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Climatic and human impact on the environment?: A question of scale

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ABSTRACT

The environmental context of cultural transformation' - frames the central issue of this paper – how were Neolithic and Chalcolithic landscapes in the Aegean, Balkan and Carpathian (ABC) zones shaped and transformed by climatic and anthropogenic impacts? The difficulties in interpreting proxy records for the middle, transitional stage of the Holocene aridification sequence, falling between the early wet stage and the late arid stage, have been created by the conjoint influence of two kinds of impact – climatic and anthropogenic. An unhelpful influence in this debate stems from Willis and Bennett's (1994) hypothesis of minimal human impact on the pre-Bronze Age landscapes of South East Europe. In this paper, two questions are posed: (1) what were the effects of the claimed global changes in Holocene climate at the regional and local scale in the ABC zones?; and (2) can we recognise human impact in these proxy records prior to the Bronze Age of our study regions? Following a discussion of general long-term climatic trends and RCCs (episodes of rapid climatic change), I base a discussion of the so-called 8200BP 'event' and pre-Bronze Age human impacts on a suite of 24 well-dated proxy records – mostly pollen sequences. The principal findings are that there is little evidence for impact from the 8200BP 'event' in these records, while there is substantial evidence for pre-Bronze Age human impacts on the landscapes of the Aegean, Balkan and Carpathian regions.

1. Introduction

The middle Holocene period witnessed one of the most dramatic periods of change in European prehistory – the spread of a farming way of life from Western and North West Anatolia to the Aegean zone (zone A), the Balkans (zone B), the Carpathians (zone C) and beyond into North-Central Europe. This period of change in three contiguous and inter-related zones – the ABC of South East Europe – was the focus of the Saloniki Conference from which this Special Issue of ***QI*** has been distilled. The title of 'The Neolithic of Northern Greece and the Balkans. The environmental context of cultural transformation' frames the central issue of this paper – how were Neolithic and Chalcolithic landscapes in the ABC zones shaped and transformed by climatic and anthropogenic impacts?

The general climatic framework for this discussion is the three-stage division of the Holocene into an Early Holocene wetter stage, a transitional stage and a Mid - Late Holocene aridification stage. Several commentators (e.g., Roberts et al., 2011) have suggested that the difficulties in interpreting proxy records for the transitional period (7000–4000 cal BC: Brayshaw et al., 2011; or 5000–3500 cal BC: Galop et al., 2009) relate to the unknown strength of anthropogenic influences on local and regional ecologies in relation to climate-forced changes to vegetation history. There is still no agreement on the causes of the aridification trend or the ways in which this was materialized in proxy records. In a discussion of both the climatic and the anthropogenic impacts on middle Holocene landscapes, I seek to answer two questions: (1) what were the effects of the claimed global changes in Holocene climate at the regional and local scale in the ABC zones?; and (2) can we recognise human impact in these proxy records prior to the Bronze Age of our study regions? It is inevitable that I confront issues of scale in these questions, from global trends to local events. An example of scalar issues is the way that annual changes in grain-sowing or hunting strategies represented much more fine-tuned practices than the colossus of global climatic changes such as the 8200BP event. I approach this topic from the viewpoint of an environmentally-aware prehistorian with a scepticism to environmental determinism, on the grounds that human communities must have been flexible enough to react to, if not to predict, the directions in regional environmental changes and make thoughtful choices about where to live and what cuisine (food and drink) to select. Here, I shall make "the default assumption … that the humans and non-humans are mutually implicated - that they co-constituted the

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world" (Head, 2008: 376). It is clear that this approach relates closely to the approach to cultural entanglements made by Hodder (2012). This approach contrasts with what most palaeo-environmental scientists working in the Holocene of the Balkans and the Carpathian Basin take as a 'normal' research goal – the identification of 'human impacts' on the 'natural' vegetation (e.g., Willis and Bennett, 1994; Magyari et al., 2012; Connor et al., 2013).

2. Holocene climatic trends

A broad perspective on climatic trends in the study region depends increasingly on the results of the analysis of large data sets, consisting of as many pollen diagrams or other multi-proxy sequences as are available, often at a millennial time-scale. As Giesecke et al. (2011: 2809) observe, "a large number of Holocene climate shifts or short-lived excursions are reported in the literature so that it seems almost possible to find one within the uncertainty of any standard radiocarbon date." Because of forest resilience, a high-amplitude or long-lasting shift in climate parameters is needed to produce vegetational change recognizable at a millennial timescale. In this account, I do not focus on the effects of the Younger Dryas phase (10950–9750 cal BC: Straus and Goebel, 2012), since it is earlier than the periods discussed in this Special Issue. However, the impact of the '8200BP event' is an important part of the general climatic story in later Balkan prehistory (8000–4000 cal BC).

The quantity and quality of palaeo-environmental research in the Balkans and the Carpathian Basin has improved enormously over the last decade, particularly in respect of well-dated proxy sequences. A key publication milestone was volume 21 of the journal '*The Holocene*' (2011), devoted to Holocene climate change. We can identify two cross-cutting trends in this research narrative – long-term trends in European climate and episodes of rapid climate change (henceforth 'RCC', following Denton and Karlén, 1973).

In the former, the stadial terms used since the Blytt-Sernander system (Pre-Boreal, Boreal, Atlantic and Sub-Boreal) have been replaced by a three-stage division of the Holocene into an Early Holocene wetter stage, a transitional stage and a Mid - Late Holocene aridification stage. The Early Holocene stage was a period dated 9500 BCE to 5000 BCE by some (Galop et al., 2009), while others suggest aridification began earlier, in the early 7th millennium BC (Brayshaw et al., 2011; Sadori et al., 2011) or cca. 6000 cal BC (Peyron et al., 2011). Roberts et al. (2011) identify a stable Early Holocene boundary in the Adriatic Sea between a wetter Eastern Mediterranean and a West Mediterranean zone where warm, wet westerlies had less impact. It is important to recall that major glaciers continued to exist until cca. 4800 cal BC, cooling the global climate mainly through the introduction of melt-water into oceans (Wanner et al., 2008). The Late Holocene aridification phase marks a period of decreasing precipitation in the east Mediterranean, beginning at some point in the 4th millennium cal BC (Galop et al., 2009; Brayshaw et al., 2011) and continuing until the present day. The effects of these East Mediterranean climatic trends are important for our understanding of climatic change in the ABC zones, as much as human dwelling in these regions.

The identification of synchronous RCC episodes has been attempted by, *inter alia*, Majewski et al. (2005), Magny (2006) and Giesecke et al. (2011). The last-named underline that such efforts are based upon the acceptance of one of the two main climatic hypotheses – the dynamic equilibrium hypothesis (Prentice et al., 1991), by which directional changes in climate can produce changes in the spatial patterning of species distributions.[1] Since Majewski et al. (2005) work at a millennial time-scale, it is hard to imagine the effects of RCCs on local communities because of the fuzziness of their temporal definition. Thus, Majewski's 7th millennium cal BC RCC – termed the 'Glacial Aftermath' phase - may well be tied into the '8200BP event', while it is possible that his 4th millennium cal BC RCC, marked by Alpine glacial re-advances and increases in the tree-line, is related to the inception of the Mediterranean aridification stage. Magny's research into long-term West-Central European lake levels correlates higher-than-average lake-levels with higher annual precipitation, lower summer temperatures and a shorter growing season. The greater chronological precision of his regional database enables Magny to identify three RSS episodes – at 7600–7200 cal BC, 6350–6150 cal BC (equivalent to the '8200BP event') and 4400–3950 cal BC (perhaps coeval with Majewski et al.'s later RCC episode). Thirdly, in a wide-ranging test of the dynamic equilibrium hypothesis conducted at a centenarial timescale, Giesecke et al. (2011) highlight three peaks of RCC in the majority of the 59 proxy records under study: the start of the Holocene period, the '8200BP event' and an episode in the late 5th millennium BC (perhaps related to Magny's third RSS episode). In vegetational terms, Giesecke makes a strong case for synchronous expansion of *Corylus avellana* from a variety of *refugia* in the Early Holocene.

What we can infer from these studies is that the timescale of the analysis is critical in producing useful results for regional and local social practices. There does appear, however, to be agreement on an earlier RSS episode (the '8200BP event') and a later episode (dated somewhat less precisely in the late 5th millennium cal BC). How was the '8200BP event' caused and what results did it produce?

Peyron et al. (2011: 141) have published a succinct account of the 8200BP 'event', which they maintain was triggered by a weakening of the thermohaline circulation in the North Atlantic, in turn leading to more ice-cover in Baltic Seas, stopping the penetration of mild, moist Atlantic air into Europe and allowing greater penetration of the Eurasian/Siberian high, which led to cooler, drier winters and springs (cf. Pross et al., 2009). If summer cooling is invoked as a major explanatory factor for the 'event' (Heiri et al., 2003), climatic modeling would produce the biggest fall in the Alpine tree-line in the whole of the Holocene (Heiri et al., 2006). While the mechanism for the 'event' is clear, however, the chronological resolution of the 'event' is by no means well-defined. According to Giesecke et al.'s (2011) results, the 'event' had effects on two sets of pollen proxy records: one group dated 7600/7450 BCE – 7100 BCE and the other group dated 7400/7100 BCE – 6800/6600 BCE. They suggest an initial change in vegetation, with progressive destabilizing effects on other vegetation cover, such that the 'event' acted as a large-scale disturbance. However, the actual timescale of the initial trigger in what is called an 'event' (but is clearly nothing like an event!) remains mysterious – perhaps centuries - with the most comprehensive investigation (Giesecke et al., 2011) characterizing the effects of the 'event' over 700 years and Weninger et al. (2014) embedding the '8200BP event' into a 600-year rapid climate change interval (6600–6000 cal BC). It is possible to conceive of an 'event of such major significance that its effects were profound and long-lasting but I await a chronological definition of the trigger 'event'.

Weninger et al. (2009) have been the strongest advocate of major cultural impacts from the rapid climate change events identified by Majewski et al. (2005). The 2006 paper (Weninger et al., 2006, Figs. 3–5) exploring the archaeological effects of the '8200BP event' presents cumulative 14C diagrams to check whether there were declining regional settlement at the time of the 'event'. Despite their own data, which show that Greece, Cyprus and

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[1] The other hypothesis – the 'disequlibrium hypothesis', involving differential expansions of species from plant *refugia* (Prentice et al., 1991).

Bulgaria, as well as a majority of sites (e.g., Nea Nikomedeia) showed cumulative 14C ***peaks*** at the time of the 'event', Weninger et al. continue to claim (p. 401) that this aridity event triggered the spread of early farming in the East Mediterranean! This is as sloppy as Ghilardi et al.'s (2012) claim that a marine transgression in the NW Aegean preceded the first occupation of Early Neolithic Nea Nikomedeia by a few centuries, when, in fact, the recent re-dating of this site (Souvatzi, 2008, 64) makes the interval more like a millennium. Again, Ghilardi et al.'s claim that the onset of a lagoon environment near Nea Nikomedeia was related to the '8200BP' event ignores their own dating of the lagoon formation to 5826/5659 calBC - centuries after the 'event'.

In the second paper (Weninger et al., 2009), by an inversion of the usual invasion route (Clark, 1965), Weninger's team proposed that the major disturbance to Greek and Balkan vegetation was a series of extremely cold air masses that swept over the Balkans and down into Greece – part of the Eurasian/Siberian High proposed for the '8200BP event' (Peyron et al., 2011) and also striking the region between 4000 and 3200 BCE. While, on this occasion, Weninger's team does not comment in detail on the relationship between the '8200BP event and the spread of farming through the Balkans, the team proposes that the 4th millennium rapid climate change episode had a deleterious effect on Climax Copper Age tell settlement structures, whether in Greece, Bulgaria and Romania The weakness of this proposal is that the dates of the episode do not correlate well with the supposed changes in settlement pattern in any of the three areas. The alleged Siberian High pre-dates the dwindling site numbers in the Final Neolithic); reliance on Todorova's (2002) reconstruction of catastrophic environmental change in Bulgaria is hardly wise since this is based upon a very outdated sea-level reconstruction (Fairbridge, 1961); and the abandonment of Gumelniţa tells post-dates the alleged 'event' (while Pietrele may have been abandoned c. 4250 cal BC, it is by no means the latest occupation of tells in the Lower Danube valley, which go on into the early 4th millennium calBC. Even if there was a closer chronological correlation between the alleged climatic cause and the settlement effect, no flexibility is afforded the prehistoric communities in finding ways to adapt to fluctuations in climate.

The latest paper from Weninger's team (Weninger et al., 2014) presents an extraordinary mass of 14C data, coring results and site-based archaeology but completely fails to link all of these data sets to support their main proposal: "We demonstrate a precise temporal coincidence (within given error limits) and strong social impact of rapid climate changes on Neolithic dispersal processes" (2014, 2). An important change in Weninger et al.'s approach (2014, 8) is to propose that the '8200BP event' (viz., the Hudson Bay outflow) was embedded within one of several Holocene rapid climate change intervals lasting 600 years (6600–6000 cal BC). It is argued that these intervals were defined by more pronounced bouts of Siberian High pressure originating in Central Asia and moving over the North Pontic, South East Europe, the Aegean and the Adriatic. However, although Weninger et al. produce summaries of the latest dates from early sites in Turkey, Greece and North Bulgaria, there is no explanation of how the alleged Siberian High affected these sites, whether to cut short their occupations or to initiate supposed demographic shifts to new areas. The absence of any serious discussion of settlement archaeology, not to mention subsistence studies or social arguments, makes this paper of limited value.

A fourth example of exaggerated claims for the '8200BP event' comes from the re-analysis of the Tenaghi Philippon pollen core, Northern Greece (Pross et al., 2009). Here, a massive disturbance in terrestrial ecosystems, with greater aridity and lower winter temperatures, is claimed for the event (p. 889). The issue here is the dating of the core, which certainly does not support Pross et al.'s claim for a 'decadal-scale-resolution' study (p. 887). The five Tenaghi Philippon dates show stratigraphic reversals and dates with unexpected values showing millennial errors (2009, Fig. 2). Pross et al. acknowledge the problem of the compromising effects of hard-water on peat-based and pollen-based ^{14}C dates turning to what they claim to be a well-dated marine core SL 152 (near the Chalkidiki). However, Kotthoff et al. (2008, 1019) state at the outset that the chronological resolution for SL 152 is 125–300 years – hardly sufficient to provide close analogical dating for the Tenaghi Philippon diagram. Moreover, the results of coring sediments dating to the late 7th millennium BC at the North Greek site of Dikili Tash show not greater aridity but increased hydrological activity in the local environment (Lespez et al., 2013) (for evidence of human impacts, see below, p. xx).

In summary, the traditional climate narrative of a cooler and wetter Anathermal, or Pre-Boreal and Boreal, a 'Thermal Maximum' termed the 'Altithermal', or 'Atlantic' period (5500–2500 cal BC), and a cooler and wetter Medithermal, or Sub-Boreal and Sub-Atlantic, has been replaced by a parallel three-stage narrative based upon an Early Holocene wetter stage, a transitional period, and a Mid - Late Holocene aridification stage. There is still disagreement among the palaeoclimatologists about the causes of the changes in their proxy records, especially in the transitional stage. The hitherto imprecise timescale of Rapid Climate Change episodes in the Holocene proxy records limits their utility in discussions of climatic impact on cultural development. While there is widespread agreement about the significance of the 8200BP 'event' in general terms, it is hard to date the duration of the trigger event within two to four centuries, and the dates of its effects can extend to over 700 years. It remains difficult to relate the effects of the 8200BP 'event' to any particular cultural development or collapse, let alone any settlement dislocation. Can the impact of the 8200BP 'event' be seen in mid-Holocene vegetational records?

3. Mid-Holocene vegetation records and the 8200BP 'event'

This summary of trends in mid-Holocene vegetational histories is based upon 25 proxy records, for the most part pollen sequences, all of which dated by a minimum of six AMS calibrated BC dates (Fig. 1 & Tables 1 and 2). The sites range in altitude from sea-level (Mljet, Black Sea cores, Durankulak Lake, Mount Athos Basin) to 2190 masl, at Lake Ribno Banderishko in the Pirin Mountains, SW Bulgaria. For this review, sites are classed as 'lowland' (<300 masl); 'upland' (300–1000 masl) and 'mountain' (>1000 masl). The East – West transect of sites ranges from Griblje (Slovenia) in the West to the Heraklea Peninsula in the Crimea in the East. The North – South transect stretches from Sirok and Sárlo-hát (NE Hungary) in the North to Lakes Maliq (South Albania), Prespa (FYROM) and Tenaghi Philippon/Dikili Tash in the South via Prokoško Jezero in the Dinaric Alps. Key details from the proxy records have been extracted for this comparison (Table 1). Both the East – West and the North – South transects will be discussed so as to reach a general picture of vegetational change for the Mesolithic, Neolithic and Chalcolithic of the Balkans and the Carpathian Basin. Although the effects of mixed farming practices are often difficult to separate from climatically-forced ecological changes (e.g., Magyari et al., 2012), the former is considered in a later section, with a focus on a smaller number of proxy records.

The proxy records with sections dated between 6500 and 5000 cal BC were examined with a view to detecting the effects of the 8200BP 'event'. The overall increased winter precipitation record at Taul (based on changing arboreal pollen values) is a key indicator for climatic influences on vegetational changes in the early part of the Altithermal period. The only area with a continuing *Artemisia – Chenopod* steppe is the Durankulak area of the North

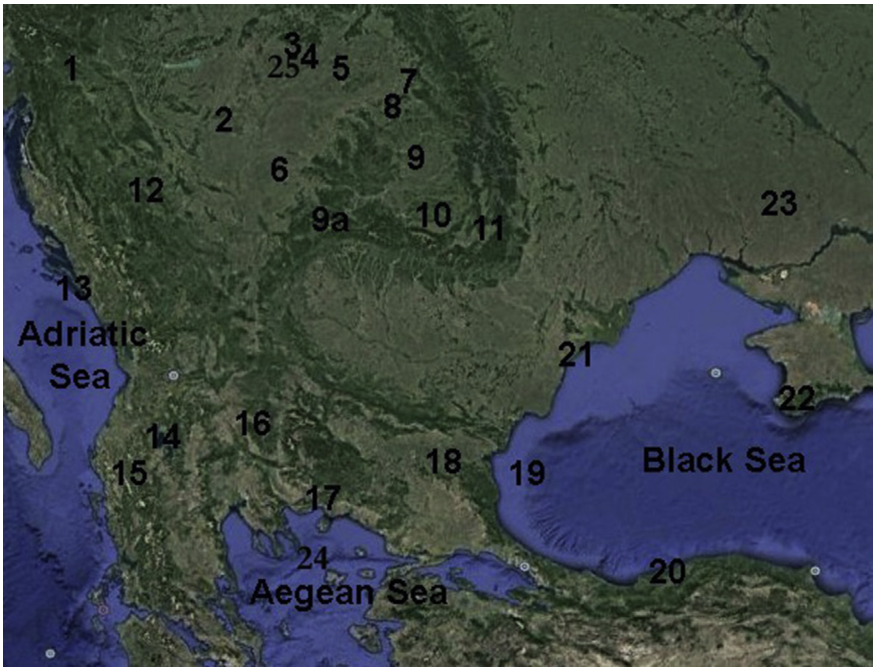

Fig. 1. Location of cores: 1. Griblje; 2. Lake Kolon; 3. Sirok; 4. Kismohos; 5. Sárlo-hát; 6. Kiri-tó; 7. Preluca; 8. Turbata; 9. Lake Stiucii; 10. Lake Brazi, Taul; 11. Avrig; 12. Prokoško jezero; 13. Malo jezero, Mljet; 14. Lake Prespa; 15. Lake Maliq; 16. Lake Ribno Banderishko, Pirin Mountains; 17. Tenaghi Philippon/Dikili Tash; 18. Straldzha; 19. Black Sea cores; 20. Sofular cave; 21. Durankulak; 22. Heraklea; 23. Nebelivka; 24 Mount Athos Basin; 25 Mohos.

Bulgarian Black Sea coast. Elsewhere, steppe grassland was replaced by evergreen parkland on the Crimean Peninsula and by mixed oak forest in the Bulgarian Thracian Plain and the Southwest Black Sea area. However, in the Southern and Western parts of the region, evergreen forests expanded in the lowlands (Tenaghi Philippon, Mljet). But there is an overall continuity, if not expansion, of deciduous oak forests in much of the region. The variety of dominant species (*Corylus* at Avrig and Kiri-tó, *Fraxinus* at Mohos, *Corylus* at Turbata and *Ulmus* at Preluca) indicates considerable diversity of deciduous forest cover at the inter-regional as well as the local level. Two species which later came to prominence over much of temperate Europe – *Carpinus* and *Fagus* – are recognized for the first time in several areas. *Carpinus* develops at all altitudes - in the lowlands (Lake Stiucii), the upland zone (Prespa) and the mountain zone (Pirin), while the expansion of *Fagus* occurred in the North-Westernmost site of Griblje and the SE Hungarian lowland site of Kiri-tó, with special prominence at Prokoško Jezero. A general trend in the late 7th – 6th millennia BC would appear to be a greater vertical differentiation in the zonation of woodland, offering wider opportunities to communities which could integrate their (seasonal) movements with this differentiation.

It is significant that there are signs of vegetational change that could be attributed to the impact of the so-called 8200BP 'event' in far fewer than half of the proxy records. There is a fall in rainfall in the Sofular Cave record, while there are drops in overall Arboreal Pollen combined with increases in *Artemisia*, *Chenopodium* and/or *Poaceae* peaks at varying altitudes in the Southern Balkans (Maliq, Prespa and Tenaghi Philippon). It is also possible that this 'event' influenced the development of a true coniferous altitudinal zone in the mountains (Pirin). However, the vast majority of proxy records dominated by mixed deciduous forest have shown no or minimal impact from the 8200BP 'event'. The most likely interpretation of these data is that the climatic impact of the 8200BP 'event' must have been small to minimal for the communities living in such a wide range of environments as were present in our study region. An alternative interpretation is that the 8200BP 'event' had serious consequences for people and landscapes but that these impacts were so short-term and rapidly reversible that no impact could be detected in the vast majority of the proxy records. Indeed, the Mount Athos Basin core showed five centennial-scale climatic perturbations between 7300 calBC and 4500 calBC, marked by the abrupt decline of *Quercus* and a concomitant rise in non-steppe grasses (especially *Cichorioideae*), suggesting that human communities could well have learned from their previous experience and built in a certain resistance to these changes.

4. The interaction of human practices and changing environments

The proximity of the Balkans and the Carpathian Basin to the steppe zones of the Near East, Anatolia and the North Pontic meant a considerable diversity of plant associations in the Early Holocene period. In contrast to the closed deciduous oak woodlands of the temperate zone (e.g., the Lower Oder valley diagrams, Northern Germany: Jahns, 2000), there were parts of the lowland landscape which were naturally open, with normal steppe components such as large-grained grasses (*Poaceae*, *Artemisia*, Chenopods, *Plantago*, *Rumex* and *Polygonum*). For this reason, we cannot automatically interpret such species as indicators of 'human' activities, as would have been the case in Northern Germany, at least without the presence of additional plant species (Connor et al., 2013). Such open areas, juxtaposed with various woodland associations, would have been attractive to the earliest farmers, whose cropping and pasturing was on such a scale that required little, if any, deforestation. Equally, the natural forest fires which remained at a high level from 8700 – 5100 BCE (Feurdean et al., 2013) would have helped to maintain natural clearings in the woodland canopy, especially near rivers and streams. These open woodlands would have made attractive places for dwelling for the earliest farmers, whose tool-kit did not, for the most part, include large stone felling

Table 1
Palaeo-environmental trends in the Balkans on the basis of proxy records.

Coring site: reference	Height (masl)	Time interval	Vegetation dynamics	Human impact
Gribje: Andrić 2007	160	8700–6700	Deciduous oak woodland, increases in Fagus, Alnus and Corylus	Small-scale burning Low-intensity (Cerealia-type pollen & SI)
		6700–6100	Betula–Pinus forest replaced deciduous woodland	
		6000–4100	Increase in Fagus, Alnus and Corylus	
		4100–3500	Decrease in Pinus and Betula	
Prokoško Jezero, Bosnia: Dörfler 2013	1670	8680–7360	Mixed oak forest with Picea and Pinus	Continuous Plantago lanceolata curve (minimal human impact)
		7360–5500	Increases in Fagus, Carpinus and Abies	
		5500–4330	Fagus – Ulmus – Quercus woodland; expansion of Carpinus and decline in Tilia and Corylus	Continuing Plantago curve Artemisia and Chenopodiaceae, with some Plantago
		4330–3830	Strong increase in Carpinus, with declining Tilia and Corylus	
		3830–3430	Increases in Abies, Picea, Pinus and Corylus	
Malo Jezero, Mljet: Beug 1961	40	8250–6530	Deciduous oak forest, with Carpinus increase from 7230	negligible Cerelia-type pollen + Sis
		6450–5020	Evergreen Juniperus - Phillyrea	
		5020–3500	Increase in evergreen Quercus	
Lake Maliq: Fouache et al., 2010	818	9950–6300	Mixed deciduous oak forest	Negligible
		7400–7065	Short cooling 'event'	
		7065–1	Mixed deciduous oak forest	
Lake Prespa: Panagiotopoulos et al., 2013	850	9500–6300	Quercus forest, with Ulmus & Betula maxima; Pistachia from 8000	SI (Rumex, Olea, Plantago)
		6300–5900	Fall in AP, Artemisia & Poaceae peaks	
		5900–1000	Increases in Corylus, Alnus & Carpinus (late)	
Lake Kolon: Sümegi et al., 2011	100	9000–7300	Disappearance of tundra elements; Picea & Betula woods, with Corylus, Tilia & Quercus	Cerealia-type pollen from 6400; intensive forest clearance from 4500
		7300–4000	Mixed oak deciduous forest	
Sirok: Gardner 1999	200	8000–7200	Open Poaceae-dominated parkland, +Picea, Quercus and Corylus	Pollarding & coppicing
		7200–6300	Increased Tilia	
		6300–4900	Mixed oak forest, +rapid increase in Corylus	
		4900–3200	Corylus-dominated mixed oak forest	
Kismohos: Willis et al., 1998	310	9500–7500	Increase in Pinus, Betula & Larix Decrease in tundra-like elements & Picea	Small-scale farming between 5330 and 4400
		7500–4000	Increase in thermophilous trees (Quercus, Tilia, Fraxinus, Ulmus & Corylus)	
		4000–2000	Fagus and Betula increase at expense of thermophilous trees	
Sarlo-hat: Magyari et al., 2012	86	7900–6400	Corylus-dominated mixed oak forest	Fires, Triticum-like pollen & Sis
		6400–5250	Quercus-, later Ulmus-dominated woodland	Fields + Triticum-type & Secale-type pollen; wet meadows & dry pasture
		5250–4400	Increased Fraxinus & Artemisia decreased Quercus	Fields, wet meadows and burning
		4400–3400	increased Quercus, decreased Corylus & AP	
Kiri-tó, Ecsegfalva 23: Willis 2007	80	8200–6200	Increased Quercus- and Corylus-woods; decreased Pinus, Betula, Picea & Poaceae	Small increase in regional charcoal Major increase in burning (6000–5500), with lower charcoal peaks later
		6200–4600	Major increase in Corylus, with some Fraxinus, Alnus, Tilia & Fagus and decreased grasses	Cerealia-type pollen & SIs
		4600–3800	Major decrease in AP (esp. Corylus & Quercus);	
		3800–3000	Increase in grasses & Compositae Increased broad-leaved trees	
Tenaghi Philippon: Peyron et al., 2011	40	8500–6200	Evergreen oak forest	
		6200–6000	Increased Artemisia & Chenopod, decreased woody taxa	
		6000–5800	Increased evergreen oaks	
		5800–4500	Variability of woody taxa	
Pirin (Lake Ribno Banderishko): Marinova et al., 2012	2190	8000–5900	Oak forest with Corylus & Pinus	First Cerealia-type pollen at 5300 + Sis
		5900–2200	Increased C. orientalis & betulus; first coniferous belt (Picea & Pinus)	
Lake Brazi, Taul: Magyari et al., 2013a,b	1740	10300–1200	Lower winter precipitation at 8100–7500/7000–6500/5800–5300/4300–3800	
Avrig: Tantau et al., 2006	400	9200–8400	Pinus forest + Betula & increased Picea, Quercus & Tilia; decreased Artemisia	First Cerealia-type pollen & SIs Cerealia-type pollen, & increased Sis
		8400–6500	Increased mixed oak forest; first Ulmus peak	
		6500–4800	Corylus maximum, increased Ulmus, Fraxinus & Betula	
		4800–3800	Increased Corylus, Quercus & Ulmus	
Mohos (Romania): Tantau et al., 2003	1050	9000–8250	Betula-dominated woods + Picea, Pinus & first Ulmus	Artemisia Cerealia-type pollen after 3000
		8250–4890	Quercus-dominated mixed oak forest, with first Fagus	
		4890–4000	Fraxinus maximum, Quercus, increased Ulmus	
		4000–3215	Establishment of Carpinus	
		3215–1255		

(*continued on next page*)

Table 1 (*continued*)

Coring site: reference	Height (masl)	Time interval	Vegetation dynamics	Human impact
			Ulmus-, Fraxinus- & Tilia-dominated woods Maximum values of Carpinus	
Stiucii Lake: Feurdean et al., 2013	274	9500–7000	Pinus – Picea forests, some Ulmus; fluctuating Pinus/Corylus at 8500 & 7000	Increasing fire levels Fewer fires after 5100
		7000–2300	Mixed Pinus abies – Corylus woods, with high Quercus & Carpinus from 5100	
Turbata: Feurdean et al., 2007	275	9000–8000	Ulmus-dominated mixed Quercus forest; decreased shrubs & herbs	
		8000–6500	Increased Quercus & Tilia	
		6500–4500	Increased Corylus + decreased Quercus	
		4500–3000	Increased Pinus & Picea, decreased Corylus	
Preluca: Feurdean 2005	730	8700–7300	Ulmus- & Picea-dominated woods; increased Quercus, Tilia & Fraxinus (later Corylus)	
		7300–4800	Ulmus- & Picea-dominated woods, Corylus peak	
		4800–3750	High Corylus, increased Picea; Fagus peak at 4500	
		3750–2000	Picea-dominated woods + deciduous trees; increased Carpinus	
Sofular Cave: Göktürk et al., 2011	440	8965–7500	Increased precipitation and intensity	
		7500–6630	Stable, lower precipitation phase	
		6630–4295	Increased precipitation and intensity	
SW Black Sea: Atanassova 2005	0	9890–9180	Artemisia – Chenopod steppe + Ephedra	First signs of human impact
		9180–5685	Increased mixed Quercus forest, with Corylus maximum at 7340–5685	
		6390s	Short, sharp decrease in arboreal pollen	
		5685–2135	Dense mixed oak forest, with maximum spread c. 3795 and expansion of Fagus after 4500	
Straldzha: Connor et al., 2013	130	8300–7000	Forest steppe + Pistachia	Low-level Triticum-type pollen, with SIs – garden cultivation
		7000–2000	Mixed Quercus forest (Quercus peak at 4600)	
Durankulak: Tonkov et al., 2014	0.40	6000–4000	Chenopod – Artemisia steppe, with Poaceae & stands of trees	Hordeum-type, Triticum-type pollen 5300–4200; increased pastoral & arable SIs from 4800
		4000–3250	Forest steppe (C. betulus, Ulmus, Tilia, Acer & Fraxinus)	Abandonment of fields; no Sis
Heraklea, Crimea: Cordova and Lehman 2005	100	12–11000	Mixed oak forest	
		11000–6400	Steppe conditions with chernozoem formation	
		6400–3775	Spread of Mediterranean taxa, with summer drought	
		3775–3365	Increased rainfall with more arboreal pollen	
Nebelivka, South Central Ukraine: Albert et al. (submitted)		4360–4300	Tilia – Quercus – Corylus woodland with Poaceae	First of several major Cerealia peaks (4200) in continuous curve; one large fire event (4100) and several small fire events
		4300–3620	Increasing Poaceae	
		3620–3170	Fluctuating Poaceae and mixed oak forest, with increasing Tilia and Corylus before increase in Quercus	Increased pastoral indicators with continuous Cerealia curve; several small fire events
Mount Athos Basin Core SL 152 (Kotthoff et al., 2008)	0	9800–8000	Major increase in non-steppe grasses	
		8000–7700	Decline in non-steppe grasses, expansion of broad-leaved forest	
		7700–4600	Extensive broad-leaved oakwoods; Pinus/Abies increase from 5000	
		4600–3000	Thinning out of forest, still oak-dominated; 1st heather and hornbeam pollen	

Key: SI – secondary indicator of arable or pastoral activities.

axes for extensive forest clearance (Chapman, in prep.).

Two decades ago, Willis and Bennett (1994) proposed an influential two-part hypothesis in which they argued (1) against Neolithic 'human impacts' on the Balkan – Carpathian landscape and (2) in favour of the first intensive forest clearance in the Bronze Age. Their first proposal depended on the absence, or paucity, of primary and secondary indicators of farming in pollen cores dated to the Neolithic period – an absence of evidence partly attributed to the availability of partially open landscapes for many farming communities (1994). The second possible reason for minimal 'indicator' species was the distance of Neolithic and Copper Age sites from the pollen coring sites – an issue that Willis et al. (1998) sought to control for in their counts of Neolithic sites within a 50-km radius of the Kismohos coring site in NE Hungary. In this case, they argued that the ten erosion episodes identified at Kismohos were caused by local disturbances to the vegetation and burning – the results of human farming practices. This rather coarse-grained measure of settlement impact remains less convincing than the results from pollen coring sites in close proximity to dated Neolithic settlements. The essential problem is to decide whether the (near-) absence of farming indicators can be interpreted as a lack of Neolithic farming 'impact' or a sign that farming sites are relatively far from the pollen coring sites, with no detection of their farming signals.

It is apparent that Willis & Bennett's first hypothesis is in urgent need of a rigorous test to overcome its inherent sampling and methodological problems. Such an evaluation should be based upon the spatial relationship between the pollen coring sites and their neighbouring prehistoric occupations (or lack of them). Pollen diagrams with negligible signs of farming practices &/or further opening-up of the forest in the period 7000–4000 BCE can be divided into three groups: (1) locales with local potential for burning but little evidence for local or even meso-local dwelling (e.g., Taul, Prokoško Jezero, Mohos Lake and Preluca); (2) locales with archaeological sites within a few km (Malo Jezero on Mljet (until 4100 BCE), Maliq, Tenaghi Philippon/Dikili Tash and Turbata)

Table 2
Indicators of farming practices in AMS-dated pollen proxy records (dates in Calibrated BC).

Pollen site	How far to site(S)	Cereal-type pollen	Secondary indicators	Woodland management	Increased burning
Dikili Tash cores 4 & 12	159 m/ 1.75 km		6200 BCE		
Sarló-hat	<1 km	6300–3000	6300–3000	6000–5000; 5000–4500	6700–5900; 5200; 4900; 4200
Durankulak	<1 km	5300–4200	5200–4200		
Kiri-tó, Ecsegfalva	<1 km	6000–5500	6000–5500		6000–5500
Lake Prespa	<5 km	6800	5900–4000		6300–6100;
Griblje	<10 km	7500–5500	5000–3500		4100–3700
Mlaka	<10 km	4100–3700	4100–3700	? 5000–4100	4100–3700
Malo Jezero, Mljet	<10 km	4100–3500	4100–3500		
Straldzha	<10 km	7000 – post-4000	7000 – post-4000		7700–7000; 3600–3400
Pirin Mountains	Regional	5500–5000	5500–3800		
Prokoško Jezero (Bosnia)	35 km	Early Holocene (natural, not anthropogenic)	5500–3430		6000–3300 BCE
Lake Kolon	Regional	6400–4000	6400–4000		
Avrig	Regional	4500–3800	4500–3800		
Kismohos	Regional		5300–3500		5300–5200; 5100–4900; 4000–3800
Sirok	Regional		4900–3750	4900–3750	4900–3200 (slight increase)
Nebelivka, South Central Ukraine	250 m	4200–3340	4200–3340	Especially during mega-site occupation, 3950–3800	9 Fire Events between 4200 and 3340

(3) others with no clear evidence about settlement (e.g., the SW Black Sea marine cores). The pollen coring sites in the first group are all medium-to high-altitude locales (730–1670 masl), where Neolithic or Copper Age settlement was improbable, except perhaps for summer transhumant sites which would have left few traces in the pollen diagrams. By contrast, pollen sites in the second group offer a better means of assessing the Willis & Bennett hypothesis, since there are documented examples of Neolithic and/or Copper Age sites within a 10 km range.

Turning to the pollen proxy records which registered indicators of human farming practices (Table 2), there are five pollen sites within 1 km of a prehistoric site; five diagrams within 5–10 km of a settlement; and six pollen sites with regional evidence for prehistoric settlement, often 25–50 km from the coring site. The overall expectation would be that the strongest signals for farming would occur on coring sites closest to settlements. This is the case for the 5th millennium BC sections of the Sárlo-hát core, the 5th – 4th millennium BC sections of the Durankulak and Nebelivka cores (Albert et al.,submitted) but not for the Kiri-tó core, close to Phase 2 Ecsegfalva 23 (Whittle, 2007). While the higher level of local burning at Ecsegfalva was attributed to local settlement practices, there were low frequencies of cereal-type pollen and secondary indicators (Willis, 2007). The small size of the Körös settlement, with its permanent garden cultivation, is the most likely reason that relatively few traces of farming were found in the nearby lake core – a result supporting the Willis and Bennett thesis. However, there is indubitable evidence from both Sárlo-hát and Durankulak for intensive agriculture and/or extensive pastoralism prior to 4000 BCE, as well as from Nebelivka in the first centuries of the 4th millennium BC - causing the rejection of the Willis & Bennett thesis. The most intriguing example is the Lake Maliq core, where the only traces of human impact produced by the long-term occupation at the lake-side site of Maliq (dated 6200–3000 BCE) came in the earliest dwelling phase in the form of a short-lived forest clearance (Denèfle et al., 2000; Bordon et al., 2009).

In the next group of pollen coring sites, each of the authors emphasizes the small-scale nature of the farming practices attested in their cores. The Straldzha core, located in the Yambol Basin in SE Bulgaria, lies close to several 6th – 5th millennium BC tells, whose farming practices were marked by a continuous low level of *Triticum*-type pollen (Connor et al., 2013). Comparable findings, with the addition of charcoal peaks, were made at Lake Prespa despite the absence as yet of any Phase 3 lakeside settlement (Panagiotopoulos et al., 2013). The Slovenian diagrams of Mlaka and Griblje (Andrić, 2007) show the creation of a mosaic of fields, pastures and meadows under the influence of local farmers. An intriguing occurrence at both Griblje and Lake Prespa is the short-lived occurrence of cereal-type pollen in the late 7th millennium BC – well before the local beginning of farming. A final pattern concerns the intensification of farming, in conjunction with charcoal peaks, cca. 4000 BCE and in the succeeding centuries – found in both Mljet and the Slovenian cores. Both of these areas lie on the periphery of the core distribution of major Chalcolithic settlement, with a delayed-action farming expansion perhaps related to cultural changes in the core zone. The general pattern of these vegetation stories – the small-scale interventions of Neolithic and Copper Age farmers – can offer only limited support to the Willis – Bennett model because there is no clear definition of the source of the indicator pollens. It could equally well be argued that an apparently small-scale intervention created by a settlement 10 km distant from the pollen coring site would represent a much bigger ‘impact’ than if the same indicator species had been found on a pollen site next to a Neolithic settlement.

In the absence of precise archaeological mapping in the micro-region of the third group of five pollen coring locations, it becomes even harder to evaluate the data in the light of the Willis – Bennett notion. The most remarkable case is the suite of farming indicators in the Pirin Mountains diagram, in a lake at an altitude of 2190 masl! There is evidence of a continuous curve of secondary indicators from 5500 – 3800 BCE, with cereal-type pollen in the earlier part of this period (Marinova et al., 2012). While this period coincides with an intensification of Neolithic settlement in the Struma valley to the West, it is still hard to identify the mechanisms by which these pollen species were incorporated into such a high-altitude lake. Dörfler (2013: 352) proposes that the *Plantago lanceolata* curve at Prokoško Jezero – over 1,000 m higher than the Neolithic sites in the Visoko Basin - could result from either lowland pollen blown upslope or moderate human disturbance round the lake, perhaps indicating small-scale cattle herding. All of the pollen coring sites related to prehistoric settlements at a regional scale could be used to support an argument for a much bigger 'impact' than if the same indicator species had been found next to a Neolithic settlement.

In summary, if the Willis – Bennett hypothesis for minimal 'human impact' on the Balkan environment during the Neolithic and Copper Age has not yet been falsified on a broad scale, it has certainly been challenged at a series of individual sites. The most general result is that, in the period 6200–3000 BCE, approximately a half of the proxy records showed signs of human impact at varying levels of intensity. The principle can be proposed of a general relationship between the scale of the 'impact' and the distance of a pollen coring site from the prehistoric settlement(s) whose inhabitants were supposed to have caused that 'impact'. In the final part of this section, I shall examine in more detail a set of four pollen cores whose relationship with a nearby site has been well established.

5. Proxy records next to prehistoric settlements

The Dikili Tash cores were collected close to the 17 m-high Neolithic tell, with the Dik4 core 1.75 km from the tell and the Dik12 core only 150 m from the tell (Glais et al., 2015). While the Dik12 core shows perennial pasture plants from the mid-7th millennium BC (the local Early Neolithic) and anthropozoogenous taxa from the mid-6th millennium BC (the local Middle Neolithic) (2015, Fig. 4), there was a sudden appearance of *Cerealia* pollen in the mid-7th millennium BC in the Dik4 core, with *Cerealia* values rising to 10% - a clear sign of human impact (2015, Fig. 6). The human impact from the mid-6th millennium BC onwards was masked by the dramatic increase in alder-carr, showing a local closing of the environment. However, once alder values had declined to c. 30%, there were renewed signs of human impact, especially pastoral practices, in the late 6th millennium BC. These data are significantly early in the settlement of North Greece, showing local human impact on what was then 'a pristine forested environment' (2015, 246), representing a far earlier series of human impacts than was detected in the regional pollen diagram of Tenaghi Philippon.

At Sárlo-hát, North East Hungary, a series of changes in the type and scale of land-use can be detected in pollen cores taken less than 100 m from a Middle Neolithic and a Copper Age site (Magyari et al., 2012; esp. 294–6). Woodland clearance and burning was practiced by the Middle Neolithic Alföld Linearbandkeramik groups to produce wetland pasture, presumably for cattle as much as caprines, rather more than for arable farming. Low-intensity farming is proposed for this group, in which settlement dispersion reaches its Neolithic maximum. In the following Late Neolithic, there is an increase in open grassland indicators of up to 40%, suggesting large open areas for cattle husbandry. However, mixed farming is indicated by the shared cereal species and crop weeds found in both the Sárlo-hát core and the plant macro-fossil assemblage at the Late Neolithic tell site of Polgár-Csőszhalom, 11 km to the South (Fairbairn, 1992: 1993: Raczky et al., 2011). Forest clearances through burning continued on into the Early Copper Age, but with fewer pastoral and arable indicators, suggesting a dispersion of both cattle-keeping and cereal cultivation in smaller homesteads rather than a decrease in the number of cattle kept in comparison with the Late Neolithic. This vegetation record shows that Neolithic and Copper Age environments could be strongly modified in this region, in which *Corylus*-dominated broad-leaved forests have been extensively cleared round the lake predominantly for animal-keeping rather than arable farming. The scale of clearances are also consistent with the fluctuations in the settlement record in Eastern Hungary, from Middle Neolithic dispersion to Late Neolithic tell-based nucleation to Copper Age dispersion.

At Durankulak, a series of pollen cores from the lake is located at 100 m from the Late Neolithic settlement on the shore and from the Chalcolithic tell on the 'Big Island' (Todorova, 2002; Bozhilova and Tonkov, 1985; Marinova, 2003; Marinova and Atanassova, 2006; Tonkov et al., 2014). The extent of clearance required for any farming practices is uncertain, since the dominant vegetation around the Durankulak Lake continues to be an open Chenopod – Artemisia steppe with stands of trees in moister areas until 4000 BCE, whereupon a forest-steppe developed lasting well into the 2nd millennium BC. The low level of cereal-type pollen in the late Neolithic and even earlier, at the turn of the 7th millennium BC (Tonkov et al., 2014: 280), suggests small-scale farming in the area, mostly in the open areas with better-quality soils. It is only in the Chalcolithic that we see increased signs of *Triticum* and *Hordeum* pollen, in combination with secondary indicators and lower percentages of arboreal pollen. These data point to not only larger-scale arable and pastoral practices but also clearance of some of the remaining forests. In the 4th millennium BC (transition from the Final Chalcolithic to the Early Bronze Age), the absence of primary and secondary indicators of farming suggests the abandonment of fields near Durankulak Lake, until an increase in pastoral indicators is noted after 2700 BCE. As in North East Hungary, it is in the 5th millennium BC - well before the Bronze Age! - that local communities increased the openness of their local environment for the intensification of arable cultivation and pastoralism.

One of the surprises of the Nebelivka core, located 250 m from the 236-ha. Trypillia mega-site, was not that there was early 4th millennium BC human impact but that there was not an overwhelming human impact. The human impact showed up as a series of deforestation episodes, a suite of nine fire events, including a massive fire event dated to c. 4190 BCE, and a continuous, if not particularly high, Cerealia curve (Albert et al., submitted). However, these impact events can be dated to before and after the 150-year duration of the Nebelivka mega-site (3950–3800 BCE: Millard et al., in prep) as well as during the occupation. Moreover, there was remarkably little soil erosion in the whole sequence, as confirmed by a very slow sedimentation rate. All of these findings create a problem for the interpretation of Trypillia mega-sites as long-term, permanently occupied settlements with massive populations; the Nebelivka group is modeling various alternative scenarios which involve either seasonal aggregations or far lower populations (Gaydarska, 2016; Gaydarska and Chapman, 2016).

In the Slovenian karst areas, where farming began much later than in the East Balkans, the Griblje and Mlaka diagrams (Andrić, 2007) indicate burning of the forest for clearance through much of the Holocene, with greater diversity of species associated with the local start of farming in the 5th millennium BC. At this time at Mlaka, coppicing and burning were used to maintain the *Carpinus betulus* forest and prevent the expansion of *Fagus*. This *Carpinus* woodland was not encountered at Griblje, where cereal-type pollen and secondary indicators occurred in the 5th millennium BC. The greatest extent of human activities was dated to c. 4100 BCE, resulting in a mosaic of plant associations which included meadows, fields and pastures. A decline in farming practices is dated to after 3700 BCE, which lasted until the first large-scale landscape modifications in the Late Bronze Age. The Slovenian records are good examples of the Willis & Bennett model working in a lowland region where agriculture developed late in the middle Holocene. The intensification of pre-Bronze Age farming practices a millennium after the earliest farming is paralleled in the other diagrams discussed here.

The results of the comparisons of proxy vegetational records with dwelling sequences at settlements close to the pollen cores show clear evidence for 'human impact' in the Neolithic and Chalcolithic periods, dated to one or two millennia before the Bronze Age when impact began according to the Willis – Bennett model. The key factor which Willis and Bennett overlooked was the scale of agricultural practice (Bogaard, 2004), which remained small-scale in the Early Neolithic but increased in scale in the Later Neolithic and Chalcolithic.

6. Conclusions

In this paper, two questions have been investigated: the effects of claimed global changes in Holocene climate at the regional and local scale and the extent of human impact in these proxy records prior to the Bronze Age of the ABC zones. I selected several claims for environmentally generated settlement changes, including what has become the most notorious of the climatic forcing mechanisms – the 8200BP 'event'. The worst correlation of supposed environmental changes with settlement changes were Weninger et al.'s (2009 and 2014) studies, when, in the former, the supposed climatic forcer coincided with the biggest expansion of Moldavian – Ukrainian Neolithic settlement – the Cucuteni A – Trypillia B phases – throughout the 4th millennium BC, while, in the latter, there were several major peaks in the cumulative 14C record coinciding with the '8200BP event' In the numerous studies of the alleged impact of the 8200BP 'event', it was difficult to pin down the chronology of the 'event' to within 500 years – meaning that it has not been possible to examine the question of supposed correlations with changes in settlement patterns or subsistence strategies at local or regional level. At a more detailed level, the investigation of the impact of the 8200BP 'event' on proxy records such as well-dated pollen sequences revealed that changes in regional or local vegetation could be related, even with relative chronological imprecision, to the 8200BP 'event' in only a minority of cases. The rarity of climatic impact on 25 well-dated pollen sequences shows that either there was a minimal impact from the 8200BP 'event' (more probable) or the impact was short-lived and rapidly reversible (less probable). Given the failure of the environmentally determinist model, the message to Aegean - Balkan – Carpathian prehistorians is that alternative causes of settlement and/or cultural change in the late 7th millennium BC should be urgently sought.

We could make a start by noting that local communities made thoughtful choices about where to live, how to cope with slow or minor changes in vegetation cover or lake/river levels, as well as what to eat and drink. The current dating of proxy records provides at best a centennial record, equating to three or four human generations. The choices made by communities, households and persons meant varying pressures on local landscapes, leading to different perceptions as well as varied actual environments (Head, 2008). The increase in *Corylus* meant greater potential for nut-crops, while *Cornus mas* increases led to the wider consumption of Cornelian cherry. Both developments may have led to renewed communal focus on these harvested 'crops', with the potential for woodland management. There was also a significant development of medicinal plants from the Late Glacial onwards (Magyari et al., 2013a).

Even more important was the way households valued timber for firewood and building. The Neolithic has been described as 'the age of building' (Borić, 2008: Chapman, 2014), with dozens of houses built on the nucleated settlements of the Aegean, the Balkans and the Carpathians. Advanced time planning was necessary for the coppicing of hazel for wattle-and-daub construction (a 5-year cycle), as well as planting new oak trees for the next generation of houses (a 10-year cycle). One of the key findings of an experimental programme of 'Neolithic' house-building in the Ukraine was the realisation that the production of an individual house can be viewed as a symbolic fusion of the different elements that made up the Trypillia landscape, including clay from the earth, straw from the steppe or cultivated fields, wood from the forest and reeds and water from rivers and lakes (Johnston et al., in press). There was a multitude of ways in which environments and human communities co-created themselves.

The question of human impact at the settlement scale has been influenced for two decades now by the Willis – Bennett hypothesis that there was minimal human impact on local vegetations until the Bronze Age. This claim has been reviewed in the light of 25 proxy records, several based on cores collected very close to prehistoric settlements. While it is true that the smaller sites of the earliest Neolithic, such as Ecsegfalva 23, have produced minimal impact on their local environment, vegetation sequences close to larger Later Neolithic and Chalcolithic sites have demonstrated a varying scale of human impact, as at Durankulak, Sárlo-hát and Nebelivka. How many exceptions to the claimed lack of human impact on pre-Bronze Age landscapes does it take to constitute a formal falsification of the Willis – Bennett hypothesis?

The well-documented existence of human impacts in the Neolithic and Chalcolithic of the Aegean – Balkan – Carpathian zones makes it harder to interpret complex proxies in terms of climatic impacts alone. The two key elements in the Holocene environment of many parts of the Balkans and the Carpathian Basin which were attractive to local communities consisted of natural open grasslands or steppes and a moderate to high level of natural fires which helped to maintain any existing openness of the landscape. The extent of open landscape available to the earliest lowland farmers allowed choices of where to farm and how much open land was needed for domestic plants and animals. In upland areas, such as the Carpathians, mixed oak and hazel-dominated woodland meant that natural fires generated most of the less frequent natural clearances. This meant that farmers accepted the smaller-scale opportunities for farming or started to burn the local forest for their clearances (Bogaard, 2004). It seems likely that, for the Early Neolithic of the South Balkans and for the Hungarian Plain, only slight modifications were made to the forests, which tended to increased patchiness and species diversity. This led especially to increased forest-edge zones and secondary forests, which were ideal for farming practices such as coppicing and pollarding and the forest pasture of small ruminants (Marinova et al., 2012). The combination of population nucleation and an increased scale of farming, both arable and pastoral, from 5300 BCE onwards led to the need for forest clearance, often through burning, with long-term effects on the diversity and structure of the broad-leaved forests. An increased tendency to altitudinal differentiation of vegetation zones led to a greater variety of forest resources, which may have been an important factor in strategies of vertical movement, such as transhumance. There was a widespread re-afforestation in many areas of the study region in the 4th millennium BC, which combined with a greater tendency for settlement dispersion, the expansion of woody taxa such as *Carpinus* and *Fagus* and a lower incidence of natural fires to produce less disturbed, more closed forest landscapes. In a new cycle of farming expansion, Early Bronze Age communities reached a different balance with their trees and grasses, often leading to the signs of an apparently greater removal of trees than had happened before.

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