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Production, Subsistence, and Environment 20

Neolithic Corporate Identities

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Marion Benz,

Hans Georg K. Gebel

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Trevor Watkins

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dedicated to Klaus Schmidt

who pioneered the change in understanding the Neolithic

Contents

M. Benz, H.G.K. Gebel and T. Watkins (eds.), Neolithic Corporate Identities
Studies in Early Near Eastern Production, Subsistence, and Environment 20 (2017): 21-53. Berlin, ex oriente

Human Palaeoecology in Southwest Asia During the Early Pre-Pottery Neolithic (*c.* 9700-8500 cal BC): the Plant Story

Eleni Asouti[1]

"According to the materialist conception of history, the ultimately determining element in history is the production and reproduction of real life … We make our history ourselves, but, in the first place, under very definite assumptions and conditions. Among these the economic ones are ultimately decisive. But the political ones, etc., and indeed even the traditions which haunt human minds also play a part … In the second place, however, history is made in such a way that the final result always arises from conflicts between many individual wills, of which each in turn has been made what it is by a host of particular conditions of life. Thus there are innumerable intersecting forces, an infinite series of parallelograms of forces, which give rise to one resultant - the historical event. This may again itself be viewed as the product of a power [that] works as a whole unconsciously and without volition. For what each individual wills is obstructed by everyone else, and what emerges is something that no one willed."

Letter of F. Engels to J. Bloch (London, September 21, 1890)

Abstract: This chapter tackles one of the most enduring questions posed by prehistoric archaeology worldwide attracting the interest of prehistorians, anthropologists, economists, geographers and natural scientists alike: how and why did late Palaeolithic societies abandon long-lived and highly successful foraging and hunting economies in order to adopt farming? The chapter provides a critical overview of how this transformation unfolded in Southwest Asia, the place of origin for some of the economically most important contemporary plant and animal food staples, at the very end of the Pleistocene and the beginning of the Holocene some 12,000 years ago. It focuses in particular on the nature of plant management practices during this period and how they were intertwined with changes in climate and vegetation, seasonality patterns, local micro-ecological variability, people's historical experiences and perceptions of the landscape, mobility strategies, community interactions, and associated symbolic and ritual behaviours. Some of the currently accepted notions about the nature, ecology and economic returns of predomestication cultivation, the causes and evolution of the morphological domestication syndrome in crop progenitor species, and the predicted impacts of climate and environmental change on economic decision-making are critically reviewed and revisited. The chapter concludes by discussing some of the implications of the Southwest Asian case study for understanding the nature and evolution of prehistoric human economic behaviours, and the central role that resource ecologies play in determining the directionality and pace of macroeconomic change.

Keywords: Southwest Asia, Neolithic, domestication, climate change, niche construction theory

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Introduction: Setting the Issues

This chapter provides a critical overview and reassessment of the nature and palaeoecology of the Pre-Pottery Neolithic (PPN) subsistence economies of Southwest Asia, one of the most intensively researched hotspots of the transition from foraging to farming worldwide (Barker 2006). It focuses on the earliest part of the Neolithic transformation, the first two millennia of the Holocene. This timespan between the end of the Younger Dryas at ~11,700 cal BP and 10,500 cal BP, broadly overlaps with the chrono-cultural horizon identified as the early PPN (Asouti and Fuller 2013; see also Table 1, Fig. 1). In palaeoeconomic terms, the early PPN witnessed the onset of various pre-agricultural plant and animal management practices collectively categorized as "low-level food production" (*cf.* Smith 2001; Asouti and Fuller 2013; Zeder 2015). "Pre-domestication cultivation" (PDC) conventionally defined as the planting and harvesting of morphologically wild crop progenitor species (Willcox 2013; Willcox *et al.* 2008) is considered a typical manifestation of this mode of production in Southwest Asia, and is believed to have developed independently across the different areas of the Fertile Crescent alongside a diverse array of foraging and hunting strategies. In sociocultural terms, the early PPN is marked by the florescence of symbolic and ritual behaviours associated with corporate social groups (*e.g.* lineages, sodalities, age groups, networks) which are believed to be reflected in the communal structures unearthed at several sites in both the southern and the northern Fertile Crescent including Göbekli Tepe, Gusir Höyük, Mureybet, Jerf el Ahmar, Tell 'Abr, Tell Qaramel, WF16, Tell es Sultan (Jericho) and elsewhere (*cf*. Kenyon 1981; Stordeur *et al.* 2000; Mazurowski and Yartah 2002; Yartah 2005; Schmidt 2007, 2010, 2012; Stordeur and Ibáñez 2008; Kuijt and Finlayson 2009; Finlayson *et al.* 2011; Karul 2011). Concentrations of material culture of a distinctive symbolic nature (*e.g*. animal, human and humanoid reliefs and sculptures, pillars, bucrania and other animal bone installations, skulls, engraved stones and other artefact caches, *etc*.) and burials are often found associated with such structures. For this reason, they have been interpreted by several scholars as foci of symbolically and/or ritually charged activities such as communal food storage and consumption, mortuary and feasting rites, and as aggregation sites (see chapters in this volume; also Watkins 2010; Finlayson *et al.* 2011; Dietrich *et al.* 2012; Asouti and Fuller 2013).

The ubiquity of communal buildings across the different regions of the Fertile Crescent alongside the material record of regionally distinctive symbolic and ritual behaviours, are treated by some scholars as indicators of increasing social complexity in the course of the early PPN (*cf*. Byrd 2005; Watkins 2010). Inasmuch as the ecological context of these socioeconomic developments and symbolic

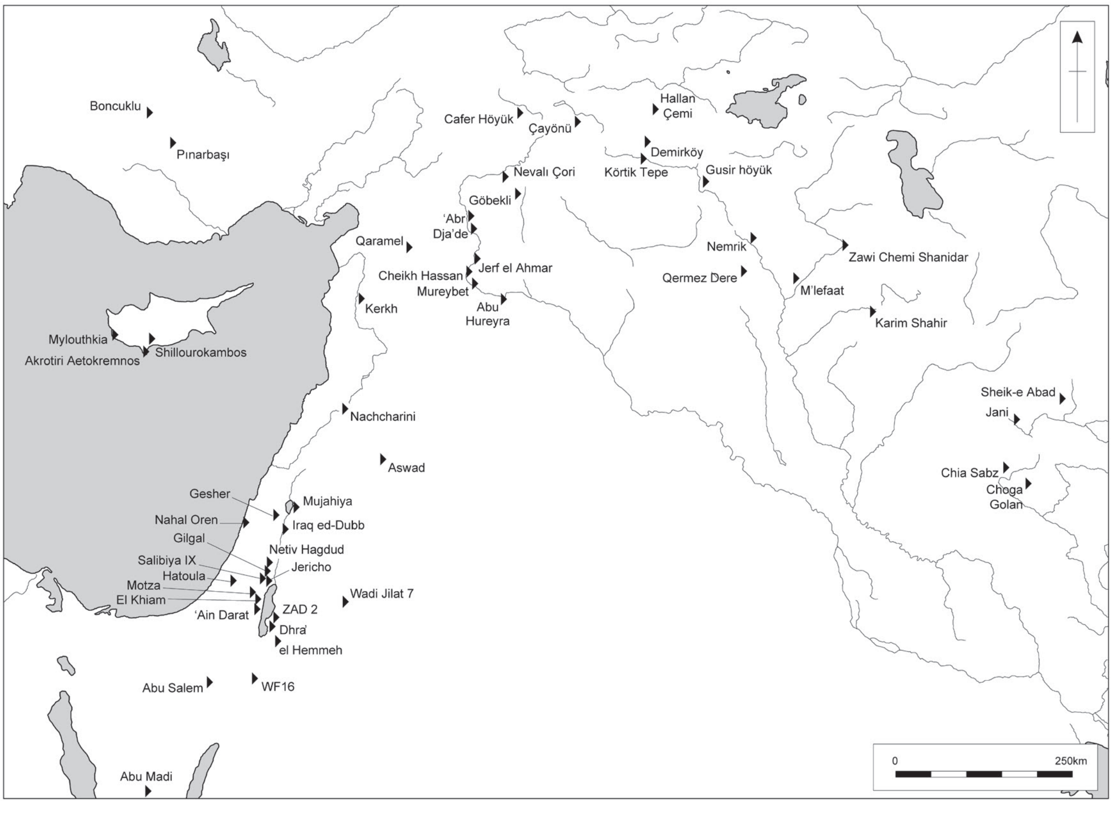

Fig. 1 Map showing the location of key excavated early PPN sites in Southwest Asia.

florescence is taken into consideration it has also been hypothesized that they were facilitated by the rapid climatic improvement that marked the start of the Holocene (Byrd 2005). Early Holocene climatic amelioration is believed to have prompted the emergence of highly productive and stable resource environments. This facilitated the intensification of resource use by groups that lived permanently in favourable ecotones and controlled stable, well-defined territories (Zeder 2015). Overall, the current consensus in the literature is that this unprecedented mix of ecological, socioeconomic and cultural developments paved the way for the appearance at the end of the early PPN of plant and animal domestication, which was followed by the establishment and spread of agro-pastoral economies and "village" life during the late PPN (*i.e.*, from the second half of the 9th millennium cal BC onwards) (see overviews by Harris 2002; Byrd 2005; Zeder 2008, 2015; Asouti and Fuller 2012, 2013).

Much of the ecological argument invoked in support of early PPN resource intensification and its relation to increasing sedentism, symbolic behaviours and social complexity and the emergence of regionally distinctive corporate institutions and identities, has been based on the conceptualization of the first two millennia of the Holocene as a period of remarkable climatic and ecological stability, which radically transformed the nature and scale of the regional hunter-gatherer landscape practices. This is contradistinguished with the pattern of punctuated climatic instability that prevailed during the late Pleistocene, which is believed to have inhibited the macroevolutionary development of the ecological and socioeconomic processes associated with the transition to food production (Richerson *et al.* 2001). The notion of the importance of resource-rich environments in the formation of food producing economies is of course not new in the prehistoric archaeology of Southwest Asia. Similar ideas were tested for the first time in the 1940s and 1950s by Robert and Linda Braidwood of the Chicago Oriental Institute, in the context of their fieldwork expeditions in northern Iraq. The "Nuclear Zone Hypothesis" (NZH) (Braidwood and Howe 1960) postulated that post-Pleistocene hunter-gatherers gradually settled in resource-rich areas where they developed close, symbiotic relationships with preferred plant and animal resources alongside processing and storage technologies that eventually led to their domestication and the emergence of agriculture. The NZH represents in many ways the archaeological offshoot of the much earlier theory of the "centres of origin" formulated by the Russian plant geneticist Nikolai Vavilov, who proposed that present-day hotspots of genetic crop diversity overlap geographically with the ancient centres of origin of the domesticated crop species (Vavilov 1992). In Southwest Asia the "hilly flanks" (*i.e.*, the piedmont zone) of the Taurus-Zagros arc were subsequently identified by Harlan and Zohary (1966) as the primary habitats and centres of origin of the Near Eastern crop progenitor species, which overlapped with Braidwood and Howe's (1960) "nuclear zone" of initial domestication.

The NZH represents a classic example of a pull theory, based on the notion that resource abundance (the "pull" factor) is a key precondition of economic, technological, and sociocultural innovation and progress. As such, it stands in direct opposition to "push" theories positing that resource stress (instead of abundance) played a central role in prehistoric socioeconomic change. Resource-stress theories first became popular by Gordon Vere Childe. His "Oasis Hypothesis" (inspired by a similar theory proposed in 1908 by the American geologist Raphael Pumpelly) posited that climate desiccation at the end of the Pleistocene forced the crowding of humans, plants and animals around shrinking water bodies

Late Pleistocene-Early Holocene chrono-cultural horizons in Southwest Asia	**Dates (calibrated years BC)**
Late Epipalaeolithic	~12,000-10,000
Pre-Pottery Neolithic A (PPNA)	~ 10,000/9700-8700
Early PPNB (EPPNB)	~8700-8200
Middle PPNB (MPPNB)	~8200-7500
Late PPNB (LPPNB)	~7500-7000
Pottery Neolithic	~7000-6000
Chalcolithic	~6000-4000

Table 1 Summary of prehistoric chrono-cultural horizons and associated radiocarbon chronologies in Southwest Asia.

("oases") eventually leading to the development of symbiotic, domesticatory relationships (Childe 1928). Later examples of push theories focused primarily on demographics (in particular population pressure) as the cause of resource depletion and stress rather than negative climate change, including Lewis Binford's (1968) "Marginal Zone Hypothesis" and, in relation to it, Kent Flannery's (1969) "Broad Spectrum Revolution". Both pull and push models of the probable causes of the Neolithic transformation represent the intellectual backbone of several influential theories of global agricultural origins including David Rindos' Coevolution Theory (1984), hypotheses about the role of the Younger Dryas cold and arid spell in the onset of early cereal cultivation and domestication (Moore and Hillman 1992; Sherratt 1997; Hillman *et al.* 2001; Bar-Yosef and Belfer-Cohen 2002) and, more recently, Optimal Foraging Theory (OFT) (Kennett and Winterhalder 2006; Gremillion *et al.* 2014) and Niche Construction Theory (NCT) (Smith 2011, 2015; Zeder 2015). OFT and NCT are also based on the same fundamental opposition between conditions of resource stress (OFT) and resource abundance (NCT) as the prime enablers of prehistoric economic behaviours and decision-making.

The main theoretical position developed in this chapter is that both pull and push models provide binary and normative definitions and predictions of resource availability, properties and ecologies that are unrealistically removed from human experience. This is because they draw on abstract concepts of environmental stability and instability that are respectively equated with macro-climatic improvement and deterioration. They thus provide limited tools for understanding periods of human history during which dynamic, multi-scalar, complex processes of change were manifest in all domains of life, ecological and sociocultural, and in the environment. The early PPN of Southwest Asia represents a prime example of such a period, for which there are furthermore no viable ecological and socioeconomic analogues in the historical and the ethnographic present (Asouti 2013). As it will be demonstrated later in this chapter, despite the dramatic climatic improvement that marked the onset of the Holocene, its first two millennia were an era of profound short- to medium-term ecological instability that was particularly pronounced in the semi-arid, continental interiors of Southwest Asia, and impacted significantly the distribution and predictability of landscape resources. Therefore, a more realistic reconstruction of early PPN human palaeoecology requires a more dynamic standpoint, one that takes into account the regional bioclimatic and ecological diversity, and the complexity and dynamics of the interactions between climate, resources and economic behaviours. Moreover, in the diverse and rapidly changing environments of early PPN Southwest Asia economic behaviours did not depend solely or even primarily on expediency, but also on historical landscape experiences and memories of past events, which informed socialized forms of environmental knowledge transmission.

Based on these premises, this chapter proposes an explicitly historical-ecological approach focusing on understanding the ecological impacts of short- to medium scale climate oscillations (centennial, decadal), the seasonality of critical variables (precipitation, temperature), how they affected the balance of woodland and grassland vegetation, fire frequency and herbivory, and their cumulative impacts on resource distributions, ecology, physiology and phenotypes. Such a survey of the regional ecologies (rather than the traditional format of palaeoecological investigations in Southwest Asia concentrating on millennial-scale environmental change) reveals a picture of rich, yet fragmentary and seasonally unstable resource environments and highly fluctuating resource ceilings. It is argued that these ecological constraints severely limited the capacity of PDC to generate sufficient and predictable enough subsistence yields, and therefore the ability of early PPN hunter-gatherer societies to depend on it as the staple subsistence provider. Meso- to micro-ecological instability, experienced in the context of the resource-rich environments of the first two millennia of the Holocene, also provided early PPN societies with the impetus for developing locally distinctive resilience strategies. These included flexible economic behaviours alongside social practices that fostered inter- and intra-group cooperation through the acquisition, storage, and transmission of environmental and landscape knowledge, and the circulation of material culture and foodstuffs through community interaction networks. Furthermore, the material culture record provides evidence for the prominent role of historical experiences of environmental change in early PPN symbolic behaviours and cosmologies.

A cornerstone of the arguments presented in this chapter relates to the reconstructed impacts of short- to medium-term climatic instability on the ecology, productivity and predictability of crop progenitor species and associated economic behaviours. With notable exceptions (*e.g.* Hillman 1996) the landscape ecology of plant gathering and early cultivation is an issue that has been mostly overlooked by archaeobotanical studies of PDC and the regional evolution of the domestication syndrome. More often than not plant domestication in Southwest Asia is approached from a narrowly defined biological viewpoint, in isolation from its wider ecological and sociocultural contexts. However, these contexts provide an appropriately inclusive framework for understanding the nature and limitations of early PPN plant management practices and, by extension, the underlying causes of the slow pace of morphological domestication observed during this period (see discussion in Asouti and Fuller 2013). This argument is developed further in this chapter, by drawing on previously overlooked aspects of the regional palaeoecological and archaeobotanical records. It is proposed that early Holocene climate change and associated vegetation ecologies (rather than the intensification of PDC by early PPN hunter-gatherer communities) played a significant role in the development of larger seed size in cereal crop progenitor species. The archaeobotanical and ecological indicators traditionally associated with the identification of PDC are also reviewed in detail, in order to provide a more realistic reconstruction of its nature and predicted ecological impacts and economic returns. Furthermore, drawing on recent genetic studies, it is argued that community interactions (rather than the polycentric development of PDC by insular sedentary communities) played a pivotal role in the regional spread of socially valued cultivars that gave rise to domesticated crop species during the late PPN.

The agronomic limitations of PDC were not overcome until the late PPN (*i.e.*, after the mid-9th millennium cal BC) in a process that overlapped temporally and spatially with the spread of domesticated caprine herding. It is proposed that the use of animal manure as fertiliser was the tipping point, by enabling the development of fixed-plot intensive horticulture and boosting the productivity of cereal and pulse cultivation while also buffering it against seasonal environmental risks. The herding of domesticated caprines altered irreversibly the ecological balance of Southwest Asia through the conversion of steppe grasslands into pastures. It is argued that it was these direction-changing developments in the nature, technology and organization of food production, rather than the putative impacts of PDC on the biology of managed plant species, that enabled the spread of domesticated crop mixtures and anthropogenic agroecologies and the establishment of long-lived, sedentary "village" communities dependent on mixed agropastoral production as the staple subsistence provider. The chapter concludes by outlining a historical-evolutionary model for the comparative study of global agricultural origins and, more generally, human economic behaviours during periods of major ecological and socioeconomic change. This emphasises the need to construct hypotheses that address the interconnectedness of geographically and historically contingent resource ecologies with the multi-layered ecological, economic and sociocultural factors that constitute human lifeways.

Climate Change and the Relationship of Resource Ecologies to Resource Choice in Late Pleistocene and Early Holocene Southwest Asia

Global palaeoclimatic archives derived from marine sediments and polar ice cores have established the existence of large-scale shifts in global climate (*e.g.* glacial-interglacial climate cycles) caused by the interaction of the Milankovitch cycles: periodic variations in the Earth's eccentricity, axial tilt and precession (lasting ~100 kya, 41 kya and 19 kya respectively) that impact the amount, seasonality and location of solar insolation around the planet at supra-millennial time scales (Hays *et al.* 1976; Wunsch 2004). The last Ice Age was paced by shorter-scale climate oscillations, known as the Dansgaard-Oeschger (DO) events, occurring in cycles of ~1500 years: in the northern hemisphere these took the form of decadal-scale warming episodes, followed by gradual cooling over a longer period of time that was then terminated by another decadal-scale cold and arid episode (Dansgaard *et al.* 1993; Bond *et al.* 1997; Alley 2000). Some of the DO cycles were preceded by rapid cold episodes known as the Heinrich (H) events that lasted ~1000 years and resulted from the release of ice raft debris in the North Atlantic (Bond *et al.* 1992; Bond and Loti 1995) (see also Fig. 2). Some researchers identify the Younger Dryas (dated in the ice core records at ~12,900-11,500 cal BP) as the last Heinrich event (H0) of the Pleistocene, while others attribute its rapid onset to the release of large amounts of glacial meltwater from North America (*cf.* Bond and Loti 1995; Broecker 1998). Typically, the end of the Younger Dryas is identified through abrupt increases in temperature and precipitation that marked the onset of the Holocene (Alley *et al.* 1993; Severinghaus *et al.* 1998). This improving trend was reversed at ~11,400 cal BP by a cold episode known as the Pre-Boreal Oscillation (PBO) that lasted ~200 years and was terminated by another decadal-scale warming at ~11,270 cal BP (Bjork *et al.* 1997; Kobashi *et al.* 2008). Reconstructions of surface temperatures have indicated that temperatures after the PBO were warmer than before it, which has led some authors to hypothesize that this phenomenon may be consistent with observations of a two-step warming at the onset of the Holocene (Seppä *et al.* 2002; Kobashi *et al.* 2008). After ~11,200 cal BP Holocene climate was characterized by remarkable, by comparison to earlier periods, stability; climatic conditions reached an optimum by ~9000 cal BP. During this period, the most notable change in northern hemisphere climate was in temperature seasonality. Annual mean changes in surface air temperature

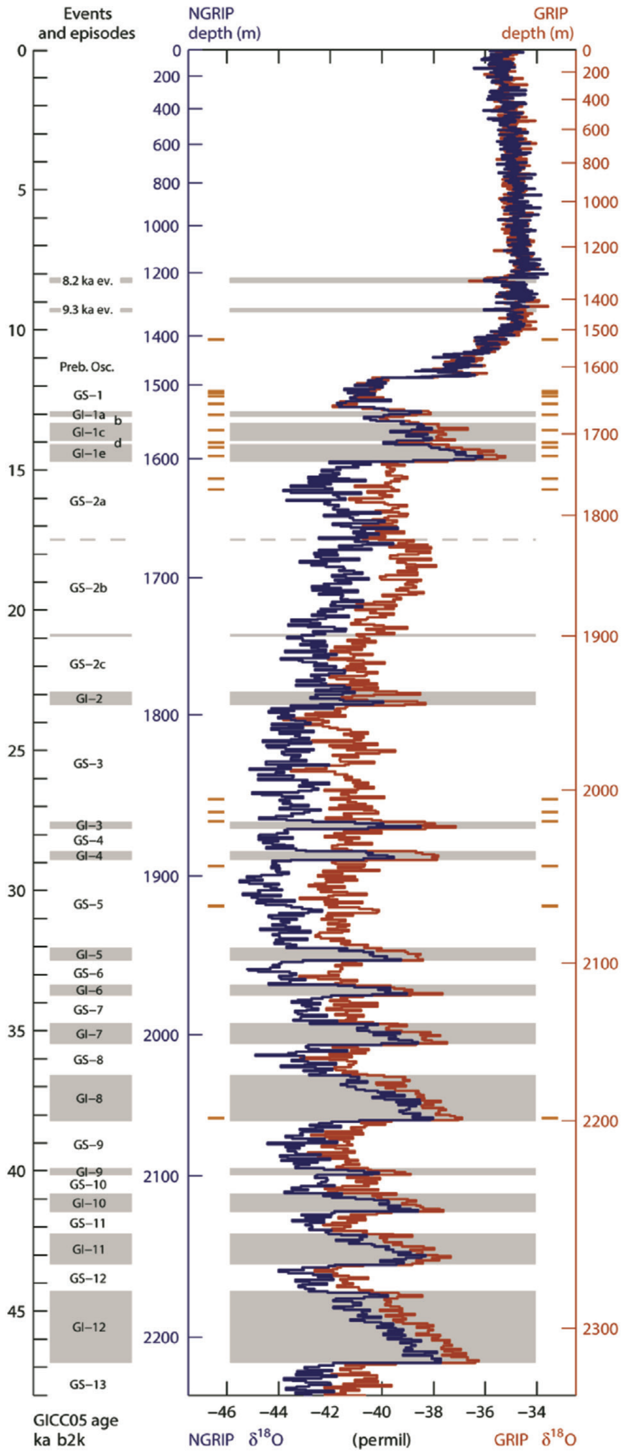

Fig. 2 INTIMATE Project stratigraphy of Greenland Stadial/Interstadial (GS/GI) cycles for the last 48 kyr BP (before 2000 AD) based on the Greenland ice core records and GICC05 ice core chronology (modified after Blockley *et al*. 2012: Fig. 1).

were of lower amplitude than seasonal changes: between ~12,000-8000 cal BP winters were cooler and summers warmer than today, with the maximum winter-summer difference observed around 9000 cal BP (Brayshaw *et al.* 2011).

In Southwest Asia, the Younger Dryas has been identified as a period of intensely cold and arid conditions. Jones *et al.* (2007) have calculated from lake oxygen isotope records that precipitation and temperature were lower by comparison to the late Holocene (see also Bar-Matthews *et al.* 1997; Table 2). This general precipitation pattern appears to have been consistent between Anatolia and the Levant although, as expected, regional N-S and E-W gradients are also evidenced in the available records: the Soreq cave speleothems in the southern Levant record higher values than the Eski Acıgöl crater lake in central Anatolia, and the latter higher values than lake Van in eastern Anatolia. Terrestrial pollen records match closely these regional precipitation gradients: in the Hula basin catchment (situated in the Mediterranean Woodland Zone of the Levantine littoral) oak pollen values dropped from ~70% during the warm and wet Bølling-Allerød interstadial to ~30% during the Younger Dryas stadial, while at the same time grass pollen values *increased* to 30% (Baruch and Bottema 1999; Bottema 2002; Wright and Thorpe 2003) (Fig. 3). This pattern of vegetation response suggests that in the wetter (by comparison to inland Southwest Asia) Levantine littoral, grasses were able to compete more effectively with trees for finite ground moisture resources under the cold and arid conditions of the Younger Dryas. Further north, in the Syrian Ghab valley catchment its re-dated pollen sequence points to a more pronounced decline of oaks during this period, and the coeval expansion of *Artemisia*-Chenopodiaceae steppe instead of grasses (Niklewski and Van Zeist 1970; Wright and Thorpe 2003). Similarly, in the more continental inland regions of central and eastern Anatolia the Younger Dryas was marked by the retreat of grasslands and the expansion of *Artemisia*-Chenopodiaceae steppe (Roberts *et al.* 2001; Woldring and Bottema 2002/2003; Wick *et al.* 2003). The combined pollen and anthracological data also indicate that, in contrast to the western Levantine littoral, trees never formed a significant component of the vegetation of inner Anatolia during the warm and wet conditions of the Bølling-Allerød. Instead, grassland vegetation (including Cerealia) prevailed associated with a sparse, low-density tree cover (dominated by members of the Rosaceae family, *Pistacia*, with low representation of *Juniperus* and

Dates cal BP	Key climatostratigraphic subdivisions	INTIMATE Project nomenclature for Greenland Stadial – Interstadial cycles (GS/GI)	General climate trends in Southwest Asia
21,200-14,700	Last Glacial	GS-2	Cold, arid (low precipitation and evaporation)
14,700-12,650	Bølling-Allerød interstadial	GI-1	Warm and wet (increasing temperatures [14.5-18.0°C] and precipitation [~550-750 mm p.a.])
12,650-11,500	Younger Dryas stadial	GS-1	Cold, arid (low precipitation and temperature)
11,500-8,200	Early Holocene		Warm and wet (increasing temperatures ~14.5-19.0°C and precipitation ~675-950 mm p.a.); increased seasonality of climate with wet winters and dry summers.
8,200-present	Mid Holocene to present		Establishment of modern climatic regime (temperatures ~18.0-22.0°C; precipitation ~450-580 mm p.a.); increasing aridification impacts compounded by anthropogenic impacts on the environment

Table 2 Major climatic regimes in the Eastern Mediterranean from the Last Glacial Maximum to the Holocene (based on Bar-Matthews *et al.* 1997, 1999; Robinson *et al.* 2006; Orland *et al.* 2012; Dean 2014; see also Fig. 2).

deciduous *Quercus*) (Roberts *et al.* 2001; Woldring and Bottema 2001/2002; Litt *et al.* 2009; Asouti and Kabukcu 2014; Kabukcu in press) (see also Fig. 4). Further east, on the Zagros mountain range, sparsely wooded *Pistacia* grasslands were dominant during the Bølling-Allerød, which were replaced by *Artemisia*-grass steppe during the Younger Dryas (Van Zeist 2008). These important differences between the vegetation histories of the Mediterranean and the Irano-Anatolian bioclimatic regions are verified by the exceptionally long pollen sequences obtained from lakes Van, Urmia and Zeribar, which confirm that, unlike grasses, trees did not form a prominent element of the vegetation of continental inland Southwest Asia before mid- to late Holocene times[2] (Bottema 1986; Wick *et al.* 2003; Djamali *et al.* 2008; Van Zeist 2008; Litt *et al.* 2009).

Previous models of the impacts of climate change on the availability of plant resources to late Pleistocene hunter-gatherers assumed the existence of a positive correlation between stable "climax" arboreal-grassland habitats (dominated by deciduous oaks and/or *Pistacia*) and periods of climate improvement, and of steppe habitats (dominated by shrubs and herbs) with periods of climate deterioration (*e.g.* Zohary 1989; Hillman 1996). However, as discussed above, the available data on the regional Late Glacial palaeoclimatic and vegetation histories reveal a much more complex picture of terrestrial biome responses to the Younger Dryas across the different bioclimatic regions of Southwest Asia. Recently obtained palaeoclimatic records from the Soreq cave in Israel have provided additional insights into aspects of climate that are critical for subsistence economies, particularly seasonality: while climate conditions in the southern Levant were overall arid and cold during the Younger Dryas, seasonal variations in precipitation appear to have been of lower amplitude by comparison to the Holocene and the Bølling-Allerød (Orland *et al.* 2012). In addition, due to lower temperatures and decreased evaporation rates, major water-bodies such as the Dead Sea appear to have been characterized by a more positive water balance, inferred by high lake levels (Litt *et al.* 2012). In turn, these inferences of decreased precipitation seasonality point to the possibility that in the southern Levant resource predictability (hence the ability of prehistoric groups to anticipate and cope with seasonal resource shortfalls) might have been somewhat higher during

2 Djamali *et al.* (2008) have reported a pre-Holocene peak in oak pollen observed in the long sequence from lake Urmia during the last interglacial period. However, the presence in the same pollen zone of the mesic, thermophilous, Euxino–Hyrcanian element *Zelkova caprinifolia* (which is notably absent from Holocene pollen spectra) points to climate conditions (milder winters and more spring or summer rainfall) during the last interglacial that were much more favourable for the expansion and establishment of woodland vegetation by comparison to the Holocene.

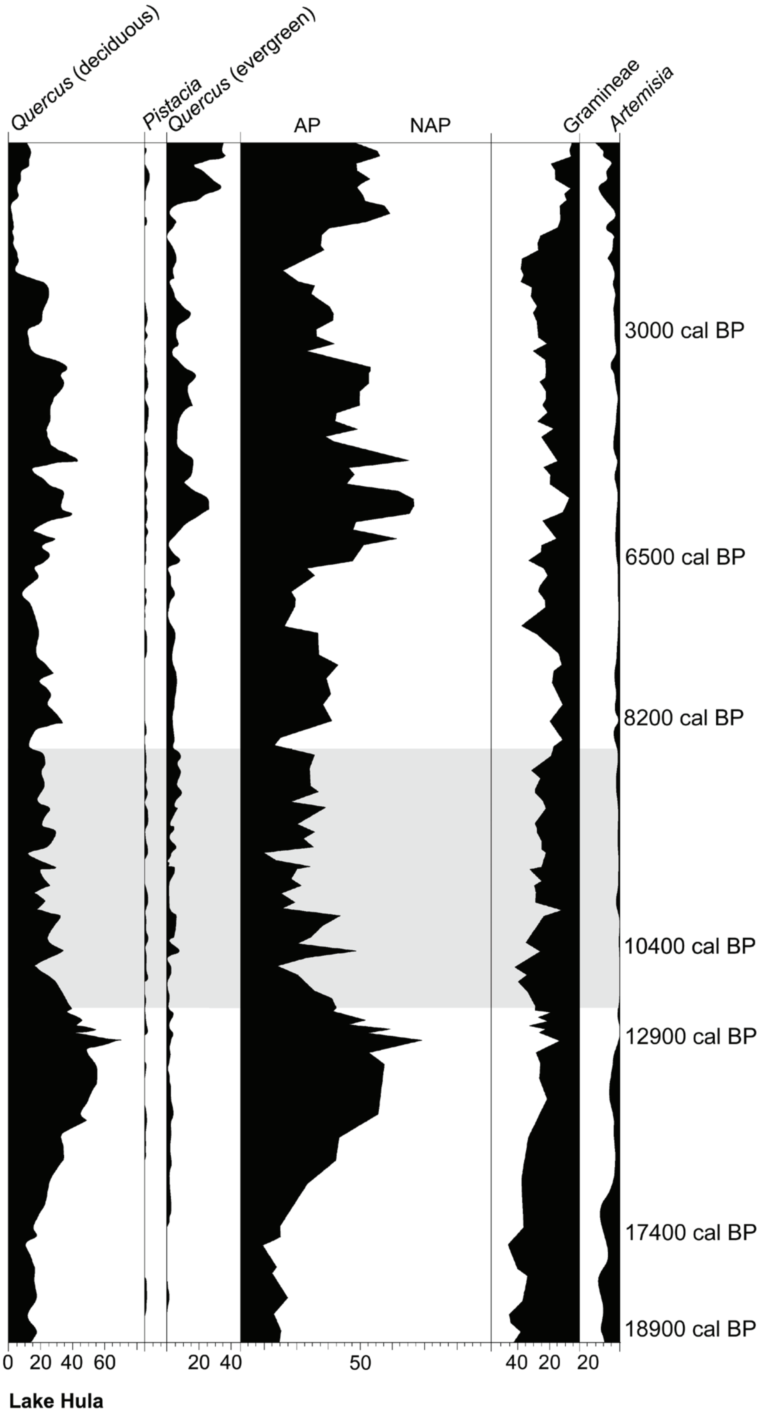

Fig. 3 Select curves from the Lake Hula pollen diagram (shaded area indicates early Holocene) (dating follows Wright and Thorpe 2003).

the Younger Dryas *independently* of net resource ceilings. Palaeoecological records thus add an important new dimension to ongoing debates about the nature of the transition from the early to the late Natufian, and the evolution of the southern Levantine late Epipalaeolithic subsistence strategies (see discussion in Henry 2013). This inference of decreased climate seasonality during the Younger Dryas seems unlikely to have applied to other regions of Southwest Asia. High lake levels have not been deduced from palaeolimnological records in central Anatolia (Dean 2014) while, as discussed earlier, trees and grasslands appear to have been equally negatively impacted by the cold and arid conditions of the Younger Dryas. Evidence for habitation sites dating from this period is, tellingly, lacking from the central Anatolian plateau (Woldring and Bottema 2001/2002). In other parts of inland Southwest Asia, prehistoric groups adjusted their mobility and subsistence strategies to the marked shifts in the availability of woodlands and grassland biomes, by managing ecotonal catchments characterized by more diverse ecologies including alluvial-steppe and persistent arboreal habitats (*cf.* Savard *et al.* 2006; Asouti and Fuller 2012; Riehl *et al.* 2012; Willcox 2012a; Henry 2013 and references therein). Thus it appears that only in the harshest environments (*e.g.*, in central Anatolia) the Younger Dryas might have forced prehistoric communities to adopt highly mobile lifeways leaving few if any archaeological traces.

The hypothesis that cultivation and domestication first emerged in the Levant during the Younger Dryas as a response to the reduction of wild cereal stands due to adverse climatic conditions, saw its initial verification in Gordon Hillman's analysis of the archaeobotanical remains from Abu Hureyra in northern Syria (Hillman 2000). Hillman based his conclusions on the finds of larger "plump" rye seeds in late Epipalaeolithic layers and the coeval increase in small-seeded grasses and legumes, which he viewed respectively as evidence for selection for large seed size under cultivation and the local development of an arable "weed" flora (Hillman *et al.* 2001). While the finds of domesticated-type rye grain from the late Natufian levels of Abu Hureyra were soon afterwards dismissed as intrusive (Nesbitt 2002) the impression of the site as a Natufian example of PDC has persisted in the literature (*cf.* Willcox 2012a). However, in their recent comprehensive re-assessment of the Abu Hureyra archaeobotanical record Colledge and Conolly (2010) have cast serious doubt on the hypothesis of late Natufian PDC. They argue that the higher

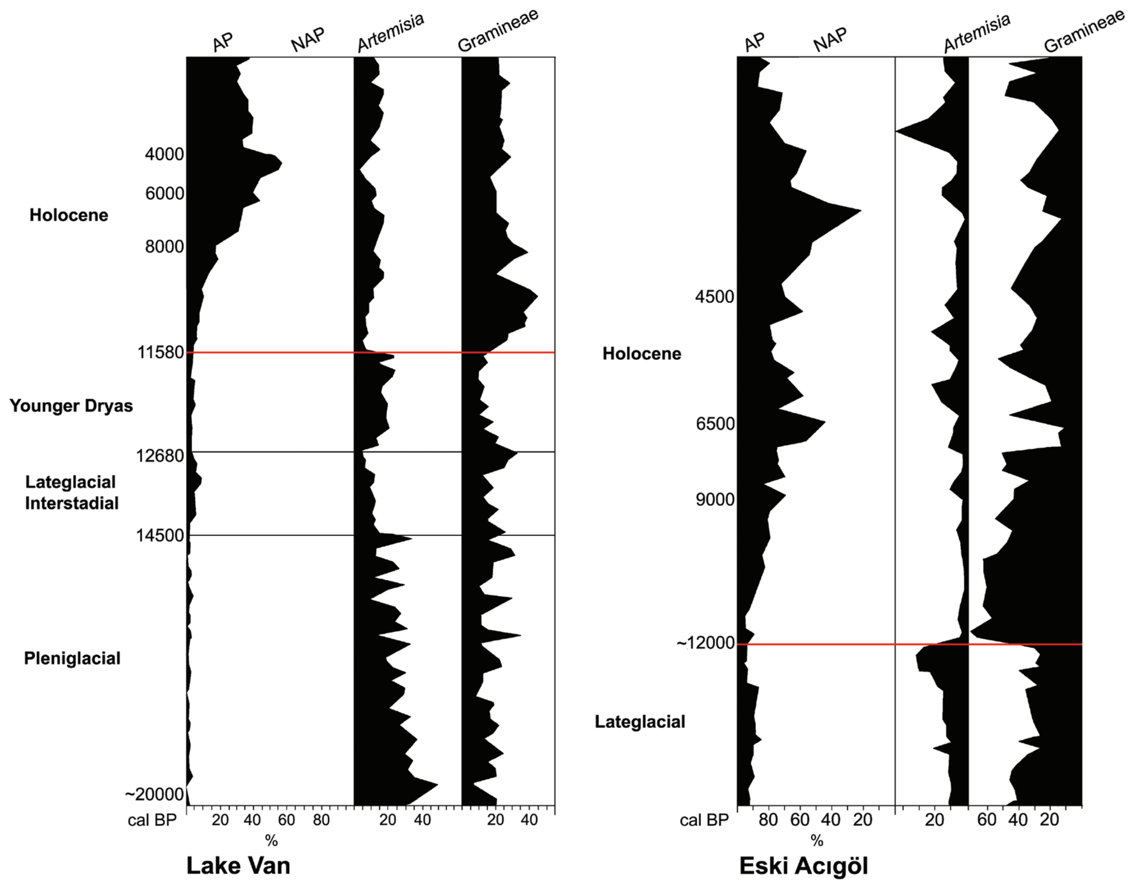

Fig. 4 Select curves from the Lake Van (Eastern Anatolia) and Eski Acıgöl (Central Anatolia) pollen diagrams (original data published by Wick *et al.* 2003; Litt *et al.* 2009, and Roberts *et al.* 2001; Woldring and Bottema 2001/2 respectively).

frequencies of small-seeded grasses and legumes in the late Natufian archaeobotanical samples can be more parsimoniously explained as plant foods gathered from the wild. Colledge and Conolly propose that the gradual reduction in the frequencies of large-seeded cereals and legumes, and the coeval increase of small-seeded grasses and legumes, are more likely to reflect the substitution of high-ranked, large-seeded plants as the preferred plant food subsistence source by a broad spectrum of low-ranked, small-seeded taxa. They thus interpret the changes observed in relative taxon frequencies as evidence of an increase in diet-breadth through time, which was caused by negative climate impacts on the availability of high-ranked, large-seeded taxa in the environs of Abu Hureyra during the Younger Dryas (Colledge and Conolly 2010: 137 [thus largely following a similar line of argument to that previously proposed by Hillman *et al.* 1989]).

The Abu Hureyra case study represents a classic example of the conceptual divide between "environmental determinist" and "optimal foraging" models of prehistoric economic behaviours (*cf.* Bettinger 1991; Winterhalder 2001). While the former view prehistoric societies as passively responding to external impacts on the resource base (exemplified in the case of Abu Hureyra by Hillman's interpretation of the pivotal role played by the Younger Dryas in the adoption of cultivation), the latter view economic decision-making as underpinned by environmentally constrained resource selection. Resource selection refers to the ranking of resources according to their abundance and preference. In turn, preference is defined primarily by microeconomic criteria including caloric yields and acquisition (collection and processing) costs. The interpretation of the Abu Hureyra archaeobotanical sequence proposed by Colledge and Conolly represents an example of an optimal foraging model, with its emphasis on diet-breadth increase as a response to the reduced availability of high-ranked resources. However, modelling resource choice based on microeconomic benchmarks can be misleading on both ecological and economic grounds. For example, collecting and processing of low-ranked, small-seeded plants is typically predicted to be low-return in terms of harvested calories and more labour-intensive compared to high-ranked, large-seeded species (*e.g.* crop progenitor species). Yet, it has been observed that small-seeded grasses harvested from the wild tend to have lower seed-chaff ratios and a higher number of seeds per stalk compared to large-

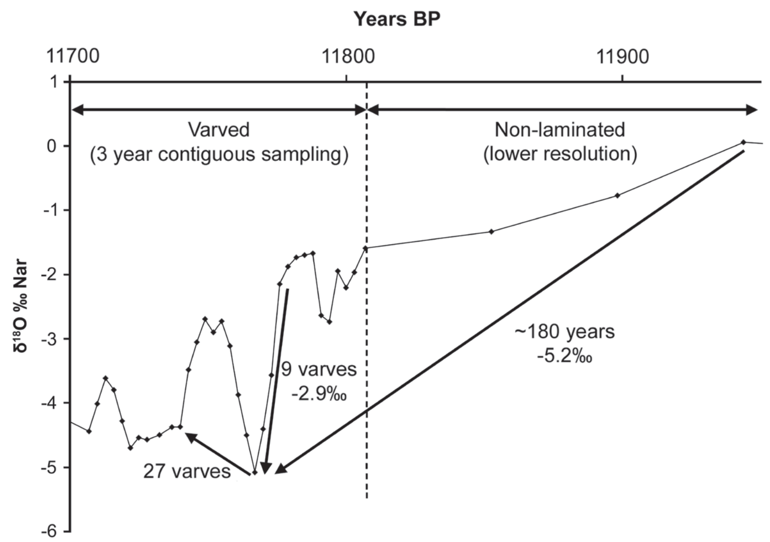

Fig. 5 The Younger Dryas termination as recorded in the Nar Gölü stable oxygen isotope sequence (modified after Dean 2014: Fig. 10.6).

seeded glume progenitor species such as wild-type einkorn, emmer and barley (Blumler 2002). More recent studies have found no significant differences in yields and seed-chaff ratios between progenitor and non-progenitor taxa (Preece *et al.* 2015). A different reading of the Abu Hureyra archaeobotanical data might thus emphasize the greater availability and abundance of small-seeded grasses and legumes in the site environs as the main determinant of resource selection by its inhabitants during the Younger Dryas, and the opportunities they afforded for routine subsistence scheduling. Due to their wider ecological preferences these taxa are also likely to have returned more predictable yields by comparison to large-seeded species irrespectively of (assumed) processing costs. Large-seeded species would actually have been more costly to pursue, because they would have had to be collected from increasingly scarce and diminishing natural stands or (following Hillman's interpretation) their seeds planted and tended for several months under a suboptimal climatic regime before they could actually return a yield.

The assumption of substantial reliance on the management of seed plants, including large-seeded cereal progenitor taxa, during the Natufian period in the Levant is widespread in the literature (Bar-Yosef 1998; Valla 2000; Byrd 2005). Direct archaeobotanical evidence is available from few sites, of which only two have provided indications for the significant presence of wild-type cereals: early Natufian Dederiyeh cave (Tanno *et al.* 2013) and late Natufian Abu Hureyra 1 (Hillman 2000) both predating the Younger Dryas. Other northern Levantine facies contemporary with the Younger Dryas include the later phases (2-3) of Abu Hureyra discussed above, Mureybet 1 (Van Zeist and Bakker-Heeres 1986) and the Baaz rock-shelter (Conard *et al.* 2013). These sites have provided very little or no evidence for reliance on crop progenitor species. In the southern Levant, phytolith analyses from early Natufian sites located in the Mediterranean Woodland Zone have indicated that plant-based subsistence derived mainly from tree nuts and fruits rather than large-seeded grasses; by contrast, phytolith finds from late Natufian sites point to an increased reliance on non-cereal grass taxa (Rosen 2010, 2013; see also overview by Asouti and Fuller 2012). However, at the same time (and in agreement with the off-site palynological archives discussed earlier) pollen data have revealed the co-existence of both cereal and tree pollen at several Natufian sites (see Henry 2013 and references therein). Overall, the combined macrobotanical, phytolith and pollen records point to significant variations (alongside some points of convergence) in Natufian plant-based subsistence strategies between the southern and the northern Levant, which cannot be easily reconciled with the expectations of classic "push" '(*i.e.*, resource-stress) models of prehistoric economic behaviours. Instead, they appear much more likely to reflect regional environmental gradients and diversity in the availability and local ecologies of plant resources across different landscape units (*e.g.*, upland and steppe areas, steppe-woodland ecotones and the Mediterranean Woodland Zone).

Across Southwest Asia the termination of the Younger Dryas ushered in a period of warm and wet conditions corresponding to the early Holocene (~11,700-6000 cal BP) (Robinson *et al.* 2006; Dean 2014). The Younger Dryas-early Holocene transition was markedly abrupt. Recent analyses of annually laminated lake sediments from Nar Gölü in Cappadocia (central Anatolia) have indicated that the tempo of the climatic transition was very punctuated, with over half of it occurring within a decade (Dean 2014). A similarly rapid event of ~12 years is registered in the Soreq cave speleothems (Orland *et al.* 2012) (Fig. 5). The Nar Gölü sequence indicates that this extremely rapid, decadal-scale event was followed by a brief very wet episode lasting for 26 varve years, which was terminated at ~11,400 cal BP by a bimodal cooling and arid event (corresponding to the PBO) that lasted for 126 varve years (Dean 2014) (Fig. 6). While the Soreq cave sequence is poorly resolved with regard to the start of the Holocene, the available data nevertheless suggest the prevalence during this period of high-amplitude climate shifts, which did not stabilise in a Mediterranean-type climatic regime before ~10,500 cal BP (Orland *et al.* 2012). Other regional palaeoclimatic records alongside climate modelling have also indicated that the early Holocene was characterized by heightened seasonality in surface air temperature, with markedly dry summer conditions and high levels of winter precipitation (COHMAP 1988; Robinson *et al.* 2006; Brayshaw *et al.* 2011) (Fig. 7). Thus, although early Holocene climate was on the whole wetter and interannual variability was also lower (Allcock 2013; Dean 2014) at the same time seasonality was particularly pronounced with colder and wetter winters and hotter and more arid summers by comparison to later periods.

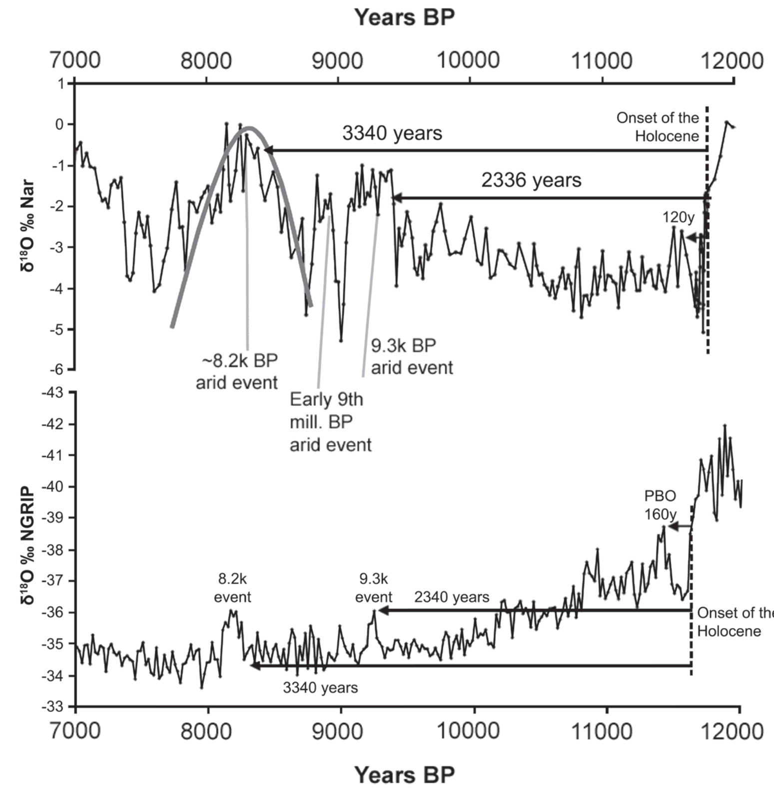

Fig. 6 Comparison of Nar Gölü and NGRIP Holocene stable oxygen isotope records (modified after Dean 2014: Fig. 10.11).

The most noticeable terrestrial response to the rapid climatic improvement at the start of the Holocene was the dramatic expansion of grasslands, including cereal progenitor taxa, which reached their greatest extent during this period particularly in inland Southwest Asia. Grassland expansion in the first two millennia of the Holocene also coincided with a peak in wildfire signals, deduced from micro-charcoal records and charred plant macrofossil frequencies in lake sediments (Wick *et al.* 2003; Wasylikowa 2005; Langer and Wasylikowa 2008; Turner *et al.* 2008, 2010). These studies found very little evidence to suggest that grassland fires were primarily of anthropogenic origin. Their higher frequency fits very well with the reconstructed seasonality patterns for this period, and most likely resulted from the increased availability of high grass fuel loads that were extremely susceptible to fire disturbance during the hot and dry summer seasons (Turner *et al.* 2010). Once more it is possible to trace divergent trajectories of regional fire histories between the west Levantine littoral and the semi-arid, continental interiors of Southwest Asia: micro-charcoal records from the Hula basin in Israel have indicated that woody plants made a greater contribution to micro-charcoal influx; by contrast, sites in continental inland regions such as Eski Acıgöl (central Anatolia), lake Van (eastern Anatolia) and lake Zeribar (Zagros) present the reverse pattern with the predominance of grass charcoals (Wasylikowa 2005; Turner *et al.* 2010: Fig. 7). Overall, this pattern matches very closely the available pollen and anthracological and seed archaeobotanical records, which point to significant regional variations in the composition, density and structure of early Holocene woodland vegetation: oak-grass vegetation was dominant in the Levantine littoral while sparsely wooded *Pistacia*-Rosaceae grasslands prevailed in semi-arid inland areas (*cf.* Roberts *et al.* 2001; Woldring and Bottema 2001/2002; Wick *et al.* 2003; Wright and Thorpe 2003; Van Zeist 2008; Litt *et al.* 2009; Asouti and Kabukcu 2014, Asouti *et al.* 2015; Riehl *et al.* 2015; Kabukcu in press). Some authors (Roberts 2002; Turner *et al.* 2010) have hypothesized that these regional differences in vegetation composition and ecology might reflect early PPN human impacts on woodlands, which delayed the spread of trees, especially deciduous oaks, across inland Southwest Asia. However, considering also the evidence (already discussed) for the sparseness and open structure of Late Glacial woodlands in the continental interiors of Southwest Asia, a more parsimonious explanation is that this time-lag reflects the more rapid response of grasslands to the abrupt increases in moisture and temperature at the start of the Holocene. Cyclic vegetation disturbances, including high-amplitude seasonal differences in precipitation and temperature resulting in higher natural fire frequencies, would have provided grasses with an additional competitive advantage over trees. The prevalence of grasslands over woodlands would have been especially pronounced in inland regions that were characterized by lower annual rainfall averages compared to those of the Mediterranean littoral (Asouti and Kabukcu 2014).

	Surface air temperature		Precipitation			
	Seasonal cycle		*Summer*	*Winter*		
	North Hemisphere continents	East Mediterranean coast	East Mediterranean	All Mediterranean	Anatolia	East Mediterranean coast
Early Holocene	+++	++	0	++	++	+
Late Holocene	++	+	0	+	+	–

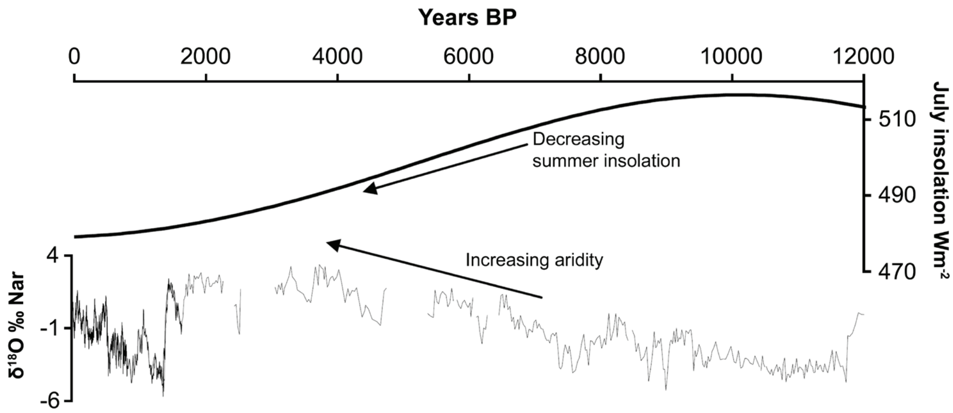

Fig. 7 Modelled climate seasonality for the northern hemisphere continents and the Eastern Mediterranean regions (top) and comparison of insolation changes with aridity trends reconstructed from stable oxygen isotope records at Nar Gölü (+, -, 0 denote increase, decrease and no change relative to the pre-industrial present respectively) (modified after Brayshaw *et al*. 2011: Table 3.2 and Dean 2014: Fig. 10.10).

Early Holocene Resource-rich Environments and the Nature of Early PPN Low-level Food Production

In recent years, resource abundance models of past economic behaviours have provided useful insights into the structure and ecologies of early Holocene low-level food production. Most prominent has been Cultural Niche Construction Theory (CNC) (for detailed overviews see Smith 2011, 2015; Zeder 2015). The basic premise of the CNC is that, instead of passively adapting to environmental conditions, hunter-gatherer groups living on the eve of food production intentionally manipulated and modified their habitats in order to enhance resource productivity, stability and predictability. Smith (2011, 2015) has defined the main predictions of the CNC framework for the characterization of early Holocene low-level food production economies as follows:

(1) They occupied relatively small and few in number settlements located in resource-rich environments and controlled spatially limited, well-defined resource territories.
(2) Archaeobiological assemblages contain evidence for the harvesting of a broad and diverse spectrum of species from biotic communities with no evidence for resource depression.
(3) They established various forms of ownership of "wild" (*i.e.,* biologically non-domesticated) resources and resource-rich territories.
(4) They maintained and consistently updated a comprehensive knowledge of local ecosystems, landscape activities and environmental experience, which was encoded in stories, belief systems and cosmologies.
(5) They engineered ecosystems over multiple generations via sustained and repetitive resource management practices and traditional ecological knowledge transfer, resulting with time in major ecological and genetic transformations of the biotic components of ecosystems.
(6) They increased the relative abundance, predictability, and availability of targeted wild species within resource-catchment areas by enhancing their net primary productivity through niche construction, including modifying local environments through activities such as burning and clearance.

Several elements of the CNC framework provide an overall good fit with the early PPN archaeological and palaeoecological records of Southwest Asia. As discussed in the previous section, climatic improvement was very rapid at the start of the Holocene resulting in the equally rapid, albeit regionally variable, expansion and abundance of grasslands, woodlands and water resources. Regional settlement patterns indicate that habitation sites were relatively small (0.5-1 hectares on average) and widely dispersed in the landscape. A degree of residential and/or logistical mobility is suggested by the occurrence of sites that functioned as transient hunting/foraging camps and activity areas, the relatively limited lifespan of several habitation sites (often not exceeding a few centuries), and the presence of stratigraphic and radiocarbon discontinuities even at sites with long habitation sequences, which indicate episodes of site abandonment and re-occupation (see also Asouti and Fuller 2013 and references therein). The archaeobiological record points to the increasing exploitation of diverse and regionally distinctive repertoires of plant and animal species. Significantly, there is very little evidence for even localised resource depletion during this period (*cf.* Starkovich and Stiner 2009; Zeder 2012). It is also interesting to note that (as least with regard to the available pollen, anthracological and archaeobotanical records) evidence for significant early PPN human impacts on the landscape has remained hitherto elusive (*cf.* Asouti and Kabukcu 2014; Asouti *et al.* 2015; Kabukcu in press). It seems doubtful therefore whether relatively long-lived residential bases managing tightly controlled and temporally stable resource territories were as common in the early PPN settlement patterns of Southwest Asia as is sometimes implied in the regional archaeological literature. The earliest detectable human landscape impacts in the regional pollen and anthracological records date from the late PPN (*i.e*., from the late 9th millennium cal BC onwards). The available evidence points to the suppression of grasslands and the coeval expansion of semi-arid woodland pastures, due to the combined effects of domesticated caprine grazing and increasing woodland management practices that promoted the spread of preferred firewood species across the semi-arid regions of the southern Levant, inner Anatolia, and the Taurus-Zagros foothills and mid-altitude slopes (Asouti and Kabukcu 2014; Asouti *et al.* 2015; Kabukcu in press). Furthermore, the establishment and spread of regionally distinctive agroecologies also dates from the late PPN and the Pottery Neolithic periods (Colledge 2001; Colledge *et al.* 2004).

One of the most important contributions of CNC in agricultural origins research is its conceptualization of low-level food production as "multigenerational ecosystem engineering" targeted at generating sizeable and predictable resource yields (Smith 2011; Zeder 2015). In Southwest Asia, PDC forms one of the most plausible candidates of such a process. In the regional archaeobotanical literature PDC is widely viewed as representative of the intensification of crop progenitor cultivation by year-round settled communities, and as a direct precursor to crop domestication and the development of agriculture. Its archaeobotanical indicators have been attested at several early PPN sites across the Fertile Crescent (*cf.* Van Zeist and Bakker-Heeres 1986; Van Zeist and de Roller 1991/1992; Kislev 1997; Colledge 1998, 2001; Edwards *et al.* 2004; Tanno and Willcox 2006; Weiss *et al.* 2006; Feldman and Kislev 2007; Willcox *et al.* 2008, 2009; White and Makarewicz 2012; Riehl *et al.* 2012, 2013, 2015; Willcox 2012a). Typically, the presence of PDC is assessed through a combination of archaeobotanical and ecological criteria including: (a) an increase in grain size, (b) the decline in the presence and relative frequencies of non-progenitor seed taxa coevally with the increasing frequencies of crop progenitor species, (c) the identification of "weed" floras in higher proportions than their expected presence and abundance in natural grassland vegetation, and (d) the transference of crop progenitor species outside their predicted natural habitats and geographical distributions (*cf.* Colledge 1998, 2001; Willcox *et al.* 2008; Willcox 2012b).

These criteria provide a useful yardstick with which to assess empirically the ecology of PDC, and the agronomic stability and predictability of its economic returns in early Holocene Southwest Asia. Beginning with seed size, the predominant view in the regional archaeobotanical literature is that it increased primarily as a response to the favourable conditions generated by cultivation: soil disturbance via clearance and tillage, and deep seed burial through planting (Fuller 2007; Willcox *et al.* 2008). However, it is also the case that large-seeded progenitor species growing naturally on heavy and deep terra rossa and alluvial soils will display the same plastic response (Blumler 2002). Seed size is furthermore strongly affected by density stand, inter-specific competition and rapid climate change, all of which impose selection on plant populations (Neytcheva and Aarssen 2008; Nicotra *et al.* 2010; Cunniff *et al.* 2014). The heightened seasonality of the first two millennia of the Holocene (characterized by wet winters and pronounced summer aridity) would also have favoured the development of large-seeded varieties (Blumler 1992). Systematic archaeobotanical evaluations of the regional rates and pace of seed size increase have indicated that it was a step-like process, with most of it occurring during the early Neolithic (Willcox 2004). However, at the same time, seed size increase does not appear to have been associated with other archaeobotanically more reliable phenotypic indicators of domestication, such as the occurrence in significant proportions of non-shattering rachises, which are not reported from any of the sampled early PPN sites. According to Willcox (2004) the absence of evidence for other phenotypic changes reduces the likelihood that seed size increase in cereal cultivars resulted from selection pressures imposed by long-lived cultivation practices. Systematic comparisons of cereal seed sizes recorded from the later phases of early PPN sites such as Jerf el Ahmar and Dja'dé with those from the Chalcolithic site of Kosak Shamali (all in northern Syria), have also indicated that there was no significant grain size increase *after* the initial leap manifested during the early PPN (Willcox 2004; see also Fig. 8). In the absence of other indicators of phenotypic change Willcox (2004) concluded that early PPN seed size increase might reflect the introduction of exotic "plump-grain" varieties into northern Syria from moister habitats further north in Anatolia, where wild cereals probably grew under more favourable conditions. An alternative explanation for this step-like increase in grain size, which furthermore accounts for its coeval occurrence in areas outside the northern Euphrates basin, relates to early Holocene fluctuations in atmospheric CO_2 concentrations and their potential impacts on plant productivity. CO_2 values derived from leaf stomatal index data in northwest Europe have indicated a rapid increase from 210-215 ppmv at the beginning of the Younger Dryas to 270-290 ppmv at the start of the Holocene; after a drop to 240-250 ppmv during the PBO (~11,400-11,270 cal yr BP) CO_2 levels rose again to 270-290 ppmv until ~10,800 cal BP (Rundgren and Björck 2003; Fig. 9). In turn, the chronology of these fluctuations correlates very well with the beginning of the later early PPN phase at Jerf el Ahmar (11,200 cal BP) while it also overlaps with the greater part of the habitation at Dja'dé (~11,000-10,300 cal BP). Regardless of the ultimate causes of early PPN seed size increase, the inescapable conclusion seems to be that the potential role of early Holocene climate change in this process has been seriously underestimated; it appears unlikely that repeatedly practiced, multigenerational, stable cultivation activities and their assumed ecological and phenotypic impacts were the major contributing factors.

With regard to seed assemblage composition, the available archaeobotanical datasets reveal considerable diversity and variation between sites and across the different regions of Southwest Asia. This is expected if one considers the diversity of the regional climate gradients and associated vegetation ecologies (see previous section; also overviews of the composition of early PPN archaeobotanical assemblages in Asouti and Fuller 2012, 2013; Riehl *et al.* 2013, 2015). Again, the potential role of climate change and regional ecological variation resulting from natural vegetation disturbance is not sufficiently emphasized in the literature. Inter-regional variation in the presence and relative abundance of cereal crop progenitor species likely relates to climate factors, especially the length of the rainy season (Blumler 1996, 2002). Grasses (including cereal progenitor taxa) are present in a majority of early PPN sites. The predominant presence of barley in Levantine sites as opposed to einkorn in the northern Fertile Crescent may reflect the alignment of plant-derived subsistence averages with the general regional gradients in temperature and the length of the rainy season. By contrast, the differences observed in assemblage composition between sites located in the same bioclimatic region may reflect local micro-ecological diversity alongside cultural preferences. Several sites in eastern Anatolia and northwest Zagros (*e.g*. Hallan Çemi, Demirköy, Qermez Dere, M'lefaat) and in the southern Levant (*e.g.*, 'Iraq ed-Dubb, Netiv Hagdud) contained large quantities of non-cereal taxa and nuts suggesting their preferential management as subsistence mainstays (*cf.* Colledge 2001; Savard *et al.* 2006; Willcox and Savard 2011; Willcox 2012a). At other eastern Anatolian sites such as Körtik Tepe large-seeded grasses were abundant, although on the whole progenitor taxa formed a very small component of the archaeobotanical assemblage (Riehl *et al.* 2012). Annual legumes had a significant presence at several sites in Anatolia and the Zagros (*e.g*., early PPN phases at Çayönü and Nevalı Çori, Hallan Çemi, Qermez Dere, M'lefaat; references above, also Van Zeist 1988; Pasternak 1998). Fire disturbance favours the spread of annual legumes by breaking their seed dormancy and the removal of competing herbaceous growth (Merou and Papanastasis 2009). In addition, legumes are effective colonisers of heavily disturbed, nitrogen-deficient locales due to their capacity to fix nitrogen in the soil (Lajeunesse *et al.* 2006). Assuming (as proposed already) that the higher incidence of early Holocene natural vegetation fires impacted the dense grasslands of inner Anatolia and the Zagros, recurrent episodes of fire disturbance might explain the increased presence of legumes at sites in these areas. In the ecological literature, it is often assumed that fire disturbances always favour the regeneration and spread of cereal progenitor species, due to the relative protection afforded to grains by their spikelets (that facilitate post-fire soil crack penetration) and the removal of competing perennial grass growth (*e.g*. Naveh 1974; Noy-Meir 2001). However, burning of grasslands early in the summer season might have also led to crop progenitor stand collapse due to high rates of seed mortality especially for barley but also for rye, emmer and einkorn. A partial exception would have been stands growing near rocky outcrops or on deep alluvial and terra rossa cracked soils that could have allowed rapid seed burial (Blumler 1992; Hillman 1996: 191). It is thus plausible that crop progenitor populations were seasonally impacted, on occasion even decimated, by natural fires. Being closely linked to the pronounced seasonal variations in temperature and rainfall, cyclic pulses of fire-induced stand collapse likely exerted significant (if localised) impacts on

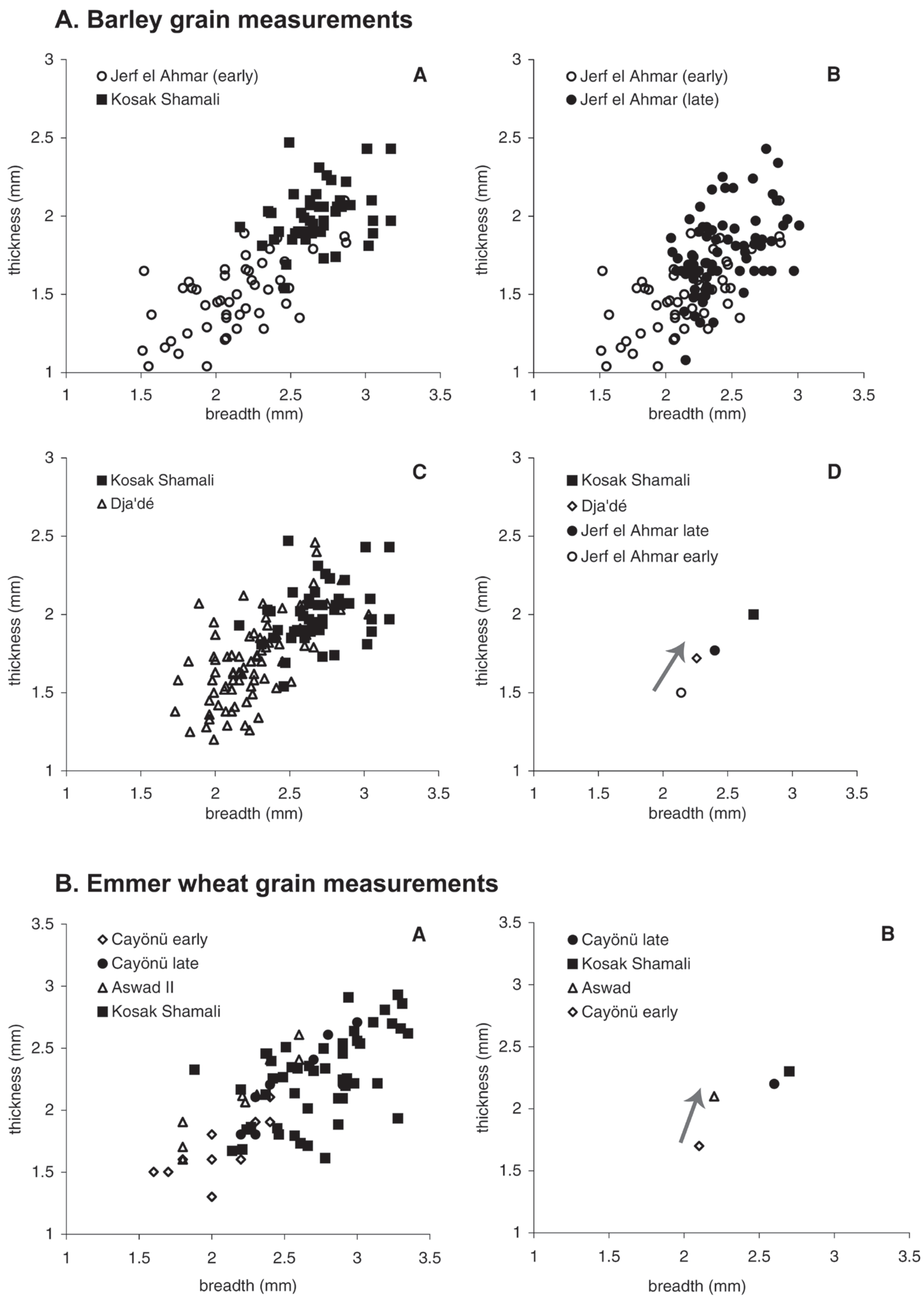

Fig. 8 Scatterplots comparing seed size measurements of (A) Barley grain from Jerf el Ahmar (JEA), Dja'dé and Chalcolithic Kosak Shamali (KS); (B) Emmer wheat grain from Çayönü, Aswad II and KS. Plot A.A shows a clear separation between smaller and larger barley grain sizes from JEA (early) and KS; Plot A.B shows an increase in grain size between JEA (early) and JEA (late); Plot A.C shows larger on average yet more dispersed values from Dja'dé, which indicate a greater overlap with JEA (late) and KS. Plot A.D shows the step-like increase (arrow) in average barley grain size between JEA (early) and JEA (late)/Dja'dé/KS (the further increase indicated by the KS mean barley grain size measurements is not significant as it most likely reflects differences in crop processing methods between early PPN PDC sites and late prehistoric farming sites: in the latter larger seed sizes appear dominant because crop processing is more systematic (including large-scale threshing) while coarse sieving (which removes most of the smaller seeds of cereal ears) also takes place off-site. Plots B.A-B show a similar step-like increase (arrow) from early to late sites. In plot B.A, the greater dispersal of emmer grain measurements (compared to barley measurements) can be again explained by the preference of later farming sites for the storage of glume wheats as whole ears (thus resulting in a greater range of preserved seed sizes). The additional increase in ventral breadth at later sites indicated in plot B.B is likely to reflect the impact of other parameters unrelated to cultivation practices *per se* (*e.g.*, cultivation of different wheat varieties) (modified after Willcox 2004: Figs. 3-4).

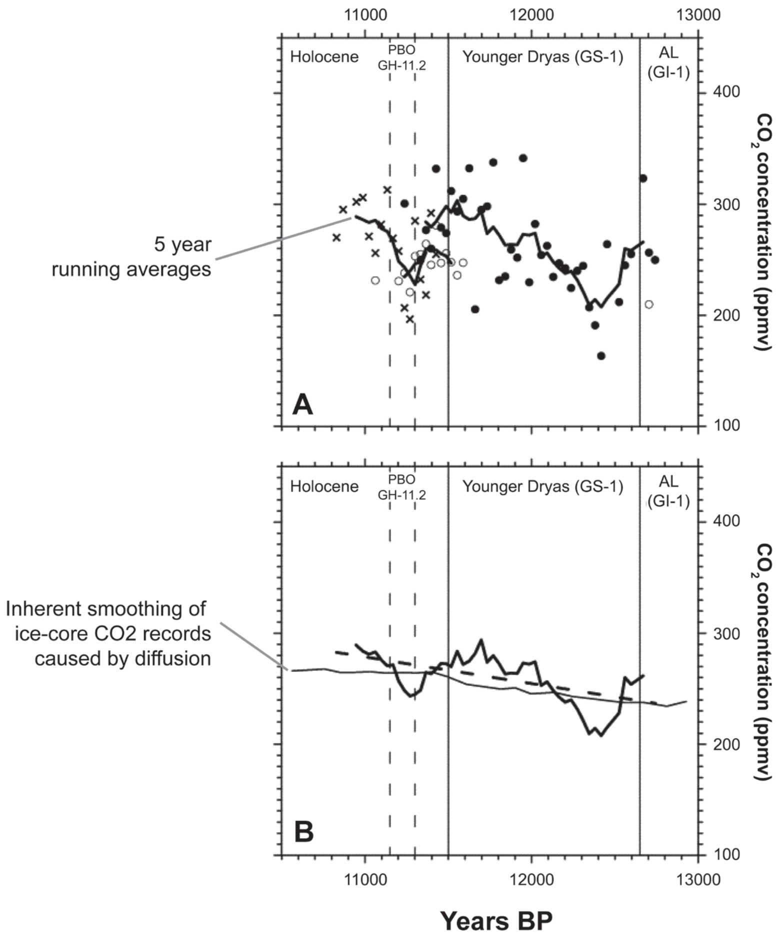

Fig. 9 CO_2 values reconstructed from leaf stomatal index data (SW Sweden) showing rapid increase from 210-215 ppmv at the beginning of the Younger Dryas to 270-290 ppmv at the start of the Holocene, and the sharp drop to 240-250 ppmv during the Pre-Boreal Oscillation (PBO; ~11,400-11,270 cal BP) (plot A) and how they compare to the CO_2 values obtained from Antarctica ice-core records (plot B) (modified after Rundgren and Björck 2003: Fig. 5).

resource availability and predictability, by altering the composition and density of grassland patches and the distribution of preferred grass species near habitation sites, as well as affecting herbivore behaviour. It would appear therefore that for large parts of inland Southwest Asia the assumption of the existence of ecologically stable, resource-rich terrestrial environments that could have supported year-round exploitation of spatially delimited territories is unlikely to hold.

The identification of predomestication cultivation "weed" floras presents its own range of analytical and interpretative challenges. Willcox (2012b) has argued in favour of a taxonomic approach, identifying as suitable candidates for inclusion in "weed" assemblages taxa which: (a) have no historically or ethnographically known uses for their seeds, (b) co-occur in archaeobotanical assemblages with phenotypically wild progenitor species, and (c) belong to the same genus as verified obligatory weeds of cultivation known from later agricultural assemblages. Based on these criteria, he has proposed a list of 19 taxa as the most likely candidates for arable "weed" status (Willcox 2012b: Table 2). An important limitation of the taxonomic approach is that, more often than not, accurate species-level identifications of the carbonized seed remains of wild/"weed" taxa are not feasible. Furthermore, several species belonging to these genera are known to occur naturally in grass steppe and woodland vegetation habitats across Southwest Asia, although Willcox *et al.* (2008: 322) have argued that outside arable habitats such taxa normally occur in low frequencies. However, this argument has been contradicted by Gordon Hillman who noted that, in the absence of very heavy grazing by sheep and goats, several species can also be found in uncultivated steppe "at densities comparable to those of weed-infested arable fields" especially after particularly wet winter seasons (Hillman *et al.* 1989: 253-254). It is therefore possible that (under the higher winter precipitation regime that characterized the first two millennia of the Holocene) wild/"weed" taxa had far wider distributions and ecologies, and occurred in much higher densities in natural grassland vegetation compared to later periods or present-day conditions. One very important implication of this observation is that the proportions of non-progenitor taxa in archaeobotanical assemblages derived from short-lived habitation phases and/or sites are unlikely to represent reliable vegetation fingerprints of PDC. As Willcox (2012a) has observed, assigning "weed" status to non-progenitor taxa should be dependent on the specific characteristics of each archaeobotanical assemblage in its entirety (including close monitoring of shifts in their relative proportions through time). For this reason, it is probably best applied only to those sites that preserve long habitation sequences that have been systematically and comprehensively sampled for archaeobotanical remains.

An explicitly ecological approach has been proposed by Colledge (1998, 2001) classifying wild/"weed" taxa according to modern ecological groupings and monitoring their presence in archaeobotanical assemblages via multivariate statistical techniques. The key assumption is that in archaeobotanical assemblages which are dominated by crop progenitor species the primary pathway for the inclusion of wild/"weed" taxa would have been as "contaminants" of cereal harvests. Their ecological groupings are thus likely to reflect the vegetation composition of the habitats in which cereals were growing. Depending on the nature of these vegetation fingerprints, it might be possible to reconstruct the specific activities that were associated with PDC (*e.g.,* the regular occurrence of soil disturbance indicators would point to tillage, *etc*.) This approach has allowed Colledge (2001) to infer the practice of PDC on naturally fertile alluvial soils. This proposition has found additional empirical support in recent studies of wild cereal progenitor functional ecology, which have indicated that wild cereals may effectively exploit sites characterized by high levels of fertility *and* disturbance (Cunniff *et al.* 2014). An obvious limitation of this approach is that its applicability is limited to archaeobotanical assemblages that are dominated by crop progenitor species: as discussed already this is a condition that is not universally applicable in early PPN Southwest Asia.

The last criterion, the displacement of crop progenitor species from their natural habitats and distributions, is probably the most difficult to evaluate with any degree of certainty based on modern and historical observations and ecological analogues. Modern climate-vegetation associations are of little utility for reconstructing prehistoric plant habitats other than assessing the general relationship between present-day temperature and precipitation gradients and species distributions. This is due to the enormous differences observed between present-day and early Holocene climate conditions in all bioclimatic regions of Southwest Asia. Based on modern observations of floristic associations Zohary (1969) had previously suggested that deciduous oak parklands represent a key primary habitat for cereal and legume crop progenitor species. In recent years, however, integrated archaeobotanical and anthracological studies have demonstrated that the early PPN ranges of progenitor and non-progenitor taxa extended well beyond those reconstructed for deciduous oak woodlands into the sparsely wooded *Pistacia*-Rosaceae semi-arid steppe grasslands that occupied the inland plains and low- to mid-altitude slopes of the Levant, Anatolia and the Zagros foothills (Asouti and Kabukcu 2014; Asouti *et al.* 2015; Riehl *et al.* 2015). Asouti and Kabukcu (2014) have argued that (outside the Mediterranean Woodland Zone and Euro-Siberian montane refugia) relic associations of deciduous oak woodlands with grasses on high-altitude slopes and rocky outcrops represent a mid- to late Holocene phenomenon caused by the retreat of annual grasses from lowland plains, moist steppe habitats and mid- to low-altitude slopes due to millennia of overgrazing and settlement expansion.

Modern and historical associations of progenitor taxa with specific soil types and edaphic conditions are no less problematic. Wild cereals are reported to thrive on terra rossa, hard limestone and basaltic soils, as well as rocky outcrops (Harlan and Zohary 1966; Willcox 2005). However, other studies report much wider edaphic tolerances (including more alkaline soils) for several progenitor taxa both in Anatolia (Karagöz *et al.* 2009) and in the Levant (Nevo *et al.* 1992). At present, such associations persist in areas that are less accessible to livestock; they are thus likely to represent the aggregated result of the retreat of wild cereals from other habitat types due to persistent overgrazing (Zohary and Brick 1961; Noy-Meir *et al.* 1989; Noy-Meir 1990; Valkoun *et al.* 1998; Waines 1998; Karagöz *et al.* 2009). Historically heavily impacted habitats otherwise capable of sustaining dense concentrations of cereal progenitor species include alluvial plains and moist steppe biomes (Harlan and Zohary 1966; Kimber and Feldman 1987). Both habitat types have been used as arable and pasture for thousands of years across all regions of Southwest Asia. The most favourable habitats for wild cereal growth are characterized by the co-occurrence of several ecological factors besides soil types or slope aspect, including highest available soil moisture both at the beginning and at the end of the growth season, least competition for light, highest available soil nitrogen content, and lowest grazing pressures (Noy-Meir *et al.* 1991a,b).

How "Intensive" or "Reliable" was PDC as a Staple Subsistence Provider?

As noted in the previous section, an empirical assessment of PDC based on the first three criteria (*i.e*., excluding modern ecological preferences and distributions) is feasible only for sites that preserve long habitation sequences and have been thoroughly sampled for archaeobotanical remains including multiple lines of evidence. One such site is Jerf el Ahmar where larger seed size emerged in its later phases alongside a reduction in the frequencies of small-seeded taxa (Willcox *et al.* 2008). However, it remains unclear whether this represents the intensification of crop progenitor cultivation, since a coeval reduction in the frequencies of some progenitor species (einkorn and rye) is also evidenced in the published dataset. As discussed already, the 1-step increase in seed size observed between the early and the late phases of Jerf el Ahmar correlates well with the PBO. Its co-occurrence with the shifts in botanical assemblage composition may thus not necessarily reflect the gradual intensification of crop production by a year-round settled community of cultivators-foragers. Alternatively, it might signify the reorganization of plant food procurement and production involving several complementary strategies such as the broadcast re-seeding of locally available wild barley stands, or the transplantation of both barley and locally scarce einkorn and rye into shifting alluvial plots of cleared riparian woodland vegetation during the PBO.

Another site that has preserved a much longer habitation sequence is Chogha Golan, on the Iranian southern Zagros foothills, dating from the end of the Younger Dryas to the 8th millennium cal BC (Riehl *et al.* 2012, 2013, 2015). To date, the published evidence does not indicate clear directional temporal trends in botanical assemblage composition, grain size or the development of wild/"weed" floras. All three key variables (proportions of dominant taxa, barley grain size and the presence and relative frequencies of wild/"weed" taxa) fluctuate widely through time, while there appears to be no consistent pattern of co-variation between them (*cf.* Riehl *et al.* 2015: Figs. 5-7). Despite the evidence for the persistent management of wild-type barley since the earliest phases of the site, the first definitive evidence for the presence of domesticated-type barley rachises dates from the MPPNB, thereafter to disappear, while domesticated-type emmer emerges suddenly in the LPPNB (Riehl *et al.* 2015; see also Fig. 10). In the view of the present author, this diversity of archaeobotanical signatures at Chogha Golan is suggestive of diverse and of highly variable intensity plant management strategies through time. Such flexibility might have developed in response to pronounced micro-ecological variation (*e.g.*, acute spatial and temporal fluctuations in the availability and distribution of alluvial habitats alongside recurrent episodes of seasonal vegetation fires and disturbance) that likely affected the availability and productivity of crop progenitor stands.

Despite their long habitation sequences neither Jerf el Ahmar nor Chogha Golan (or for that matter any other early PPN site or regional sites cluster in Southwest Asia) has produced convincing evidence for the local independent development of phenotypically domesticated crop taxa. This archaeologically verified fact places PDC at odds with CNC's prediction that "multigenerational ecosystem engineering" practised by permanently settled groups managing small, resource-rich and ecologically stable territories would have provided a sufficient condition for the emergence of initial plant domestication. To date, attempts by archaeobotanists to explain the apparent longevity of PDC have focused mostly on a nar-

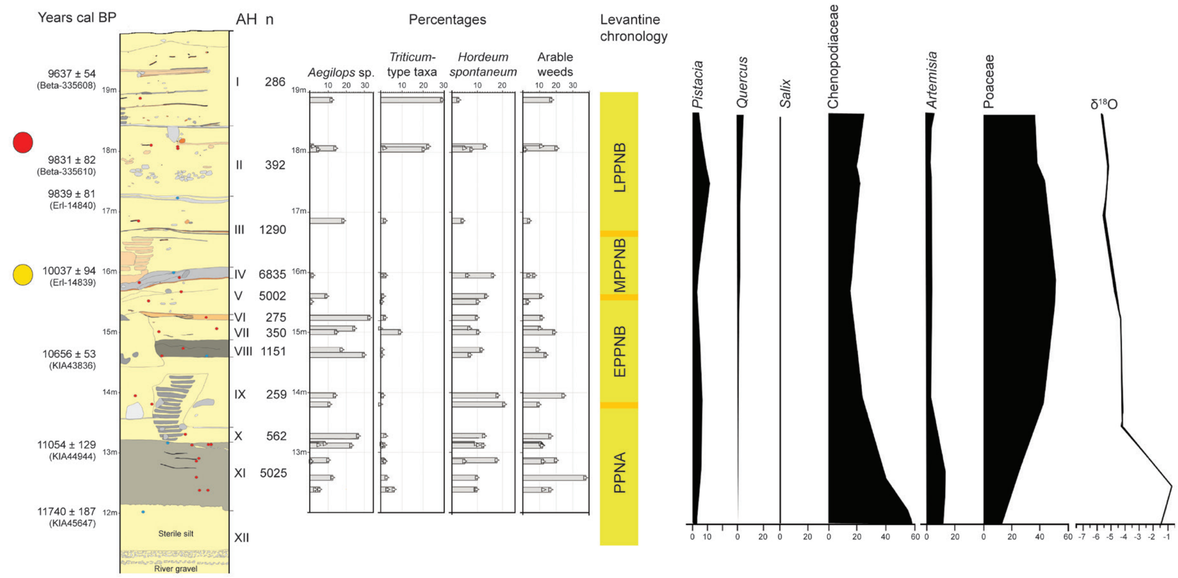

Fig. 10 Stratigraphic profile from Chogha Golan (left) alongside AMS dates (cal BP) (loci of dated samples in the profile indicated by blue circles) and archaeological horizons (AH) in Roman numbers. % frequencies of relevant taxa and groups of taxa (*Aegilops* sp., *Triticum*-type taxa, *Hordeum spontaneum* and "arable weeds") were calculated from the total number of identifications from each AH (loci of samples in the profile indicated by small red dots). n=no. of seed and chaff records from each horizon. Large yellow dot to the left marks the sole occurrence of domesticated-type barley chaff (which disappears in later AHs). Large red dot marks the first appearance of domesticated emmer wheat. To the right are shown select curves from the pollen sequence and the oxygen stable isotope record of Lake Zeribar (modified after Riehl *et al.* 2015: Fig. 10).

row range of biological and cultural selection pressures (*e.g.*, introgression from wild populations and harvesting at the dough stage or by beating cereal ears into baskets) (*cf.* Fuller and Allaby 2009; Fuller *et al.* 2011 and references therein). Few have questioned the dominant perception of PDC, at least in the regional archaeobotanical literature, as a mode of production that was practiced by permanently settled "village"-like communities in a manner and at a scale that were conceptually similar (if not functionally identical) to those of later full-time farming societies (see discussion in Asouti and Fuller 2013). The main criticism of the currently dominant PDC concept is this: if crop progenitor cultivars (cereals in particular) were intensively managed through annual planting in plots distributed near permanent habitation sites in order to secure and maximise the year-round provision of staple plant foods, then the pace of the development of the domestication syndrome would have been much faster. That this was not the case suggests at the very least the existence of diverse, low-intensity plant management practices that alleviated, and on occasion even reversed, any latent domesticatory pressures (Asouti and Fuller 2013). Here this argument is developed further by proposing that PDC practices were attuned to the short- to medium-term ecological instability that characterized much of the terrestrial environments of Southwest Asia during the early Holocene. Ecological instability arose from the marked seasonality of the early Holocene climate, its decadal-centennial scale oscillations and the resulting fragility of the regional grassland biomes. These phenomena were particularly pronounced in the semi-arid continental regions of inland Southwest Asia. Steppe grasslands, although extensive and also characterized by high species diversity due to the rapid climatic improvement that marked the start of the Holocene, were susceptible to climate-paced cyclic fire disturbances which led to periodic stand collapse and short-term depletion pulses, caused by heightened climate seasonality.

Early PPN communities responded to short- to medium term ecological instability by engaging in flexible economic strategies that precluded substantial reliance on delayed-return practices such as seed crop cultivation. Their landscape practices likely included the residential and/or logistical mobility of different community segments, the management of spatially extensive and ecologically diverse territories, and sustained social and material investment in the maintenance of long-range community interaction networks (Asouti 2013; Asouti and Fuller 2013; see also next section). Far from being black-boxed by archaeobotanists as an evolutionary precursor of fixed-plot intensive horticulture, PDC can be perhaps more accurately conceptualized as a constellation of diverse plant management practices including the harvesting at varying seasonal intensities of wild plant stands that were dispersed across wide territories, the opportunistic cultivation of plots that were scattered between the most fertile localities (*e.g.* in riparian habitats), transient habitat modifications (*e.g.*, shifting plots alongside opportunistic small-scale clearance and tillage), communal grain storage, and translocational seeding (*i.e.*, the exchange and/or transference of seed corn over long distances). The common denominator of such practices is that they are all likely to have generated low-intensity ecological and biological (phenotypic) footprints. More generally, it appears reasonable to infer that in early Holocene Southwest Asia PDC represented a somewhat different mode and scale of low-level food production and hunter-gatherer niche construction from those predicted by CNC models that were originally developed in the context of the Eastern North America and Neotropical ecoregions of the New World (*cf.* Smith 2006, 2012, 2015).

Resilience, Environmental Knowledge Transmission and Community Interactions

As noted in the introduction, the early PPN witnessed a florescence of symbolic/ritual behaviours across Southwest Asia. While a detailed discussion of the contextual attributes and potential meanings of early PPN symbolism goes well beyond the scope of this chapter, it is noteworthy that much of its material manifestations encountered in some of the most celebrated case studies (*e.g.* at Göbekli Tepe) have distinctive, if less commented upon, landscape connotations. One characteristic example is "Enclosure" D at Göbekli Tepe, one of the earliest excavated structures at the site, currently dated between the mid-10th and the early 9th millennia cal BC (Dietrich *et al.* 2013). The T-shaped pillars of "Enclosure" D bear the highest proportion of sculpted snake depictions and the highest diversity of animal representations from any other excavated structure at Göbekli (Peters and Schmidt 2004: Table 2). Venomous creatures (scorpions and snakes, the latter strongly reminiscent in shape of the native to the region *Vipera lebetina*) are depicted as moving away from wetland birds (pillar 33), while attacking mammals (pillars 20, 33) or in association with death-related themes (pillar 43) (Fig. 11). Representations on pillar 43 comprise a narrative of potential cosmological significance organized in three distinct horizontally arranged panels: the top panel contains what appear to be habitation structures in a wetland setting, suggested by the presence of reed-like patterns, a wetland bird and a boar. In the panel below two birds of prey are depicted alongside a sun-like disk and other symbols with less obvious connotations. The panel at the bottom end of the pillar is dominated by a massive scorpion, which is depicted in fine morphological detail alongside a snake, possibly a scavenging animal, and a headless male human body that appears to be led away by another bird of prey.

According to recently published radiocarbon determinations (Dietrich *et al.* 2013) the beginning of "Enclosure" D is dated to ~9700 cal BC, at the very end of the Younger Dryas and the start of the Holocene as indicated by the more precisely dated Nar Gölü palaeoclimatic sequence (Dean 2014). The palaeoecological evidence for the magnitude and rapidity of the transition (completed in the space of a single decade) suggests that its environmental impacts were experienced within individual human lifetimes. Memories of the hyper-arid environments of the Younger Dryas (possibly encoded in death-related themes and stories about swarms of venomous snakes attacking humans and mammals at a time of increased aridity) that had hitherto shaped people's landscape experiences likely formed the core of cosmologies and inter-generational knowledge transmission about past times of adverse conditions and resource stress. Comparative studies of ethnographic accounts of hunter-gatherer societies living in marginal (arctic, subarctic, arid and semi-arid) environments have indicated that oral traditions of high-impact, low-frequency episodes of environmental change have an average lifespan of ~90 years (Smith 1988). After a century has elapsed, such stories become encoded in cosmological narratives that are passed down the generations through their incorporation into highly stressful, even traumatic, once-in-a-lifetime ritual events (*e.g.* male initiation rites) experienced collectively by their participants in large aggregation sites. According to Smith (1988) such events function as vehicles for the storage and inter-generational transmission of collective passive memory (as opposed to active memory deployed in expedient, daily life tasks) and for establishing and re-affirming lifelong alliances and bonds between participant individuals and social groups.

Snakes, centipedes and birds of prey are depicted on portable objects found in several early PPN sites of the northern Fertile Crescent (Figs. 12 a, b). At Jerf el Ahmar they occur as engravings on shaft

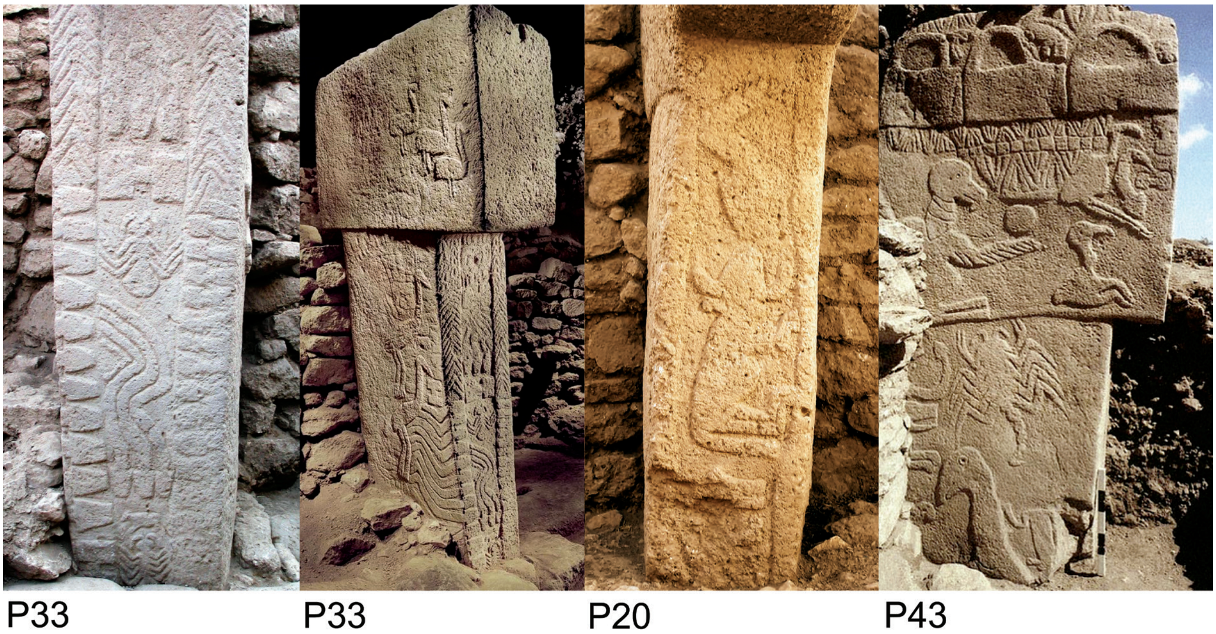

Fig. 11 T-shaped pillars from "Enclosure" D at Göbekli Tepe (images courtesy of the late Klaus Schmidt).

straighteners (a category of ground stone artefacts traditionally associated with hunting activities) or otherwise unmodified ground stone objects (Stordeur and Abbès 2002). At other sites, such as Körtik Tepe, representations of snakes and centipedes also appear on stone vessels that might have been used in communal food consumption events (Özkaya and San 2007). Snakes, giant centipedes, scorpions, lizards and spiders are common in the faunas of semi-arid steppe grasslands and were abundant in the region before the decimation of their natural habitats by overgrazing, settlement expansion and modern agriculture (*cf.* Joger 1984; Crucitti and Cicuzza 2001; Kaltsas *et al.* 2008; Simaiakis and Mylonas 2008 and references

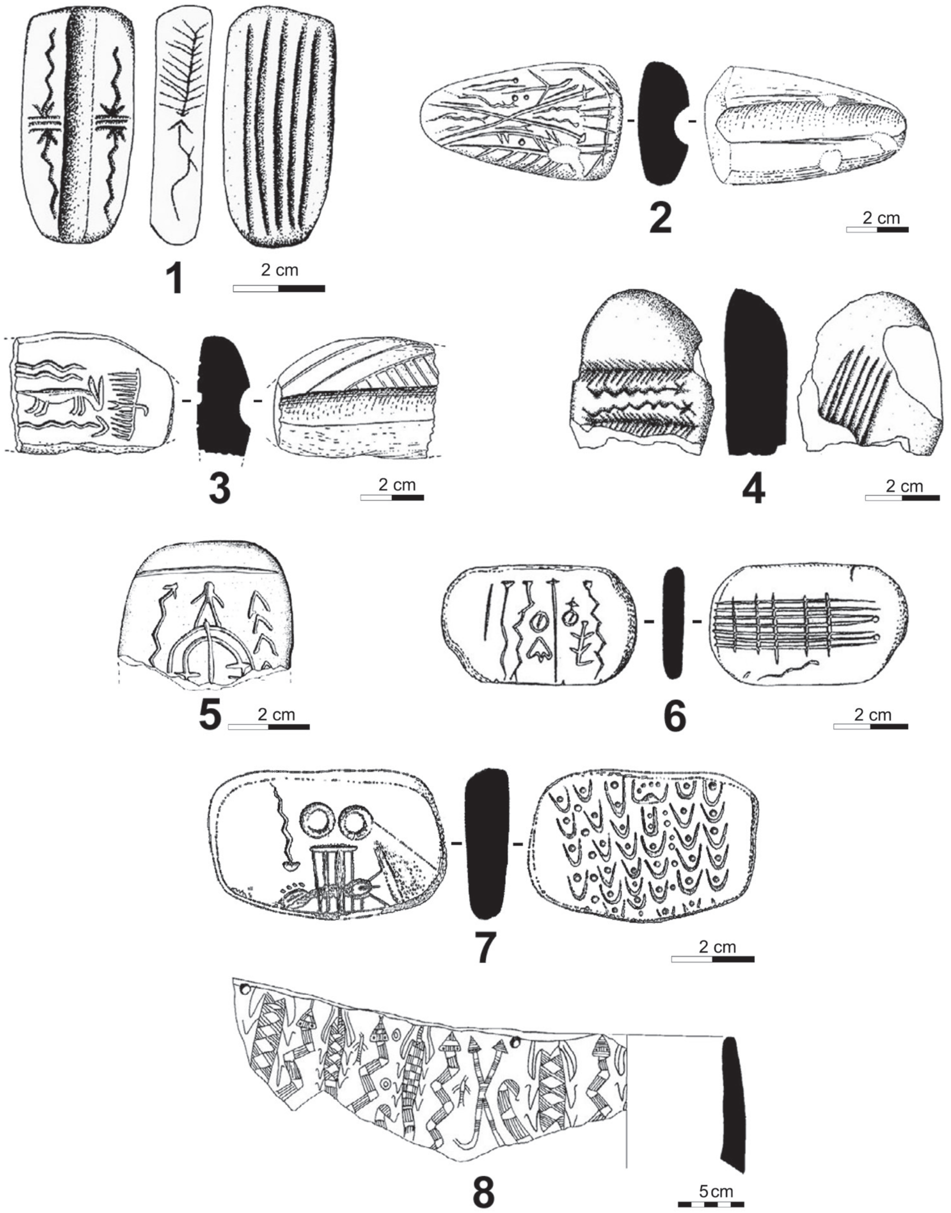

Fig. 12a Engraved stone objects: Tell Qaramel shaft-straighteners (1, 4; Mazurowski and Yartah 2002: Fig. 10); Jerf el Ahmar shaft-straighteners (2, 3, 6, 7; Stordeur and Abbès 2002: Fig. 16); Tell 'Abr 3 stone plaquette (5; Yartah 2005: Fig. 7); Körtik Tepe stone vessel (8; Özkaya and San 2007: Fig. 18).

therein).[3] Their ubiquity on early PPN portable material culture (especially objects associated with hunter-gatherer mobility and social interactions) might signify the mapping of paths of movement across the liminal space of the steppe and/or stories of the various dangerous encounters associated with such trips. The engravings on some ground stone objects are also suggestive of their potential function as mapping/orientation devices: they often combine snakes, birds of prey and hunted mammals (possible allegories for the steppe, its dangers and its resources) with fixed landmarks such as the round shapes and features

[3] A particularly poignant description of the experience of travelling across the steppe grasslands of northern Syria by foot can be found in the novel "Ariagni" by the Egyptian-Greek author Stratis Tsirkas, where he describes the forced march from Aleppo to Ar-Raqqah of two battalions of the 2nd Brigade of the Greek Armed Forces in the Middle East in June 1943, following the mutiny of their republican officers in April 1943: *"Raqqa; the steppe was like a grey yellow sea; full of wild grasses as tall as reeds, two meters; full of lizards like little crocodiles, poisonous snakes, giant centipedes, scorpions as big as little mice, hairy spiders; the pain is intolerable and their wounds stink."* (Tsirkas 1983 [1962]: 336-337)

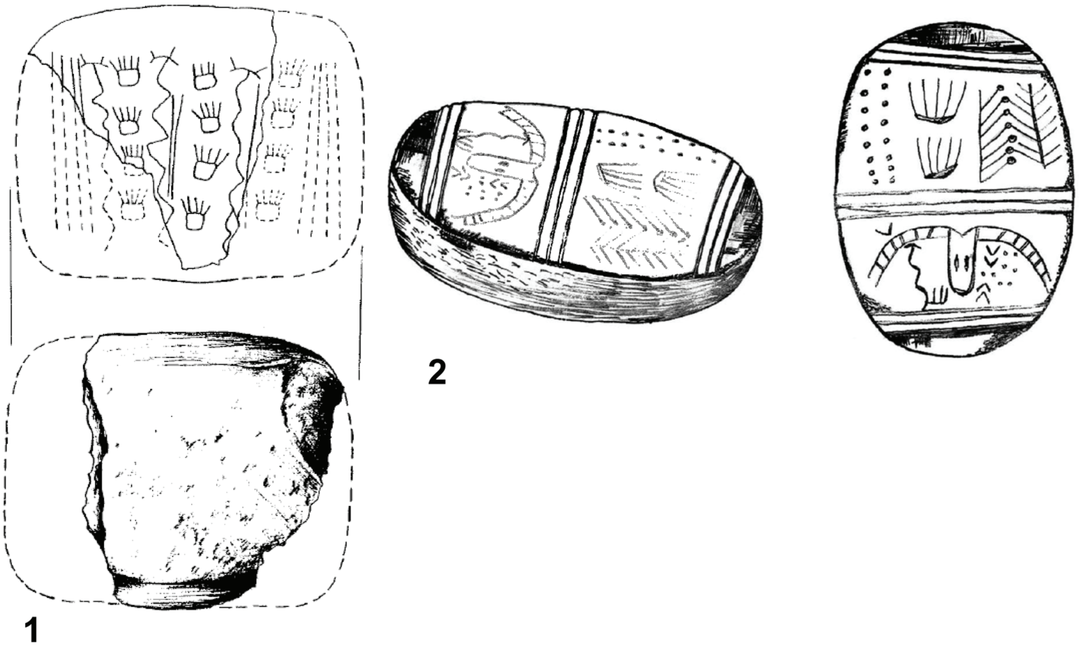

Fig. 12b Engraved stone objects: Tell Qaramel (1; Mazurowski and Yartah 2002: Fig. 11); Tell ‘Abr 3 (2; Yartah 2013: Fig. 151).

resembling standing posts reminiscent of the communal buildings at Jerf el Ahmar, potential representations of wild plant stands and more abstract motifs (*e.g.* arrow-like shapes) that might signify orientation markers (see Fig. 12a: 3, 5-7, Fig. 12b).

By placing these examples of early PPN symbolism and ritual behaviours in their broader ecological and socioeconomic context, it is possible to begin putting together a larger picture. Hunter-gatherer mobility, material culture symbolism deployed in active and passive landscape memory storage and knowledge transmission, and community interaction networks sustained by ritually invested communal food consumption events, stood at the core of regional resilience strategies aimed at mitigating early Holocene ecological instability and associated resource risks. Recently published plant genetic research has brought out even more poignantly the critical contribution of hunter-gatherer mobility and community interactions to the macro-evolutionary development of the domestication syndrome in Southwest Asian early cereal cultivars. Genetic studies suggest that domesticated emmer wheat has a reticulate rather than a phylogenetic evolutionary relationship with its wild progenitors (Civáň *et al.* 2013). Civáň *et al.* (2013) have proposed that this resulted from hybridization between different lineages effected via the utilisation and cross-pollination of wild grain derived from diverse sources over long periods of time. This process was ultimately responsible for the development of predomesticated cultivars that shared phylogenetic signals with emmer populations derived from all parts of the wild emmer geographical range. Thus, according to the reticulated origins scenario, wild-type emmer cultivars spread during the early PPN from the southern Levant into northern Syria, southeast Anatolia and northern Iraq, where their reproductive isolation from parent wild emmer populations resulted in their morphological domestication. This scenario would explain the phylogenetic proximity to the domesticated gene pool evidenced by the wild emmer populations presently found in Karacadağ (southeast Anatolia) and Sulaymaniyah (northern Iraq), which appear to represent “the remnants of the cultivated populations from which the first domesticates evolved” (Civáň *et al.* 2013: 9). If verified through further research, these observations may signal the replacement of both monophyletic and polycentric theories of agricultural origins with a new dynamic reticulate model: Epipalaeolithic and early PPN hunter-gatherer mobility was the primary determinant of the geographic distribution and genetic makeup of the wild cereal progenitor species *before* their initial domestication. A model of reticulate (*vs*. polycentric *and* monophyletic) origins of initial crop domestication also points to the existence of much more dynamic and multifaceted modes of early PPN niche construction across Southwest Asia (predicated on regional interaction networks and paths of movement) compared to CNC theory predicting the existence of spatially limited, closely controlled and temporally stable resource territories.

Pathways to Agriculture: the Switch from PDC to Agro-pastoral Food Production and its Socioeconomic and Ecological Impacts

For a delayed-return subsistence strategy such as seed crop cultivation to become established in the acutely seasonal climatic regimes and unstable vegetation ecologies of early Holocene Southwest Asia, and supersede long-lived resource management strategies firmly imbedded in social memory, identities and community interactions, a major innovation in its technology was necessary; one that would render it viable as a staple subsistence provider. Ethnoarchaeological research on traditional farming practices in the Eastern Mediterranean has demonstrated that a key condition for the sustainability of crop production is the capacity of cultivation systems to absorb and buffer recurrent seasonal and interannual environmental risks of crop failure. This is achieved primarily through the intensification of production geared at generating a *normal surplus* to use in times of need as well as underwriting social obligations (see discussion in Halstead 1989, 2014). In the context of Southwest Asia, Abbo *et al.* (2010) have proposed that a key strategy for mitigating environmental risks was the cultivation of crop packages (mixtures of cereals and pulses exhibiting variable levels of tolerance to local micro-ecologies) which would have conferred agronomic stability to early cultivation systems. The regional archaeobotanical record indicates that the formation of regionally distinctive crop packages comprising domesticated cultivars was a protracted process that was not complete until the late PPN (Asouti and Fuller 2012). Moreover, the geographical and chronological pattern of the adoption and spread of domesticated crop packages follows closely that of the spread of domesticated caprine herding (Colledge *et al.* 2004; Peters *et al.* 2005; Zeder 2008; Asouti and Fuller 2012; Arbuckle and Atici 2013; Martin and Edwards 2013). This correlation indicates that it was the integration of plant cultivation with the herding of domesticated animals that likely played a pivotal role in the establishment and spread of farming economies across Southwest Asia (Harris 2002).

A key pathway for this development was the use of animal dung as manure that might have initially occurred as the unintentional consequence of caprine herds grazing on steppe and alluvial grasslands following plant harvests. Manuring increased the ecological resilience of crop cultivation by mitigating some of the risks imposed by early Holocene climate seasonality. The use of dung as fertiliser provided a major boost to the productivity and reliability of cultivated harvests thus enabling the intensive annual cropping of fixed-boundaries plots in direct proximity to habitation sites (*cf.* Harris 2002; Bogaard 2005; Araus *et al.* 2014). The widespread adoption of small-scale horticulture integrated with domesticated caprine herding also had lasting effects on the vegetation environments of Southwest Asia through the development of regionally distinct agroecologies and other types of anthropogenic niches (Asouti and Kabukcu 2014; Asouti *et al.* 2015). Examples of the latter include the gradual reduction of grasslands and the coeval expansion of semi-arid managed woodlands and woodland pastures. Such landscape-scale vegetation changes have been detected in both central Anatolia and the arid zone of the southern Levant, and resulted from the combined impacts of domesticated caprine grazing and woodland management activities alongside increasing climatic aridity, especially from the mid-late 8th millennium cal BC (Asouti and Kabukcu 2014; Asouti *et al.* 2015).

The societal impacts of the adoption and spread of integrated agropastoral production during the late PPN were equally far reaching. Communities became perceptibly more settled, occupying larger habitation sites on a permanent basis and over successive generations (Kuijt 2000; Asouti 2006a). Residential architecture was transformed with the standardization and increasing compartmentalisation of building layouts, in order to accommodate a range of functions including storage and cooking, and heating and food preparation installations (Kuijt 2012; Goring-Morris and Belfer-Cohen 2013). Overall, it is possible to observe a shift away from group-focused social structures and corporate identities towards the household, which emerges as the principal unit of socioeconomic organization in the course of the later PPN (Kroot 2014). Evidence for the prevalence of an "egalitarian" social ethos that might have functioned as a levelling mechanism for emergent social inequalities is ubiquitous in the late PPN, being principally manifested in the lack of differentiation in residential architecture and in burial customs (*cf.* Kuijt and Goring-Morris 2002; Asouti 2006b; Kuijt 2008; Kuijt *et al.* 2011). At the same time, however, the use of communal structures for storage and other social purposes waned, whereas after the late 9th millennium cal BC most indicators of collective ritual behaviours and communal food consumption largely disappear from the regional archaeological record. Across Southwest Asia late PPN societies were characterized by settlement patterns, mobility strategies, economic practices, and ritual and symbolic behaviours that overall had little in common with their early PPN antecedents.

Conclusion

Climate change at the end of the Pleistocene and the beginning of the Holocene played a pivotal role in the radical reconfiguration of the "ecological theatre" in which the "evolutionary play"[4] of global agricultural origins unfolded in the course of the last 12,000 years. The combined archaeological and palaeoecological records of late Pleistocene and early Holocene Southwest Asia appear to corroborate the hypothesis that direction-changing, transformative economic shifts and associated technological and societal innovations are not engendered by conditions of stress (resource, climatic, demographic, or otherwise). Instead, they seem to uphold the theoretical principle that human societies are primarily risk-averse, especially when faced with stochastic and/or regime-switching environments (Zhang *et al.* 2014). When their economic base is challenged by external or internal pressures humans will opt for behaviours that are focused on security rather than optimization. At the other end of the spectrum, however, resource abundance per se also does not seem to provide a sufficient condition for direction-changing socioeconomic change. The reason for this is that change is predicated on complex historical circumstances and contingencies arising from the interplay of varied multi-scalar ecological, social and historical contexts. In early Holocene Southwest Asia the macroevolution of the regional agricultural economies ultimately depended on radical innovations in the ecology and technology of early food production, such as the integration of cultivation with domesticated caprine herding, that emerged quite separately (more like historical accidents than intended outcomes) from any supposed incremental shifts in the management, genetic makeup and phenotypes of early PPN cultivars.

The symbolic and ritual florescence that has come to define the early PPN of Southwest Asia has been widely portrayed in the literature as intimately linked to the cognitive and sociocultural shifts deduced for this period (*e.g.,* Cauvin 2000; Verhoeven 2004; Watkins 2006; Hodder and Meskell 2011; Atakuman 2014). By contrast, the potential contributions of climate change and the environment at large are often downplayed, or sometimes altogether omitted, from a debate that remains squarely focused on architecture and material culture. Environmental change is viewed as providing little more than the ecological background to the main story of sociocultural change and innovation. Contrasting with such approaches, this chapter argues that the resource-rich, yet ecologically unstable, landscapes of the first two millennia of the Holocene likely contributed to the emergence of complex symbolic and ritual behaviours in Southwest Asia, which were imbedded in regionally distinctive social identities and corporate institutions. Such behaviours were deployed in mapping the availability and locations of preferred resources, and for the storage, exchange and inter-generational transmission of landscape knowledge and historical experiences of environmental change. Raised resource ceilings in the context of early Holocene ecological instability also expedited the development of lasting mechanisms of social cooperation, which fostered the intensification of community interaction networks and the region-wide circulation of socially prized foodstuffs, including early cultivars. Increasing degrees of social cooperation are reflected in the ubiquity of ritually invested communal institutions and in behaviours such as communal food consumption that enabled alliance building, the development of shared ideologies and cosmologies, the diffusion of symbolic vocabularies, and the emergence of regionally distinctive group identities.

Cooperation is a major driver of human evolution (Nowak 2006). The critical role of environmental instability is also widely recognized in evolutionary biology. Building on the dichotomy between variability-selection versus habitat-specific hypotheses (Potts 1998, 2002) the general theoretical principle is proposed that specialized economic behaviours (such as "agriculture" or "foraging") are facilitated by environmental change in a constant direction (whether negative or positive) that renders such behaviours adaptive and sustainable in the long-term (*e.g.*, during the Younger Dryas or the Holocene Climatic Optimum). Conversely, in environments characterized by high degrees of medium- to short-term ecological instability (*e.g.*, the Younger Dryas termination and the onset of the Holocene) which impacts directly human perceptions of the environment and its resources, flexible economic practices and cooperative social behaviours provide distinct advantages. What differentiates this proposition from other ecologically oriented theories of prehistoric economic behaviours (*cf.* Binford 2001) is its decoupling of resource abundance and resource stress from idealized notions of environmental stability and instability respectively. Instead, the emphasis is placed on *resource ecologies*. For the comparative cross-cultural study of agricultural origins such a theoretical framework provides an appropriate heuristic environment for formulating and testing region- and context-specific, historical explanations of the enormous

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[4] Slightly paraphrasing the title of Evelyn Hutchinson's famous collection of essays *"The Ecological Theatre and the Evolutionary Play"* first published in 1965 by Yale University Press.

differences observed in the nature, duration, pace and directionality of socioeconomic change among early Holocene low-level food producers worldwide (*cf.* Smith 2001; Barker 2006). This is achieved by focusing on the distinctive resource ecologies characterizing each world region, in the context of global climate change, rather than the broad structural similarities of prehistoric economic behaviours.

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