towns and cities would have required some of this surplus to sustain their populations. In the region of Tell Beydar, for example, the deficit at Beydar would have been more than offset by exchanges with its surplus-producing satellite villages (Ur and Wilkinson 2008: 312–314).

The extensification of agriculture, as demonstrated by hollow ways, was accompanied by intensification, indicated by a second class of landscape feature. Across the alluvial plains of northern Mesopotamia, the landscape between sites is covered by a carpet of small and abraded potsherds. The distribution is nearly continuous but of variable density. This phenomenon was initially recognised by Williamson (1974: 90) in Oman, systematically studied by Wilkinson (1982, 1989), and is now documented throughout the Near East and beyond (Bintliff and Snodgrass 1988). In northern Mesopotamia, the densest concentrations, in the range of 60–100 sherds per hundred square metres, are found in proximity to urban sites of the later 3rd millennium (Wilkinson 1994: 491–492). Lighter densities are found around smaller sites of the same time period. Around sites of other periods, scatters are low, between five and twenty sherds per hundred square metres. The scatters themselves are difficult to date because of their small and abraded morphologies, but identifiable diagnostics are predominantly later 3rd millennium in date, and fabrics are consistent with this time as well.

There are many ways that potsherds can find their way into the fields around sites, but only one interpretation can explain their extent and ubiquity. Wilkinson (1982) has proposed that they represent the inorganic component of manuring. Cultivation removes moisture and nutrients from soils, especially when fallow cycles are shortened or skipped. The deliberate addition of organic materials to fields ameliorates this process. In Wilkinson's model, organic refuse in the form of animal dung, cooking debris and food remains was collected and composted in settlements, along with other household waste, including discarded ceramics. Subsequently this material was deposited onto the fields. The organic component has been washed through the soil but the inorganic elements remain and have been kept on the surface by over four millennia of subsequent ploughing.

By the end of the EBA, population nucleation in the great cities of northern Mesopotamia placed them in an ecologically precarious situation. The largest settlements were incapable of sustaining themselves and would have relied on exchange or transfers from settlements in their hinterlands. Because of this reliance on surplus production, this system was particularly attuned to fluctuations in climate. Under modern climatic conditions, this economic system would have existed at or near the limits of viability, since a climatic drying or merely a run of particularly dry years could have resulted in its collapse (Wilkinson 1994, 1997). The record of the archaeological landscape shows that the inhabitants of these cities and villages made technological adaptations to such climatic variation by extensifying and intensifying cultivation. A closer look at individual cities reveals, however, that such adaptations were not uniform and may explain the variation in settlement trajectories at the close of the 3rd millennium.

Adaptive variability in three urban communities

In light of these conflicting paleoclimatic reconstructions, it is worthwhile to consider urban demography and land use at three large, and therefore ecologically fragile, urban settlements of the time: Hamoukar (98 ha), Tell Brak (70 ha) and Tell Leilan (90 ha). Each of these places has a full component of excavation, survey and off-site landscape data.

The largest is Hamoukar, situated close to the Syrian-Iraqi frontier. At the start of the 3rd millennium, settlement was constrained to a 15 hectare mound, but around 2600 BC, an extensive lower area of settlement grew around it to the south. The 1999 surface collection showed ceramics from the later 3rd millennium BC covering the entire lower town, making Hamoukar a 98 hectare city (Ur 2010b). Settlement appears to have survived any abrupt events around 2200 BC, since post-Akkadian diagnostic types were found throughout the lower town (Ur 2012b).

Third millennium excavation areas on the high mound have been spatially limited, but lower town trenches have revealed dense domestic occupation (Ur and Colantoni 2010; Colantoni and Ur 2011). The associated ceramics include sherds with comb-incised decoration that are most common in the post-Akkadian period, in other words the time after the proposed abrupt climatic event of 2200 BC. The frequency of baked brick in all lower town trenches suggests that not only did urban settlement at Hamoukar last beyond 2200 BC but its inhabitants also remained considerably wealthy. The end of Hamoukar was violent: all lower town trenches show sudden abandonment, with complete ceramic inventories left on floors, some with burning. In one area, semi-articulated human remains were found where they had been left by scavengers. Hamoukar's end was abrupt, but its immediate cause was social rather than environmental.

Extensive agriculture in Hamoukar's hinterland can be reconstructed from the presence of hollow ways (fig. 3). Several trackways converge at a point on Hamoukar's western edge, likely an ancient gate into the settlement. Others radiate to the southeast. The proposed agricultural catchment of Hamoukar includes only 5,200 hectares, far less than would be required to feed its estimated population. Almost 1,000 field scatter collections were made in Hamoukar's hinterland, and they describe dense scatters immediately surrounding the site. Thus Hamoukar's cultivators extensified and intensified their agricultural production. Scatters also surround Hamoukar's 3rd millennium satellites, although at lower density. Almost all of these satellites were also settled in the post-2200 BC period.

Tell Brak has been excavated intermittently since the 1920s, and is the primary site for the archaeology and chronology of the later 3rd millennium BC in the region (Oates, Oates and McDonald 2001). After an urban expansion in the 4th millennium (Ur, Karsgaard and Oates 2007), Brak had shrunk to around 40 hectares in the early 3rd millennium. Its initial growth was later than at Leilan or Hamoukar. Around 2500 BC, settlement expanded to the south to create a lower town, totalling approximately 70 hectares (Ur, Karsgaard and Oates 2011). By around 2400 BC, Brak was known as Nagar, and it was the dominant political centre in northern Mesopotamia (Eidem,

FIGURE 3. *Hollow ways and field scatters around Hamoukar.*

Finkel and Bonechi 2001). We know nothing of the nature of settlement on its lower town, but the ancient high mound contained a sequence of monumental scale buildings, most of which were hybrid temple and administrative complexes (Oates, Oates and McDonald 2001). One such structure was the so-called Naram-Sin fortress, constructed of bricks stamped with the name of the Akkadian conqueror.

Brak's landscape also shows strong evidence for both extensive cultivation and intensification through manuring (fig. 4). The radial system of hollow ways around Brak (Ur 2003; Wilkinson et al. 2010) is the largest and most deeply etched in the basin. Some linear features extend more than five kilometres. Many coalesce around particular points on the mound's edge, near gullies that might represent the positions of gates. The fields northeast and southwest of Brak were extensively sampled for field scatters, which occur in high numbers, especially close to Brak itself (Ur, Karsgaard and Oates 2011).

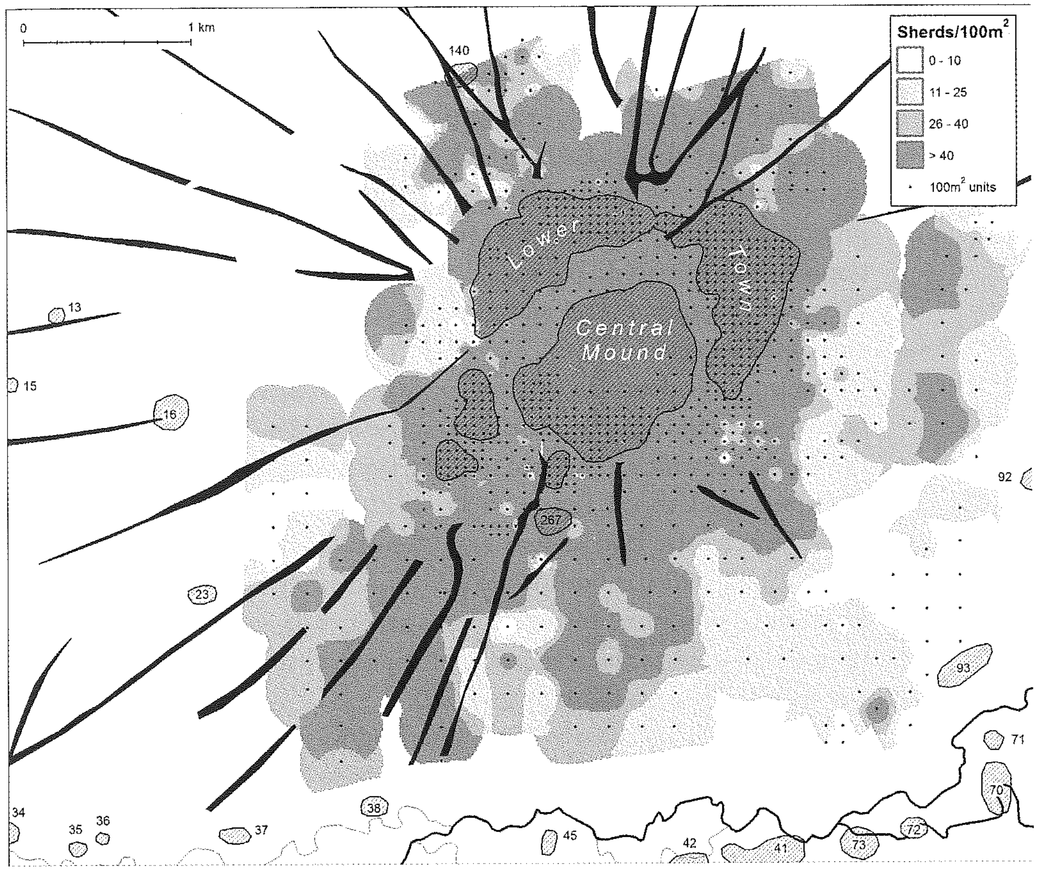

FIGURE 4. *Hollow ways and field scatters around Tell Brak (sites from Wright et al. 2006–2007).*

Like Hamoukar, Brak also survived the proposed abrupt aridification event, although substantial changes appear to have been roughly coincident with 2200 BC. Around this time, many of the large institutional complexes were ritually sealed and went out of use (Oates, Oates and McDonald 2001: 90–91, 389–390). The succeeding occupations were all domestic in origin. In the absence of the distinctive comb-incised decorated sherds, it appears that Brak's lower town ceased to be settled around this time as well (Ur, Karsgaard and Oates 2011; Ur 2012b). Brak's post-Akkadian occupation was thus reduced in scale and socially reorganised.

Yet a third settlement trajectory can be described for Tell Leilan, the point of origin of the 2200 BC abrupt aridification event hypothesis. Leilan's urban beginnings are similar to Hamoukar's. Building on several prehistoric settlements, Leilan covered 15 hectares in the early 3rd millennium BC before rapidly expanding to 90 hectares around 2600 BC. For the next four centuries, Leilan's high mound hosted elite households while the lower town was filled with dense residential occupation. Its excavators propose that it was conquered by the Akkadian state of southern Mesopotamia, which initiated a regional demographic reorganisation and closely managed the agricultural and pastoral economy of Leilan itself (Weiss and Courty 1993).

Landscape evidence for extensive agriculture takes the form of abundant hollow ways associated with Leilan and also its 3rd millennium satellites to the southeast, which have been mapped from CORONA satellite imagery (fig. 5; see also Ur 2003, fig. 10; Ur 2010b, Map 2). However, the Leilan area lacks the extensive field scatters seen elsewhere in the basin. In radial transects around several major late 3rd millennium sites, scatters were light and no material was found further than 500 metres away. These scatters have been interpreted as the result of post-depositional processes, rather than any ancient activities (Ristvet 2005: 25).

Urbanisation at Leilan and its hinterland was based on extensification of agricultural fields, as demonstrated by the hollow ways, but its farmers did not adopt intensification methods in the form of manuring.[1] They may have attempted to raise yields by reducing the fallow interval, for example by cultivating a field annually. This technique provides a short-term yield increase but would deprive the soil of the moisture carry-over that a fallow year provides, increasing the likelihood of crop failure. The combination of nucleated population, declining precipitation and fallow violation would have made Leilan's staple economy particularly fragile.

Leilan and its hinterland was rapidly abandoned around 2200 BC, based on radiocarbon dates and ceramic chronology (Weiss et al. 1993: 999–1002). The ceramic type used to identify the few surviving settlements is a style of comb-incised decoration. Based on the presence of sherds of this type, the

1 It is possible that Leilan's farmers manured their fields by allowing their animals to drop dung directly onto the fields, in which case it would be archaeologically invisible without geochemical analysis. However, raw dung left directly on fields in semi-arid climates is not beneficial as a manure because it oxidises rapidly; this problem can be avoided by settlement-based animal penning and composting (Wilkinson 1982: 324).

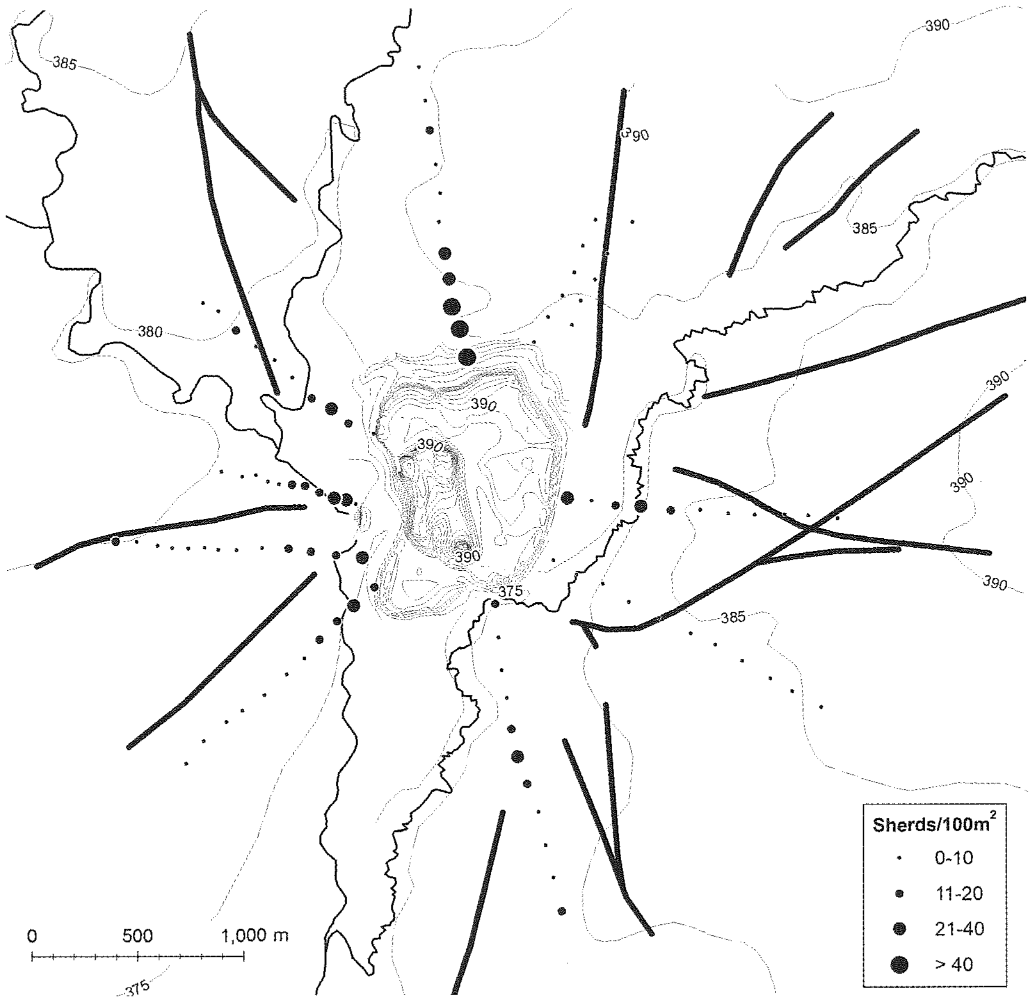

FIGURE 5. *Hollow ways and field scatters around Tell Leilan (field scatters from Ristvet 2005, fig. 1.3).*

nucleated pattern of the Akkadian period dissipated into a few small and dispersed villages; 69 per cent of sites were abandoned, and the total settled area declined by 72 per cent (Ristvet 2005: 120).

The focus here has been on three of the largest EBA cities, but a similar variability in demographic trajectories and adaptive responses can be seen in other places, including smaller towns. Tell es-Sweyhat on the Syrian Euphrates reached its maximum extent of 45 ha precisely at the time of the alleged abrupt event, and settlement continued for an additional two centuries (Danti 2010). Field scatters and hollow ways (Wilkinson 2004: 55–82) demonstrate that Sweyhat's farmers employed the same agricultural strategies that were used at Brak and Hamoukar, but its emphasis on its animal economy is perhaps the reason why it persevered at a time of arid and unstable climate (Danti 2010). As the climate dried, the small towns and villages of the Balikh drainage underwent a simultaneous nucleation and population reduction; the former is interpreted as a social adaptation via new land tenure rules to reduced resource availability, while the latter reflects the decision by some farmers to embrace a non-sedentary pastoral economy (Wossink 2010: 187–188).

In some places, no social changes or adaptations have been detected. At the large city of Urkeš (modern Tell Mozan), crop choices, vegetation patterns and animal husbandry were largely unchanged in the last century of the 3rd millennium (Deckers et al. 2010). Further to the north around Titriş Höyük, a 43 ha site in southeastern Turkey, survey and excavation revealed a similar lack of correlation between climatic events and settlement history (Algaze and Pournelle 2003). Both of these sites are on the wettest northern fringe of the Fertile Crescent today, and it may be that 3rd millennium precipitation never decreased to the point where their farmers were forced to adopt new agricultural technologies or modify their staple economies.

Thus far the discussion has considered successful responses that allowed the perseverance of sedentism or, in the case of Tell Leilan, the abandonment of sedentism in favour of pastoral nomadism. It is probable, however, that societies which perceived the climatic changes may have responded unsuccessfully, or, to a modern Western observer, inappropriately. For example, the Levantine towns of the Early Bronze (EB) III period may have turned to the gods for help (Rosen 2007). Farmers invested more authority in elite managers who were capable of interceding with the gods. One archaeological manifestation appears to be an increase in temple building at the end of the EB III, which ultimately proved to be unsuccessful; the subsequent response of most settlements by the EB IV was abandonment in favour of pastoral nomadism.

Summary and conclusions

To summarise, we have examined three major cities and seen three different settlement trajectories (table 1). In terms of demography and structure, Leilan's trajectory is the most dramatic: it was abruptly and completely abandoned relatively early, around 2200 BC. Hamoukar survived in a fully urbanised state perhaps as late as 2000 BC, and while the nature of settlement in its earliest urban phases is uncertain, its final phase appears to be one of substantial wealth, so a post-drought impoverishment seems unlikely. Brak's settlement was reduced in scale from 70 hectares to approximately 40, and it underwent substantial structural changes. The excavations have not, however, revealed evidence that this transformation was climatically induced. By the early 2nd millennium, settlement at Brak had been reduced further, but on present evidence it appears never to have been abandoned.

The nature of EBA climatic change is not agreed upon, but the continuation of settlement at Hamoukar, Brak, Sweyhat, Titriş, Mozan and others suggests that the severity of the region-wide event at 2200 BC has been overestimated. More likely, the climate of northern Mesopotamia experienced a gradual aridification that was probably only perceptible through the social memory of a past time when the rains were more reliable and crop yields were greater.

One response to reduced agricultural yields is simply to cultivate more land. At all three sites, agriculture was extensified with urban expansion, creating movement-constraining conditions that caused the formation of incised patterns of hollow way routes. In agent-based simulations, farmers who have the option to expand cultivation will do so if the productivity of their existing fields has declined, whether due to arid conditions or some other yield-reducing circumstance (Wilkinson et al. 2007: 65–66). A second possible response is to intensify cereal production to obtain more yields per area unit. The farmers in some, but not all, northern Mesopotamian cities chose to intensify by manuring their fields with settlement-derived debris. The fields around Brak, Hamoukar and Sweyhat are littered with the remaining inorganic component of this ancient practice. Farmers around Leilan, however, appear not to have adopted manuring as an intensification technology.

	Hamoukar	Brak	Leilan
Nature of late EBA Transformation	City-wide violent event	Demographic reduction, institutional reorganisation	Rapid and extensive urban abandonment
Agricultural Extensification (Hollow way proxy)	Yes	Yes	Yes
Agricultural Intensification (Field scatter proxy)	Yes	Yes	No
Abandonment	Ca. 2100–2000 BC	(not abandoned)	2200 BC

TABLE 1. *Settlement trajectories and agricultural adaptations at three Early Bronze Age cities.*

It could be proposed, therefore, that the different settlement trajectories of the sites and their differential adoption of agricultural technologies were related. On the one hand, around Hamoukar, Brak and Sweyhat, farmers extensified and intensified agricultural production, and urban settlement was sustained for a long duration through an increasingly arid and unstable climate, and also in the face of possible abrupt events. On the other hand, without such techniques, the staple economy of Leilan and its neighbours was more susceptible to an abrupt dry phase. It may not be coincidental, therefore, that when Leilan was deurbanised and its region nearly completely abandoned at 2200 BC, settlement persevered at Hamoukar, Brak, Sweyhat, Mozan, Titriş and other cities and towns. Because their farmers employed techniques to increase agricultural productivity, these other urban agglomerations were better suited to weather droughts.

We must ask to what extent were these agricultural adaptations *responses* to climatic changes. As is common for syntheses of environmental and archaeological data, causation is rendered difficult by chronological imprecision. Hollow ways and field scatters can only be generally dated to this time of urban expansion, and not to any particular phase of it. Thus we cannot say whether extensification and manuring were responses to suddenly poorer conditions for dry farming, or if these techniques emerged along with the initial expansion of urban settlement, and hence predated the climatic aridification. It has been argued, for example, that intensification was driven by the need for social surpluses to supply commensal events (Ur and Colantoni 2010), or that population growth and nucleation may have necessitated it (Wilkinson 1994). The adoption of these techniques need not have been due to a single factor, however. One can imagine a scenario in which a household manured its fields to support its social ambitions but also did well in dry years when other households' crops failed. The success of that household would be noticed by its neighbours, and its techniques emulated. If climatic drying was a process that unfolded over several centuries, it is possible that these techniques were increasingly adopted over a long period in some regions, but not at all in others. The most significant question is why Leilan's farmers elected not to employ manuring on their fields, despite being only a day's walk away from the cities at Brak and Hamoukar, whose farmers did manure.

Although they proved to be more durable than Leilan, the cities that continued past 2200 BC were transformed or eventually abandoned. Hamoukar survived for another one or two centuries before its rapid abandonment as violence and looting swept the city. Settlement at Brak contracted and was restructured, with major temple institutions sealed off and replaced by domestic structures. These variable and non-synchronic events might very well be interrelated, and an increasingly arid and unstable climate might be a part of this story. Rather than a simplistic scenario in which climate changes and human communities respond uniformly, we could envision a non-linear sequence of events in which the collapse of one major urban settlement created political, economic and demographic waves that impacted other cities and regions in a variety of ways (Coombes and Barber 2005). Military violence was pervasive throughout northern Mesopotamia in the late EBA and certainly played a role (Archi and Biga 2003; Sallaberger 2007).

Thus, at the present state of knowledge, the trajectories of urban settlement at the end of the 3rd millennium BC are far more variable than many reconstructions would suggest, and the same is true for the social response. The variability in settlement histories in the northern Fertile Crescent is now matched by variation elsewhere in western Syria and southeastern Turkey (e.g. Schwartz 2007; Danti 2010). Whether climate change was abrupt or gradual, the responses of human groups varied dramatically, sometimes within a hundred kilometres of each other. In this case, plausible responses that have been proposed include political and demographic collapse and regional abandonment, alteration of settlement patterns and occupational density, emphasis on a pastoral economy, and the development or expansion of agricultural techniques for ameliorating climatic impacts. It seems quite likely that all of these responses appeared in some form or combination at the end of the 3rd millennium BC in northern Mesopotamia.

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