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Was There a 3.2 ka Crisis in Europe? A Critical Comparison of Climatic, Environmental, and Archaeological Evidence for Radical Change during the Bronze Age–Iron Age Transition

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Abstract

The globalizing connections that defined the European Bronze Age in the second millennium BC either ended or abruptly changed in the decades around 1200 BC. The impact of climate change at 3.2 ka on such social changes has been debated for the eastern Mediterranean. This paper extends this enquiry of shifting human–climate relationships during the later Bronze Age into Europe for the first time. There, climate data indicate that significant shifts occurred in hydroclimate and temperatures in various parts of Europe ca. 3.2 ka. To test potential societal impacts, I review and evaluate archaeological data from Ireland and Britain, the Nordic area, the Carpathian Basin, the Po Valley, and the Aegean region in parallel with paleoclimate data. I argue that 1200 BC was a turning point for many societies in Europe and that climate played an important role in shaping this. Although long-term trajectories of sociopolitical systems were paramount in defining how and when specific societies changed, climate change acted as a force multiplier that undermined societal resilience in the wake of initial social disjunctures. In this way, it shaped, often detrimentally, the reconfiguration of societies. By impacting more directly on social venues of political recovery, realignment, and reorganization, climate forces accentuate societal crises and, in some areas, sustained them to the point of sociopolitical collapse.

Keywords Collapse · Late Bronze Age · Europe · 3.2 ka event · 1200 BC crisis · Paleoclimatology · Environmental change

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Introduction

This paper reviews evidence for crisis-driven changes in human–climate relations in Europe ca. 1200 BC. That date occupies a broad focal point for the onset of changes visible in both social and climatic datasets that occurred within a few decades across a large and diverse region. This correlation has been extensively studied for the eastern Mediterranean and engendered much debate regarding causal relations for collapsing states and empires. In prehistoric Europe, the first globalized and international age was at its peak ca. 1500–1200 BC (Vandkilde 2016). Then in the 12th century BC, many of the influential centers and cross-cultural connections that had defined this age were fundamentally transformed. This can be recognized across settlement, mortuary, landscape management, and material culture records.

This social transformation corresponds in time with the so-called 3.2 ka event recognized in paleoclimatology of the eastern Mediterranean. The possibility that this point in time marks a change in the relationship between social and climate trajectories has not yet been explored for Europe. While distinctly different from the large, complex social entities such as the Egyptian or the Hittite empires in the eastern Mediterranean, Europe was home to diverse societies, many of which were stratified and defined by the use of shared material culture and practices across extensive areas. Through absolute and relative dates, many of these societies have closely resolved chronologies and well-defined horizons of social change. We are also fortunate to have both extensive and diverse paleoclimatic archives covering later European prehistory. Here, I present a first synthetic, parallel overview of existing high-resolution paleoclimatic and archaeological research, both of which reveal that important changes took place during the later Bronze Age.

To do this, I focus on societies from each of the broad cultural zones of Europe in the later second millennium BC—the Atlantic, Nordic, Urnfield, Carpathian-Balkan, and Aegean areas. As such, this paper provides a review of published climatic, environmental, and archaeological studies in comparative perspective and, as a result, new insights into changing human–climate relations from the 13th to 12th centuries BC. The data indicate that one of the exceptional Holocene climate deviations can be detected in Europe in the decades around 1200 BC, synchronously affecting different regions and culturally distinct societies. I argue this climate change constituted a force multiplier that shaped the end points of social crises. This impact was particularly visible in some of Europe's most culturally influential societies, reconfiguring their own trajectories and their role in driving the regional-scale networks that were a defining characteristic of this epoch. I emphasize, however, that not all societies were equally affected and the very diversity that defined the landscapes of Europe raises "the likelihood that climatic change causing chaos or challenge in one area may produce the opposite effect in another area" (Knapp and Manning 2016, p. 111).

Past climate change was a phenomenon that required societies to adapt and change—there can be no question about this. Our challenge is to define the scale, pace, and duration of change and to evaluate if particular instances were exceptional in long-term trends and/or in the context of neighboring areas. As this review of paleoclimatic data shows, it is not yet possible to reconstruct prehistoric rainfall and temperature patterns at a regional scale with high precision or accuracy. Nonetheless, by integrating a wide range of proxy data, it is possible to define broad patterns that occurred in different parts of Europe. A tentative northwest/southeast difference is also evident in the climate data. For each area, I argue that climate change was a cause of stressors that profoundly shaped how some societies negotiated crises, including their response to the collapse of political systems and long-distance networks. In other societies, climate change can be correlated with rising prosperity, yet the very process of centralization implying growth coupled with innovations in warfare reminds us that growth as well as collapse can lead to conflict in the wake of change.

In the areas reviewed, climate change data is viewed in combination with material evidence for societal resilience. I explore four specific points. (1) Indicators of a sharp change in climate, commonly manifested as increased aridity, occurred in the 12th century BC in areas of Europe dominated by different weather systems. The impact ranged from highly detrimental to beneficial depending on the case analyzed. (2) Social change unfolded over a century (or more), and this required the ongoing mediation of uncontrolled changes in environmental conditions (3) Rather than instigating crises, this change in human–climate relations constrained recovery and reconfiguration in the immediate wake of social crises or collapse in areas of Europe that had been home to comparatively complex societies. (4) This climate change horizon coincided with a significant decrease in connectivity between many parts of Europe along with changes to practices of warfare. These indicate that social stressors driving change in long-distance networks were widespread, potentially interrelated, and contemporaneous with climate change.

It Is Complicated: The Archaeology and Climate Change Relationship

Archaeology has a long but uneasy relationship with paleoclimate research. A tendency for studies to focus on human–climate relations during periods of rapid change in either dataset commonly biases discussion toward exceptional scenarios. I consciously accommodate this bias due to the wealth of suitable data for testing the principle of a "prehistory of climate and society" in Europe, to expand on Degroot et al.'s (2021) recent manifesto for *History of Climate and Society* studies. My period of interest was selected because one of the most striking collapses of the ancient world took place in the eastern Mediterranean around 1200 BC. The Hittite empire and Aegean palatial world collapsed, Levantine and Cypriot polities were destroyed or abandoned, and New Kingdom Egypt went into decline. Globalized political and economic networks that had supported thriving large-scale societies disintegrated. Over the course of a few decades, even though people and their "grand traditions" or macrocultures survived, the structural conditions of societies—the beliefs and routines that characterized a culture—were fundamentally transformed as states and empires collapsed. Cline (2021) uses this tapestry to good effect, emphasizing the risks of invoking global influencing factors, such as climate change, to explain crises in any given society and arguing we need to view each society in the context of their mutually supporting interaction networks. Although speaking of the eastern Mediterranean, his argument is salient for Europe also.

Rapid climate change (RCC) events can transform ecosystems over the course of a few centuries, occasionally with turning points identified within a scale of decades. In Europe, a RCC can be identified around 1550–550 BC, with 1250–1150 BC a key turning point (Rohling et al. 2019, p. 38). Prior to anthropogenic impacts today, the earth's climate naturally vacillated between warmer or colder and wetter or drier. In long-term perspective, the Holocene has been quite stable, and so the parameters within which variability can be recognized are comparatively narrow. Nonetheless, as we are witnessing at a global scale today, shifts that appear minor in annually or decadally resolved climate records can bring with them extreme weather events and challenges that are all the more impactful in finely balanced ecosystems.

Exceptional climate change horizons have been noted for later prehistory around 8.2, 4.2 and 3.2 ka. While proxy climate data from the eastern Mediterranean clearly identify this latter horizon, the date for its onset, its duration, and variation in its spatial and temporal intensity and impact are debated (Knapp and Manning 2016). Focused on the eastern Mediterranean, Kaniewski et al. (2019, 2020) also include markers for the 3.2 ka event in Greenland ice cores, indicating that there is value in expanding the spatial and social parameters used to explore this turning point to areas between there and the Mediterranean.

When past climate change has been related to social change, it is not uncommon to find apocalyptic scenarios whereby a sudden and rapid change in climate led to extreme aridity, causing drought that devastated agricultural productivity, triggering famine that ultimately caused social unrest, thereby collapsing economic, political, and subsistence systems (Gill 2001; Diamond 2005; Kaniewski et al. 2015; Weiss and Bradley 2001). To work, the above formula requires change to have had a rapid onset and to be widespread, extreme, sustained, and consistent for multiple consecutive years. Climatic data are the core focus in such a model and correlation with archaeological research is commonly superficial and lacking in chronologically sensitive proxies for changes impacting on local communities, for example, using geoarchaeology or archaeobotany (Manning et al. 2020). Social science research informs us that few if any past societies were intrinsically inflexible or unresponsive to environmental change (Butzer 2012). Therefore, it is difficult to articulate visions of entire societies being overwhelmed by climate change, particularly when this places communities at the mercy of structuring conditions without scope for exercising human agency (Arponen et al. 2019; Johnson 2017; Kintigh and Ingram 2018; Knapp and Manning 2016; Middleton 2017a).

This said, we must not throw the climate-change baby out with a "determinist" bathwater. It has recently been argued that late 20th century post-processualism in its ambition to build from local conditions of life also sought to reduce the focus on external drivers of cultural transformation, with the aim of better accommodating human agency (Burke et al. 2021, pp. 2–3). In so doing, broader structuring conditions that affect choice in any specific society risk being incompletely accommodated. Our challenge is to avoid the causality trap while not disentangling societies and their environments (Arponen et al. 2019, p. 2). The question is not if climate and social change are linked, but how we can objectively deal with them as coupled systems, each of which includes a tapestry of variables that will not all neatly align (Butzer 2012, p. 3633). A truly comparative approach, therefore, cannot simply juxtapose select data from climatology onto archaeology to identify causes for past social change. Ultimately our challenge is to qualitatively explain the manner and extent to which climate change influenced human choices, beliefs, and practices.

In our current "information age" set within the Anthropocene, we are cognizant of the interplay between natural and anthropogenic global warming and the effects of extreme weather that are set to evolve into a global crisis, if unchecked, during the next century (Lane 2015). Despite having this historically exceptional knowledge of probable future conditions at our fingertips, belief and political buy-in are highly varied. A lesson from our own time may be that even with 20–20 foresight of catastrophic climate change incrementally affecting societies, short-term well-being is often in tension with long-term sustainability. When projected into the past, this incremental unfolding of change against a complex backdrop of competing priorities spanning generations is probably more reasonable than apocalyptic scenarios tied to short-term decision making. Ultimately, how past people responded to the pressures of climate change within their geographic, cultural, and historical context informs us about their understanding of their environment (Lane 2015; Manning et al. 2020, pp. 1, 38; Middleton 2018, p. 109). Consequently, simple models of ancient societies being overwhelmed by nature are of little benefit for understanding sustainability in long-term perspective—and this latter viewpoint even has potential to impact policy making today (Haldon et al. 2020, pp. 32–33).

Climate Proxies

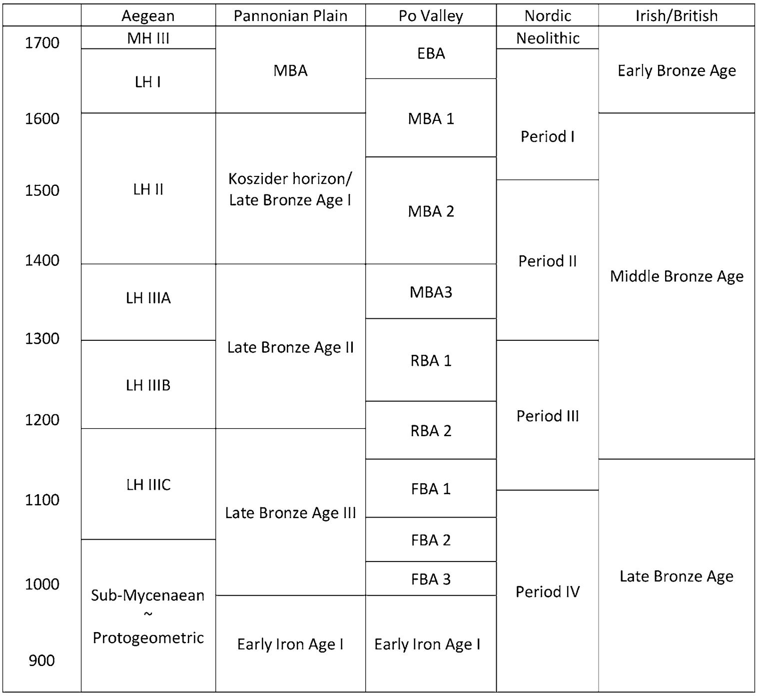
To understand past climates, different proxy data are used to develop models of specific aspects of climatic conditions and how these change over time. That is, we do not reconstruct past climatic conditions in their entirety but rather develop "estimates based on distinct statistical interpretations of available sources that may differ from each other and have important and substantial uncertainties on spatiotemporal scales" (Degroot et al. 2021, p. 540; see also Burke et al. 2021, pp. 4–5).

Paleoclimate data are obtained from incrementally laid down, or stratified, deposits of very diverse materials. Each approach has in common the isolation of strata that can be dated, thereby allowing climatic proxy data to be incrementally extracted and measured. Sources include cave speleothems (stalagmites, stalactites, flowstones), sediment cores from lakes, bog accumulations, and tree rings. While ice cores are spatially beyond this review, they do provide a well-resolved geochronological control for other proxy data at a large spatial scale. Due to the broad geographic scale of this study, I collated and reviewed the results/conclusions of paleoclimatic and environmental studies that have used a range of different proxies. This is conducted at a necessarily superficial level without detailed evaluation of uncertainties in the results. In light of this, studies with closely constrained age-depth models and tight time increments were prioritized, and observations presented herein take account of the resolution of each study. Where lower-resolution datasets are included, limitations are stated in the text.

The regional picture is constructed from multiple local-scale studies; consequently, there is rarely a uniform and clear pattern to this bigger picture, and there are occasionally partly conflicting signatures even from neighboring datasets. Nonetheless, an aggregate picture is apparent across most datasets for each area; whatever the nature of changes inferred, they occurred at an exceptional level in a horizon beginning between 1250 and 1150 BC and lasting at least into the 11th century.

Study Areas

Parallel study of contemporary past societies allows us to view society as a framework within which climate change may be evaluated but also to view a single horizon of climate change as a structure within which different societies can be evaluated. This allows the potential impact of climate change on societies to be more clearly exposed at a regional scale. Europe is ideal for such a comparative study because it ranges between subtropical Mediterranean and Polar tundra climates; it is subject to Arctic, Siberian, Atlantic, and Mediterranean weather influences; and it has myriad topographies and distinct ecosystems. In addition, of the reputed 8.2,



	Aegean	Pannonian Plain	Po Valley	Nordic	Irish/British
1700	MH III LH I	MBA	EBA	Neolithic Period I	Early Bronze Age
1600	LH II	Koszider horizon/ Late Bronze Age I	MBA 1		Middle Bronze Age
1500			MBA 2	Period II	
1400	LH IIIA	Late Bronze Age II	MBA3		
1300	LH IIIB		RBA 1	Period III	
1200	LH IIIC	Late Bronze Age III	RBA 2		
1100			FBA 1 FBA 2	Period IV	Late Bronze Age
1000	Sub-Mycenaean ~ Protogeometric		FBA 3		
900		Early Iron Age I	Early Iron Age I		

Fig. 1 Timeline of generally accepted dates for each region. Note some chronologies remain debated and low and high alternatives are posited but not engaged with here.

4.2, and 3.2 ka climate events, the resolution of archaeological relative chronology is highest for the 3.2 ka horizon, and there is also a high density of absolute ^{14}C dates (Fig. 1). Through excavation and survey, there is also a greater number of known sites in most study areas in this timeframe.

The selection of study areas was based on archaeological criteria to provide a European perspective on human–climate relations rather than being predicated on availability of paleoclimatic datasets. This helps avoid a "streetlight" effect of picking areas with (apparently) the most suitable data (Degroot et al., 2021, p. 540). Societies chosen are samples of each of the general "blocks" of social traditions/regions in Europe—the Atlantic, Nordic, Urnfield, Carpathian-Balkan, and Aegean zones (Fig. 2). The societies explored in detail vary in many regards and include politically hierarchical urban systems (the Aegean), densely settled landscapes dominated by monumental settlements and modest hierarchies (Po Valley and Pannonian Plain), multifamily long houses ranging from isolated to very densely distributed in a society with marked hierarchies (Nordic area), and finally, isolated, probably nuclear-family households with rare nucleated settlements or central places, with low visibility of social hierarchies (Ireland and Britain).

Even theoretically accepting a large-scale 3.2 ka climate event, this should have varied impacts in these areas based on prevailing weather systems, geographic location, economic networking, and internal social organization. This also has the potential for "bad" climate change in one area to equate with "good" climate change in another, when viewed through a social lens. Archaeological research has defined

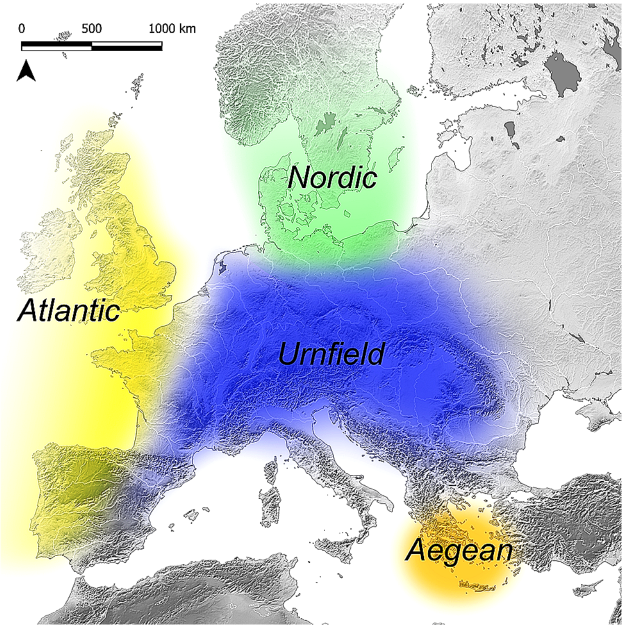


Fig. 2 Macro-cultural tradition zones of Bronze Age Europe. Basemap is a modified version of a European Environment Agency 2004 map (permalink: 070F2DAD-1AED-4B9B-950F-0047E5ADDF35) used under their copyright conditions

substantial cultural changes in each study area between 1200 and 1100 BC (Supplemental Fig. 1). I argue that while climate change constantly shaped human–landscape relationships in prehistory, the 12th century drift was unusually sharp and was a driver of exceptional social changes at a spatial scale not seen before in Europe. Some societies were more directly impacted than others, but the aggregate impact on local and regional networks conveying globalizing influences was substantial enough to mark the 12th century as a key turning point in European prehistory.

A recurrent issue is that climate change is notoriously difficult to pin down to narrow chronological parameters that can articulate with the resolution of archaeological chronologies and defined horizons of social change (Manning et al. 2020; Middleton 2017b; Swindles et al. 2013). This places a burden on archaeology at least to provide well-resolved spatial and temporal data in sufficient quantity to model the temporality and pace of change in societies. Fortunately, the late second millennium is a highly relevant window because we have (1) several areas with robust absolute and/or relative chronologies, (2) diverse social entities in which changes in complexity, land use, and population have been defined, (3) many different geographic and environmental zones with comparable datasets, (4) varied farming and land-use regimes seen in faunal, macrobotanical, and palynological datasets, and (5) a proposed horizon of crisis-driven social change around 1200 BC that affected trans-European networks (Cardarelli 2009; Kristiansen 2018; Kristiansen and Suchowska-Ducke 2015; Middleton 2020b; Molloy et al. 2020; Vandkilde 2016, pp. 116–117).

Theoretical Reflections on Palaeoclimatology and Social Change

When we consider the relative fragility of societies, which may expose them to introduced crises, then from agriculture to economics, there is a risk that the excessive specialization and interdependencies that characterize some societies led to over-connectedness and systemic rigidity (Yoffee 2019). This may lead to the transgression of a "stability threshold" that increases societal vulnerability (Haldon et al. 2020). When landscapes are pushed to the limit of their carrying capacity, then adaptation, though necessary, may go against the organizational logic of a society, constituting "a form of path dependency and lock-in effects" (Weiberg and Finné 2018, p. 586). This means there can be a risk implicit to successful strategies for utilizing a landscape because they may become in thrall to specific political-economic systems (Cumming and Peterson 2017). This in turn has potential to create hazards that arise from a dependency on suitable conditions for that system (Arponen et al. 2019). In general terms, surplus agricultural practices, with specific crop and animal management routines, might emerge in a wetter climatic niche and fuel growth of complexity and population synchronously, but the onset of drier conditions may undermine the productivity required to sustain that system. This constitutes a classic "overshoot" model (Tainter 1988). This fragile dependency scenario may also be reflected in arenas such as the resourcing of warriors to sustain power balances or provisioning of food and materials for "public" events to consolidate polities. Both arenas could encourage fealty within elites but required leaders to have specific resources to disburse and share predictably. How people reacted to interruptions or changes to these expectations may be more impactful than the material shortages driving them.

Clearly, environmental change need not render landscapes wastelands to impact social strategies; it only needed to occur at a level that challenged management strategies and, by extension, elite authority and political stability. Whether politically or divinely mandated, leadership is embedded with ideology, and the loss of belief due to an inability to mitigate fundamental challenges or threats has the potential to undermine a system (Johnson 2017, p. 60). This is particularly acute when there is an expectation for leaders (and their agents) to be capable of interceding with divine forces. It is tempting to view, for example, the increase in hoarding of bronze objects between the Po Valley and Carpathian region in the 13th to 12th centuries as reflecting just such a "failed" crisis response.

We may predict that reactions to climate change were predicated upon a given society's perception of the environment and their place within it (Haldon et al. 2020, p. 9). Climate or environmental change need not cause all infrastructures of a society to collapse to be ruinous, as they may act as force multipliers that trigger "smaller but potentially interacting collapses in different realms" unfolding with varied tempo over a century and more (Cumming and Peterson 2017, p. 695; see also Weiberg and Finné 2018, p. 597). Substantial transformations, in such circumstances, were not a linear trajectory of incremental dislocation and loss, but vacillating cycles of challenge and inadequate responses that successively depleted participation in a given system.

Discussion of collapse in archaeological literature has seen renewed interest in recent years, and the notable consensus is that the term should not be taken to infer an event that took place within one to several years. Collapse is better viewed as a particularly acute period of transition or transformation, occurring over several decades, and characterized by the substantial loss of defining elements of a given society (see Johnson 2017; Middleton 2017a). These may include political, ideological, or craft traditions. Although commonly explored from the perspective of settlement archaeology, changes to the routine material conventions of lifeways are also salient and often accessible through the analysis of material culture or ecofacts.

How a time of crises or collapse related to preceding and following conditions has recently been explored in terms of resilience and transformation. At its most basic, resilience relates to the capacity of a society to absorb challenges and adapt while retaining the basic form and function characteristic of that society (Middleton 2017a, p. 42). However, within the context of known horizons of societal change, resilience can usefully serve as a measure of continuity of key elements of a society during and following periods of crises (Bradtmöller et al. 2017). This essentially asks what defining elements of a society survive the collapse of some or many social institutions and remain centrally relevant as societies accommodate disturbance and reconfigure themselves (Degroot et al. 2021, p. 540). The legacy of organizational frameworks such as elites using socially ingrained agricultural practices or ideologies—we might even say harmful resilience—to try to maintain productivity or control may ultimately make unhappy bedfellows. For this reason, resilience should not be confused with sustainability, because it can incorporate conservatism, discrimination, polarizing beliefs, and even a lack of temporal or geographic "perspective" that may alleviate short-term or local problems.

Borrowing from ecology, formal resilience theory (RT) draws upon adaptive cycle and panarchy models to contextualize collapse within cycles of growth and decline (Bradtmöller et al. 2017; Cumming and Peterson 2017; Gunderson and Holling 2012). This approach recognizes collapse as a stage in cycles of growing and contracting prosperity and/or complexity in societies. The relevance and limitations of this for understanding prehistoric crisis-driven social change has been explored elsewhere (Middleton 2017a). One limitation in the strict application of RT as a model to structure data, rather than as a heuristic to characterize different paces and forms of social change, is that it reduces culture to its bare material attributes. Climate and environmental change, coupled with other stressors, may in principle force changes in ideological, artistic, political, religious, and economic components that give a society its identity and distinguish it as a specific historical entity—be it a culture, civilization, or otherwise. What is lost is, therefore, as important as, if not more important than, what survives or proves resilient for understanding the social characteristics of crises-driven change. Resilience in broader archaeological terms (beyond formal RT) may be measured in diachronic perspective via material markers for retention, loss, adaptation, innovation, or introduction of features specific to a society, and I have this broader perspective in mind when discussing my study areas below.

Climate and Environmental Data for European Study Areas of the 13th to 11th Centuries BC

The Nature of the Evidence

In broad terms, the blocks of time we have to measure social transformations in Europe in the later second millennium BC range between 20 and 100 years. In an ideal world, we would reconstruct weather patterns on a multiseasonal/annual basis, but with the resolution of dating methods and the stratigraphic resolution available, we are more commonly considering decadal-scale increments when we integrate multiple distinct proxies (Finné et al. 2019; Swindles et al. 2013). In archaeological language, paleoclimate proxies are generally locked into *longue durée* perspectives on past processes of change, and only rarely have resolution to address the viewpoint of event history or *histoire événementielle* (Braudel 1972). Considering spatial scales, in pre- and protohistoric research there also is a greater tendency to focus on society-specific cases, which bracket geographic extents to relatively specific niches, with comparative regional studies notably rarer. This has the advantage of accommodating uncertainties in paleoclimate data in nuanced discussion, and the disadvantage of privileging particular societal systems in particular organizational states relative to their spatial and historical contexts.

Haldon et al. (2020) emphasized the need to consider change as relative to the lived conditions of those experiencing it, which requires a multigenerational scale. Barrett (1998) similarly argued that our bird's eye view of prehistory affords a view of before, during, and after conditions of societal change, which is in turn set within a spatial context that accommodates neighboring sociopolitical entities. This has both the advantage and disadvantage of enabling us to view societies in a manner they themselves did not. In the areas examined in this paper, change took place over the course of a century, punctuated by events; my aim is to look at several lifetimes of shifting human–climate–landscape relationships in comparative regional perspective.

While some climate proxies have more tightly constrained chronologies, temporal resolution is limited by the lowest resolved record included as well as the archaeological chronologies that are considered in parallel. This means any "events" we recognize can rarely be pinned down with great precision in calendar years. I am also cautious not to use event horizons themselves as a tool to correlate different datasets independent of reliable chronologies, because regionally specific conditions may unfold differently over decades or more (Swindles et al. 2013). At the same time, we should resist blurring the often precise and well-punctuated archaeological timelines to "fit" with sometimes less precise paleoclimate data (Haldon et al. 2020).

Apart from annual trends of climate change, extreme weather events today are highly impactful, from floods to droughts. Over the course of days to months, extreme events can have devastating effects. This emphasizes the need to view paleoclimatic data cautiously; in most cases they present averages of conditions across several years and can have seasonal biases. For example, chironomid-inferred temperatures relate to summer months, tree rings relate to spring and summer growth seasons, and many speleothems from continental Europe are probably biased toward wintertime hydroclimate. Geoarchaeological studies that can capture short-term and highly localized impacts of weather conditions are rare but, for example, reveal sluggish rivers in parts of the Pannonian Plain or brief arid summer phases in the Po Valley in the 12th century BC (Cremaschi et al. 2006; French 2010). The crucial issue is that the majority of paleoclimatic and environmental data can only present general trends and rarely the highly disruptive, even catastrophic, weather events whose signature would be, broadly speaking, bundled together with different signatures within the temporal steps our proxies reveal.

By far the most chronologically precise proxy is oak growth rings, where annually resolved increments have been identified. Unfortunately, using current methods, what each ring in isolation can tell us about climate conditions is limited, and their use as climatic records is much debated. Another proxy that may have high-resolution chronological increments is speleothems. These occur in most parts of the world where karst geology exists. Water seeping into caves lays down stalagmites, stalactites, and flowstones in increments that can be distinguished, dated, and analyzed for climatic signatures. However, their development is impacted by a range of factors that shape their formation and secondary modification, as well as the relative seasonal contribution to the isotopic values that reveal hydroclimatic and/or temperature conditions (Fairchild and Baker 2012). This is relevant because "each proxy depends on its original local context, the interpretation of the hydro-climatic conditions … does not necessarily reflect just wet or dry climate" (Palmisano et al. 2021, p. 390).

Bog records depend on waterlogging and so occur typically in northern and western parts of Europe, though examples are found throughout the entire region. They provide a range of quantitative and semiquantitative markers for hydroclimate, commonly using a combination of testate amoebae, humification, and plant macrofossil analyses (Swindles et al. 2013, p. 308). They have the advantage of being sequentially laid down in layers that can be ^{14}C dated directly, but ruptures called bog bursts, for example, and the equivocal nature of proxy data impact their reliability (Gearey et al. 2020).

Analysis of pollens reveals the range of wild and cultivated plants in the capture area surrounding a sample site, which in turn provides direct evidence for the relative extent of anthropogenic activity as well as how species taxa reflect prevailing environmental conditions in chronological sequence. As dating is usually dependent on a small number of ^{14}C dates from detritus unintentionally deposited, age-depth models can be of variable precision, and so analytic increments consist of blocks the dating of which may not be more tightly constrained than several centuries. There is also an issue that pollen dispersal can overemphasize the presence of certain species, notably trees, and the preferential preservation in waterlogged areas biases analyses toward specific landscapes, which can underestimate degrees of openness of landscapes visible in grass or cereal versus arboreal pollen (e.g., Fyfe et al. 2013, fig. 1). Other proxy data are used here, each of which have limitations and inconsistencies relative to other datasets in terms of the timing and nature of conditions (hydroclimate and/or temperature).

We are also dealing with local climatic conditions across Europe that were shaped, to varying extents, by Atlantic, Arctic, Siberian, and Mediterranean weather systems. Each of these impacts the other such that changes in one region may influence unequal changes in another (Perşoiu et al. 2017). For example, Luterbacher et al.'s (2010) study of historic patterns and more recent work by Rohling et al. (2019, pp. 39, 50) demonstrate how increasingly cold and wet winters in the Aegean can be closely related to Atlantic conditions. Also increased aridity in areas dominated by Mediterranean weather systems can co-occur with increased rainfall in areas dominated by Atlantic systems in historic records (Turney et al. 2016, p. 77). As Carpenter noted in one of the earliest studies of climate–human relationships in prehistory, with the varied bodies of water, mountains, and open landscapes in Europe, the manifestations of climate change and their impact even at a local scale may be highly varied, never mind at the larger scale of this study (Carpenter 1966, pp. 63–70).

The Nature of Change Attested in Paleoclimate Proxies

With the above caveats in mind, before reviewing the available evidence, I set out general trends that are evident in many of the local proxies for each region. There are minor exceptions and contrary markers in some of these, and so the patterns presented are in broad strokes. The data from the south of Greece indicate that during the 12th century, that is after the collapse of palatial administrations had occurred, increasingly cooler and arid conditions set in for several centuries. The highly resolved Mavri Trypa cave hints that a brief arid peak occurred prior to the palatial collapse ca. 1200 BC, but aridity gradually increased in south Greece and across the eastern Mediterranean after 1200 BC. In the Carpathian Basin, there are consistent indicators of increased aridity after ca. 1250 BC, but potentially regionally differentiated temperature changes with signatures for increasing and decreasing temperatures are documented in speleothem and pollen records, respectively. Data from mountain caves and glaciers surrounding the Po Valley consistently indicate a climate shift in the 12th century, almost all indicating drier conditions, with some speleothem records suggesting warming conditions to the north of the Po Valley while others may indicate cooling to the east. While the temperature data are somewhat equivocal, the aridity markers accord with geoarchaeological data from settlements and lake cores in the Po Valley itself. Alongside palynological evidence for deforestation, geoarchaeological data from certain sites in the Po Valley indicate anthropogenically induced soil exhaustion.

Similar and contemporary markers are observed in parts of the Nordic world for both deforestation and soil exhaustion, suggesting a major anthropogenic impact on those landscapes studied in detail. In the Nordic area, the 12th century stands out as a less pronounced turning point in the climate proxies, and warmer conditions are defined in most of the relevant proxies. While there is conflicting information about hydroclimate, there is nothing to indicate an extreme shift in either direction. The picture in Ireland and Britain emerges from a variety of different types of proxy from different parts of the two islands, and while this inevitably leads to variability in the results, the general picture is one of a comparatively drier period in the 12th–10th centuries BC, with warmer conditions for at least the earlier part of this time block.

In parts of the Aegean, Po Valley, and Scandinavia, palynological evidence indicates reduced anthropogenic activity in the 12th century BC. Although very fragmentary, the data from the Pannonian Plain are at least consistent with this reduced-activity signature for areas with published records. In Britain and Ireland, some records indicate local-scale tree-clearance activities between 1200 and 1000 BC, but there is no marked shift in arboreal and anthropogenic pollen markers across larger areas of land.

I begin each section below with a general overview of the landscape and the food production traditions. The dominant focus of studies in human–climate relations has been on settlement patterns, yet it is obvious that one of the more precarious aspects of social stability relative to environmental conditions must have been agriculture. A dearth of studies and linked-up methodological approaches within, never mind between, the study areas limits what can be said. The general picture shows continuity of the range of crops produced in each area in the later second millennium into the first millennium BC, though the relative abundance of species in diachronic and regional perspective remains unclear. The picture for animal management is slightly more substantial, particularly in recent studies by Dibble and Finné (2021) and Trentacoste et al. (2018). These papers demonstrate the importance of defining changes in arable and pastoral practices for understanding sustainability or resilience within, and broader societal responses to, periods of known climate change. A key issue is not what was produced but where, by, and for whom, and what levels of surplus were created. Although we measure patterns of change in faunal, macrobotanical, and palynological datasets, this is only one element in the story. There is a clear need to build larger datasets for comparative regional-scale analyses of the social turning point identified in the later Bronze Age.

Mycenaean Greece

The landscapes surrounding the Bronze Age urban centers in the Aegean region were dominated by rocky and mountainous terrain interspersed with pockets of fertile plains, with variation over very short distances (Weiberg et al. 2016, p. 41). Watercourses were present but relatively rare and small. Agriculture was dominantly rain fed rather than dependent on terrestrial water management or irrigation. Macrobotanical, pollen, and written evidence indicate that a diverse range of crops were cultivated, including but not dominated by the Mediterranean triad of wheat, olives, and grapes (Livarda 2014; Margaritis et al. 2014; Vetters et al. 2016; Weiberg et al. 2019). Pastoral agriculture was dominated by sheep, goat, pigs, and cattle. In many contexts, sheep were dominant, apart from Tiryns (cattle), Lerna, and Athens (pig), where they are the second-most consumed taxa (Dibble and Finné 2021, fig. 2). In the later Late Bronze Age, the consumption of sheep for meat increased substantially and perhaps dominated, but this is closely related to maintaining flocks for wool production. Large flocks were managed by palace authorities for wool (primarily), according to Linear B documents, as well as for meat (Halstead 2003). The frequent consumption of sheep extended to non-palatial communities. In the Early Iron Age, perhaps as a response to increased aridity, goat husbandry increased proportionally in some parts of Greece, which may reflect the drought tolerance of this species (Dibble and Finné 2021, p. 57).

There are clear indications of climate change around the turn of the 12th century in Greece. Speleothems indicate wetter conditions had begun early in the 19th century and lasted until ca. 1150 BC, after which more arid and cooler conditions developed, peaking around 1050 BC. This same cooling pattern is found in datasets from northern Greece and in marine cores in the eastern Mediterranean. Although the evidence is limited, with poor chronological control, Crete may deviate from this pattern by remaining relatively unchanged or even warmer.

The Mavri Trypa cave speleothem (Fig. 3) is resolved to ± 31.5 years and ~5-year resolution, which provides a closely constrained dataset for hydroclimate in the 13th to 11th centuries (Finné et al. 2017). Another partially published speleothem from Alepotrypa cave on the Mani Peninsula in the south Peloponnese provides corroborating data for aridity peaks, though a switch to wetter conditions may have occurred between the 12th and 11th centuries (Boyd 2015; Finné et al. 2017, p. 8; Weiberg et al. 2016, pp. 46–47). A sediment core from Asea Valley, inland about 85 km northeast of Mavri Trypa cave, suggests cooler and wetter conditions from ca. 1350 BC until 750 BC, though the chronology is less closely constrained (Unkel et al. 2014). Halfway between these two loci, a core from central Messenia at Agios Floros mirrors more closely the Mavri Trypa data, with a wetter and cooler period that gave way to a more arid phase broadly by ca. 1150 BC (Norström et al. 2018). The

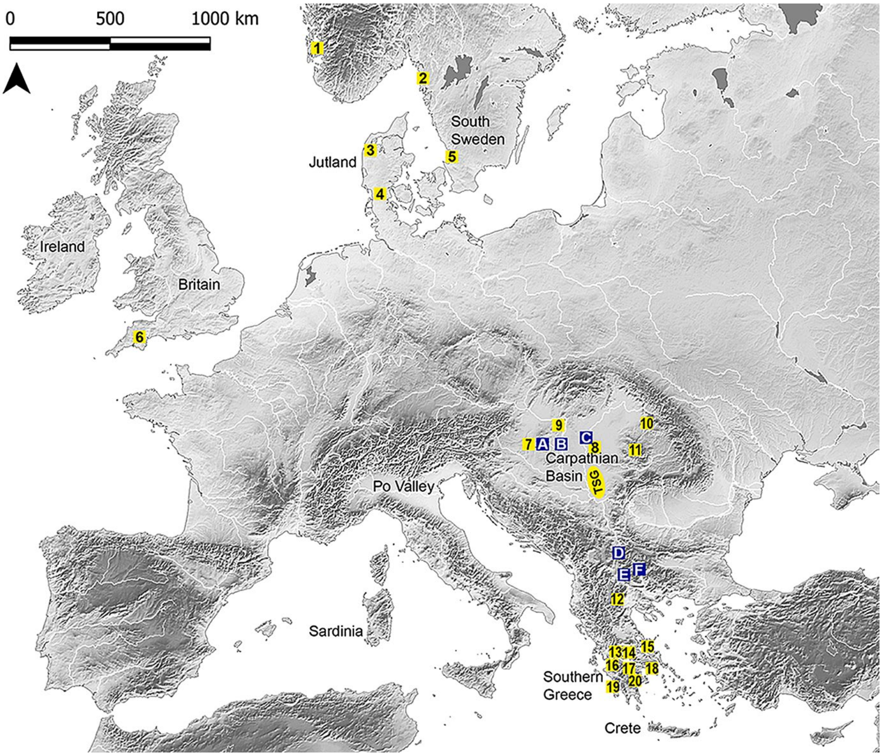


Fig. 3 Geographic areas and features mentioned in text. Areas: (A) Lake Balaton, (B) River Danube, (C) River Tisza, (D) River Morava, (E) River Vardar/Axios, (F) River Struma. Features: (1) Rogaland, (2) Bohuslän, (3) Thy, (4) South Jutland, (5) Bjäre Peninsula, (6) Dartmoor, (7) Zala County, (8) Körös area, (9) Benta Valley, (10) Gutaiului Mountains, (11) Apuseni Mountains, (12) Macedonia, (13) Phokis, (14) Boeotia, (15) Euboean Gulf, (16) Achaea, (17) Corinthia, (18) Attica, (19) Messenia, (20) Argolid, (TSG) Tisza site group. Basemap is a modified version of a European Environment Agency 2004 map (permalink: 070F2DAD-1AED-4B9B-950F-0047E5ADDF35) used under their copyright conditions.

core from Gialova lagoon on the southwest coast of Messenia, though least well-constrained chronologically, shows dry conditions throughout the Mycenaean era until the late 11th century (Katrantsiotis et al. 2018). A core with a moderately well-constrained age-depth model from Lake Lerna in the Argolid indicates a relatively wet Late Bronze Age, with a warm/dry peak for summer temperatures modeled for ca. 1250 BC before a return to cooler summers (Katrantsiotis et al. 2019, fig. 8). In the north Aegean, the speleothem from Skala Marion cave from the island of Thasos reveals a wetter horizon 1350 to 750 BC, but with a slight drift toward (relatively) more arid conditions 1250 to 1150 BC (Psomiadis et al. 2018, fig. 6). The age-depth model is least well-constrained for this phase (Psomiadis et al. 2018, fig. 3a). Notably in records showing substantial change, this was in the 12th century (i.e., after the palaces were abandoned) and not in advance of it (Norström et al. 2018, p. 572).

Marine cores from the eastern Mediterranean indicate that average sea-surface temperatures dropped by as much as 2 to 3 degrees around 1150–950 BC, and a substantial change in temperature would be required to cool this massive body of water (Drake 2012; Rohling et al. 2019, p. 39). Rohling et al. (2019) associate this sea-surface cooling with an increased frequency of northerly cold air outbreaks in the Mediterranean, which correlate with cooling periods detected in Greenland ice cores (see also Katrantsiotis et al. 2019, p. 47; Klus et al. 2018; Kobashi et al. 2011). Taking account of speleothem and sediment cores from the lands bordering the eastern Mediterranean, Rohling et al. (2019) argue these cold streams were channeled through north–south valleys such as the Morava-Vardar-Axios and Struma Valleys. This may have impacted the regionally distinct hydroclimate data from Skala Marion cave, which lies in this path.

A spread of pine and increase in herb vegetation is seen in some parts of southern Greece with palynological records dated to the 12th to 10th centuries, indicating a reduction in the extent of anthropogenic exploitation of previously prosperous landscapes, notably in Attica (Kouli 2012, pp. 274–275; Kouli et al. 2009). Conversely, a core from the Kotihi lagoon in the northwest Peloponnese does not indicate any sharp changes in landscape management anywhere near the 1200 BC horizon, although this has low chronological resolution (Lazarova et al. 2012). In Crete, the later 14th and 13th centuries are argued to have been cooler than preceding ones, followed by a warmer and more arid 12th century, though low chronological resolution is again an issue (Rohling et al. 2002; Triantaphyllou et al. 2009). In northwest Crete, more closely resolved cores present pollen signatures that do not suggest any substantial changes in that locale ca. 1200 BC (Bottema and Sarpaki 2016).

The repeated correspondence in independently well-dated proxies indicates that the pattern of increasing aridity and falling temperatures is real for many parts of Greece and not a product of using phenomena themselves to correlate datasets (Knapp and Manning 2016; Swindles et al. 2013). Most proxies indicate increasingly arid conditions beginning between 1200 and 1150 BC, though some suggest a somewhat countervailing or stable trend. While local conditions no doubt influence this, a key unifying factor for many proxies is a horizon of change in the 12th century. This is coupled with indications of reduced anthropogenic signatures in the pollen records or a shift in the focus of activity to adapt to changing conditions.

The Pannonian Plain

The Carpathian Basin is located directly north of Greece between central and southeast Europe and has notably different topography and weather patterns, with heavy rains more common throughout the year, including during the hot summers. It is characterized by its bowl shape, surrounded by mountains with a flat interior, the Pannonian Plain. This plain is drained by many rivers, ranging from small to exceptionally large in width/volume, including the Danube and Tisza Rivers. Dietary habits were somewhat different than in Greece, though relevant studies are few and commonly site specific in scale. Data on arable agriculture suggest a dominance of grain crops with nut-bearing trees also commonly exploited (Filipović et al. 2020; Gumnior et al. 2020). Broomcorn millet was introduced to the Carpathian Basin in the later Bronze Age, indicating a shift in the (potential) intensity of arable farming.

This contributed to temporal diversification in risk management due to a potential spring harvest of millet complementing a diverse autumnal harvest, a pattern also seen in the Po Valley (Filipović et al. 2020).

There are indications of a nominal change in animal husbandry between the Middle and Late Bronze Age, and meat consumption appears prevalent in diets with sheep/goat usually dominant followed by cow, pig, horse, and perhaps dog, all being consumed alongside hunted game. This latter comprised in excess of 10% of NISP at investigated sites, suggesting it was a substantial component in dietary traditions (Molloy et al. 2020; Nicodemus 2014; Szeverenyi et al. 2015). For most sites of the early Iron Age (ca. 1050/1000 BC) in the southern Pannonian Plain where data are available, the importance of sheep/goat dropped to 10–15% while cattle was commonly 35–45%. Pig was usually second-most popular at around 20–30%, and horse ranged from either very rare up to 15%. Hunted game dropped significantly in frequency, rarely exceeding 5% of NSIP (Blažić 2010; Medović 1988). This suggests that good pasture remained plentiful, but people may not have ranged as far from their settlements, despite a swing to increasingly arid conditions seen in the paleoclimate record. A pattern of increasing aridity centered on 1200 BC suggests some common trends for the Pannonian Plain and the Aegean. However, there is a less consistent picture in paleoclimate proxies for temperature change in the Pannonian Plain.

A study from the area around Lake Balaton uses multiproxy analysis of *Unio* bivalve shells and animal bone from archaeological strata and compares these with a tightly resolved speleothem from Trió cave (1–30-year increments and with an age resolution of 30–100 years) ca. 80 km to the south (Demény et al. 2019). These data show that between 1600–1250 BC there was higher winter precipitation. For the 16th and 15th centuries, the trend suggests cooler temperatures relative to the earlier centuries of the millennium before increasing aridity and temperatures from the 14th century (Demény et al. 2019, p. 91, fig. 8). This led to a dry/warm spike around 1250 BC. Following an initial slight drop in modeled temperatures toward the end of the 13th century, this study models higher temperatures than were typical for the LBA I and II ceramic phases (see below) in the 12th and 11th centuries BC (Demény et al. 2019, p. 92). This modeled increase in temperature contrasts with other datasets in the wider area. The Trió cave data primarily refer to wintertime hydroclimate, and it is important to note that in many ecosystems, winter is the opportunity for soils to recharge, particularly when they are paired with comparatively dry summers (Degroot et al. 2021, p. 544; Demény et al. 2019, pp. 90–91).

Demény et al.'s hydroclimate model finds general support in other records from the Carpathian region with less well-constrained chronologies. These include Ascunsă, Poleva, and Ursilor cave speleothems, the ice core from Scărişoara cave, a sediment core from Lake Brazi, and a bog near Fenyves-tető in Transylvania. Together these also indicate the onset of a cool and wet horizon after 1600 BC, which was followed by increasingly arid conditions beginning between 1250 and 1150 BC (Drăguşin et al. 2014; Magyari et al. 2013; Perşoiu et al. 2017; Schnitchen et al. 2006). In their study of speleothems from the highlands immediately east of the Pannonian Plain in Romania, Drăguşin et al. (2014, p. 1375) argue that during "the 3.2 ka event, both temperature and rainfall seasonality appear to have changed in southern Romania." While they find it less clear as to whether these data primarily reflect local winter or summer conditions, the increasing $\delta^{18}O$ levels would be consistent with the kind of aridity spike modeled for the Trió record as well as speleothem records in neighboring regions. It is possible the Poleva record shows a swing to wetter conditions ca. 3.2 ka before a swing back to drier conditions around 3.0 ka. However, given its low chronological resolution, Drăguşin et al. (2014, p. 1374) suggest these two turning points could be shifted back to better match other neighboring datasets. In a review of all Holocene speleothem data for east-central and southeast Europe, Kern et al. (2019, p. 19) observe that the only systematic $\delta^{13}C$ or $\delta^{18}O$ shifts or drifts observed across multiple records at this spatial scale for the Holocene occurred between 4 and 3 ka, and they propose 3.5 ka (ca. 1550 BC or the beginning of the Late Bronze Age) as a focal point worth exploring further.

Sediment cores from Lake Ighiel have a well-resolved chronology and show "highly fluctuating values increasing between" 2250 and 1350 BC, with a marked wet horizon toward the end of that sequence, followed by a drier phase (Haliuc et al. 2017, p. 104). An exceptional dry spell is documented between (broadly) 1440 and 1070 BC at the nearby bog in Fenyves-tető inside the Carpathian arc in northern Romania (Schnitchen et al. 2006). Allowing for chronological uncertainties, these data broadly support the wetter earlier centuries of the LBA followed by a 14th century BC turning point, to the 13th century BC aridity peak, and continued aridity into the 11th BC century modeled by Demény et al (2019). In the Benta Valley geoarchaeological survey, French (2010, pp. 47–48) recorded a slowing and silting up of rivers in the 12th century BC, which encouraged peat formation. He argued this was caused by deforestation and soil erosion due to an increasing emphasis on arable over pastoral agriculture, though changes to seasonal rainfall documented in climate proxies may also have contributed to such a phenomenon.

There are few published palynological sequences from the Late Bronze Age Pannonian Plain. In the eastern plain, a study around the settlement of Corneşti Iarcuri shows that arboreal pollen between 1600 and 1200 BC represents diverse species and ranges from 38–46% from strata within the settlement to 60–65% in lake sediments 7 km away (Gumnior et al. 2020, p. 184). Pollen from the settlement demonstrates that between 1200 and 1000 BC there was reduced anthropogenic activity in its environs, which is consistent with ^{14}C data modeling of activity within the settlement (Gumnior et al. 2020, p. 184; Lehmpuhl et al. 2019). From the Gutaiului Mountains in the northwest hinterland of the plain, pollen signatures suggest cooling conditions and increased precipitation after 1200 BC (Feurdean et al. 2008, p. 500). While perhaps representative of specific conditions where a vast plain meets mountains, these data demonstrate some heterogeneity in rainfall markers for the region. The suggested declining temperatures in Feurdean et al.'s study contrasts with data from the Trió cave study. Around 180 km west of this core, the Sarló Hát pollen record reveals relatively unpronounced change prior to 1000 BC, after which woodland was actively reduced and open steppe environments began to dominate (Magyari et al. 2010, p. 926).

The Po Valley

Societies in the Po Valley in the north of Italy were closely linked to those of the Pannonian Plain, both in terms of cultural practices but also managing a relatively flat riverine landscape with many wetland areas (Molloy et al. in press). The Po Valley is a wedge surrounded by mountains to the north and south and the Adriatic Sea to the east. It has a very flat interior, with low ridges separating many small to large watercourses, most feeding into the Po River before it joins the Adriatic.

A diverse arable agricultural system is in evidence in the macrobotanical record, including remains from excavated sites that demonstrate an increasing exploitation of millet at Terramare settlements (Tafuri et al. 2018). There is general continuity of species that were exploited after 1200 BC, but with a potential relative increase in consumption of legumes (Trentacoste et al. 2018, p. 5). The range of fauna consumed appears broadly similar to that of the Pannonian Plain, as does a focus on meat and secondary product consumption (Cremaschi et al. 2006; 2018; Mazzorini and Ruggini 2009; Mercuri et al. 2006). Trentacoste et al. (2018) provide the most detailed study of animal husbandry and management for any of the study regions. They show that there is heterogeneity within the Po Valley and immediate hinterlands, with distinct differences north and south of the river. In the north, in the centuries before 1200 BC, cattle gradually replaced sheep/goat as the dominant species, and pig gradually gained in importance to more or less match sheep/goat during the Iron Age, a time when the prevalence of cattle increased. The fortunes of sheep/goat are similar in the north-east plain (Veneto), but the relative prevalence of cattle and pig are reversed. South of the river, although data are more limited, sheep/goat dominated throughout the Bronze Age while cattle prevalence remained relatively low. There was a collapse in the relative importance of sheep/goat in the Iron Age, when pig came to dominate and the prevalence of cattle increased slightly, particularly in southernmost extent of the plain (Romagna). These data indicate some relevant shifts in animal husbandry in the wake of the collapse of the Terramare system.

There are suggestions that manuring and rotating arable and pastoral land use were elements of intensified agricultural production, though extensification is also evidenced through tree clearance between 1400 and 1150 (Cremaschi et al. 2018; Dalla Longa et al. 2019, p. 8). Population growth after 1500 BC may well "have been triggered by the introduction of new technologies such as the plough, crop rotation, stabling and the switch from fire–fallow cultivation to irrigated crops" (Palmisano et al. 2021, p. 411).

Virtually all climate proxies from within and around the Po Valley indicate increased aridity from the 12th century. The speleothems from Corchia and Renella caves are resolved to ca. 11–16 years. The caves are near the west coast of north-central Italy, broadly within 150 km of the Po Valley. Data from both speleothems indicate that the climate gradually became more arid after 1600 BC. After a phase of variable conditions visible more at Renella than at Corchia, these datasets indicate an aridity peak between 1200 and 1100 BC (Regattieri et al. 2014, p. 390, fig. 10; Zanchetta et al. 2016, fig. 8). In the Alps immediately west of the Po Valley, Rio Martino cave is located ca. 1200 m above the Po Valley. Multiproxy analysis of speleothems there indicate a dry period 1600–1200 BC, before a very brief swing toward wetter conditions around 1200 BC, followed by a shift to increasingly arid conditions extending well into the first millennium BC (Regattieri et al. 2019, fig. 4). The multiple speleothems from the COMNISPA I and II projects from Spannagel cave in the Austrian Alps to the northeast indicate a shift toward drier and colder winter conditions in that locale in the 16th–13th centuries BC, followed by a gradual increase in $\delta^{18}O$ equated to warmer conditions following a cold peak ca. 1200 BC (Demény et al. 2019, p. 90, fig. 8; Fohlmeister et al. 2012b, fig. 3; Scholz et al. 2012, fig. 7). In northeast Italy, the speleothem from Ernesto cave in the Alps north of the Po Valley to the east of Lake Garda indicate warmer conditions in the 16th–15th centuries BC, before cooling in the 14th and 13th centuries, followed by a sustained temperature increase from a cold peak ca. 1200 BC that ran into the beginning of the first millennium BC (Scholz et al. 2012, fig. 7). On the southeast fringe of the Alps at the head of the Adriatic part of the Mediterranean Sea, the $\delta^{18}O$ data from Savi cave indicate a warm peak in the 13th century, followed by a fall in temperatures in the 12th century BC that was sustained into the first millennium BC (Frisia et al. 2005; Scholz et al. 2012, fig. 7).

Northwest of the Po Valley, palynological and detrital data from glaciers in the northwestern arc of the Alps at Great Aletsch (Switzerland) and Mer de Glace (France) suggest warmer Bronze Age conditions came to an end between 1200 and 1100 BC, followed by a colder phase with glacial advance (Le Roy et al. 2015, pp. 13, 17, fig. 7). Despite the disparity between the climate in mountain sampling locations and the low-lying plains where population was more concentrated, a turning point in the decades around 1200 BC is consistently evident.

Closer to the Bronze Age settlement networks of the Po Valley, data from Lake Ledro indicates increased water levels from ca. 1600 BC, followed by lower levels indicative of increased aridity after ca. 1200 BC (Magny et al. 2009, pp. 585–586). Despite a low-resolution age-depth model for Lake Lucone beside Lake Garda, the data suggest that after ~1100 BC, there was substantial reduction in anthropogenic markers coupled with a reduction in lake level (Valsecchi et al. 2006, p. 110). These data also show that prior to 1200 BC, northern Italy had a humid living environment, reflecting a specific ecology.

In the eastern Po Plain, Fontana et al. (2017) argued that rising sea levels around 1200 BC contributed to the gradual abandonment of coastal settlements, emphasizing gradual rather than crisis-driven impacts on lifeways of coastal communities. Geoarchaeological data from settlements indicate a brief phase of decreased rainfall in the decades around 1200 BC (Cremaschi et al. 2006; 2018; Cupito et al. 2015). At the Terramare site of Poviglio Santa Rosa, this is recognized in stratified soil horizons within the absolute date range of 1330–1170 cal BC (Cremaschi et al. 2006, p. 92). This corresponds to a significant drop in the water table that affected the large water wells and interconnecting ditches at the site (Cremaschi et al. 2006, p. 96). This also impacted the accessibility of drinking water. A drier horizon is documented in sediment analysis dated between 1200 and 1150 BC at the Terramare sites of Montale, Casinalbo, and Fondo Paviani, though these cannot be considered extreme or lasting horizons of change. The drier period after 1200 BC correlates with a decline in cereal signatures documented in on-site pollen samples (Dal Corso et al. 2012; Dalla Longa et al. 2019; Mercuri et al. 2012, p. 366).

Cremaschi et al. (2006, fig. 6) illustrate the relative dearth of arboreal versus non-arboreal pollen signatures in the Po Valley in the second half of the second millennium compared with other regions in Italy. Mercuri et al. (2012, p. 362) compare data from marine core RF93-30 from the north Adriatic and the site of Terramare di Montale, showing incremental reduction in trees in the landscape over time. Cardarelli (2009, p. 456) recognizes this deforestation as a common feature from the time the Terramare sites were established. This contrasts substantially with the limited data for land management in the Pannonian Plain (above). Continued use of woodland includes managed, probably coppiced hardwood species along with cultivation of olive and sweet chestnut trees from ca. 1450 BC. This change is also associated with increased grass and related weed pollens in RF93-30 (Mercuri et al. 2012, fig. 4). Overall, the pattern seen in pollen and geoarchaeological datasets suggests increasingly common drought conditions in an already much deforested landscape after 1200 BC (Cupitò et al. 2012, pp. 56–57).

The Nordic Area

In the Nordic area, we may predict different conditions due to its more northerly location and greater exposure to Arctic and Atlantic influences. There are fewer and more conflicting climate proxies for this region, but in general terms the reduced precipitation seen in the southern areas may be in evidence while temperature markers suggest that this period became marginally warmer. The Nordic Bronze Age was characterized by maritime societies, with the densest activity on parts of Jutland and southern Sweden. In Jutland, the land is undulating and well drained with much of the region suited to arable and pastoral agriculture. Southern Sweden is notably hillier, and arable farmland is more fragmented and concentrated in the south and by the western coast (French 2010). The range of cultivars recognized in macrobotanical studies is more restricted than in Jutland, and it shows continuity with earlier periods (Vretemark 2010, pp. 161–162). Vretemark (2010, p. 160) notes that naked six-rowed barley was dominant in the wider region, and spelt and emmer were present. This may indicate low diversity in managing agricultural risks, though these practices may be related more generally to productivity levels in a specific climatic zone (McClatchie 2014). The species identified in pollen records also suggest increasing grassland and soil degradation into the 12th century (Søgaard et al. 2018, p. 219). Meat was perhaps a dominant food source, with cattle and sheep the most common and pigs exceptionally rare or absent, possibly due to their more diverse food requirements (Nyegaard 2018). Evidence for the consumption of game species is also rare, indicating a relatively restricted diet within homesteads and a marked deviation from diets in the southern areas.

There are no speleothems relevant to this period from the Nordic world, but studies from Bunker and Atta caves in western Germany are broadly relevant spatially (Fohlmeister et al. 2012a; Niggemann et al. 2003). The data from Bunker cave suggest a trend of increasing temperature and rainfall from the 15th century consistently into the early first millennium BC, though this trend is less pronounced in the record from nearby Atta cave (Fohlmeister et al. 2012a, fig. 5).

Store Mosse, the "Great Bog," near the coast in southwestern Sweden has been the subject of multiproxy climatic and environmental research that has a well-constrained age-depth model (Kylander et al. 2013). This shows dry conditions prior to 1500 BC after which warmer and wetter conditions set in, with increased wetness after 1200 (Kylander et al. 2013, p. 79, fig. 8). This, however, contrasts with the $\delta^{18}O$ signature from Lake Igelsjön, ca. 130 km inland to the northeast, which shows a swing to drier conditions ca. 1200 BC, though the record is fragmentary (Hammarlund et al. 2003, fig. 9). Nearly 500 km to the north, cores from Lake Blektjärnen have a well-constrained age-depth model, and data show the coldest and wettest phase occurred ca. 1550 BC, after which there was warming and drying that increased slightly after 1200 BC (Andersson et al. 2010, fig. 7). The warmer conditions after 1500 BC are also attested through chironomid analysis from lacustrine cores taken in a ca. 500 km transect from six lakes across north-central Sweden to southwest Norway, which reveal a coolest point around 1350 BC before warming again (Velle et al. 2005, p. 1451, fig. 14). The hydroclimate picture is somewhat unclear for the Nordic area, with conflicting data potentially identifying local-scale trends. Notably, however, the trend appears to be toward warmer conditions.

Pollen records and geoarchaeological analyses reveal that deforestation, and in some areas soil exhaustion, took place in densely occupied parts of Nordic Europe between 1500 and 1100 BC. This represents localized but high-level anthropogenic impacts on the environment. The Thy region of northern Denmark has been subject to interdisciplinary analysis of social landscape development. Data from there indicate that tree cover was reduced by more than half down to 33% arboreal pollen, so that forested areas all but disappeared and open grassland expanded to over 54% of the record between 1500 and 1100 BC (Andersen 2018, pp. 225–230; French 2010, pp. 36–39; Søgaard et al. 2018, p. 218). A recent study using REVEALS modeling suggests that even this low level of tree cover in Thy is overestimated in pollen records so that levels should be read as being lower still (Kristiansen et al. 2020, fig. 2).

The reuse of old and driftwood timber for the house at Bjerre Ennge 6 has been taken to indicate the infrequency of high-quality wood in the area, as does the commonly attested use of lower-quality wood species (*Betula, Salix, Populus, Alnus*) and the collection of *Quercus* and *Salix* for fuel (Søgaard et al. 2018, p. 214). From Fyn Island between southern Sweden and Jutland, pronounced deforestation is attested in a core from Gudme Lake during and after the 12th century (Rasmussen and Olsen 2009). This increase in anthropogenic activity may suggest inward migration from increasingly marginal environments surrounding this area.

French (2010, pp. 40, 42) documented significant soil degradation in Thy as well as in Bohuslän in Sweden, where there was an expansion of heathland-type vegetation. Also in southern Sweden, pollen from the Bjäre Peninsula shows development of an "opened cultural landscape" dominated by grasslands in the second millennium BC, with non-arboreal pollen increasing from a base of 60% to 90% of totals closer to settled areas (Nord 2009, p. 70). The picture in north-central and west Jutland is very similar and suggests landscapes tailored for a prevalence of pastoral over arable farming, perhaps also reflected in the low crop diversity seen in macrobotanical records. In southern Jutland, following a reduced signature for anthropogenic activities ca. 1200 BC, a strong signature returns in the pollen record ca. 1050 BC (Kneisel et al. 2019, p. 1611). Furthermore, an aggregate model of pollen data from south Jutland and north Germany reveals the century 1200–1100 BC as one of four distinct lulls in anthropogenic activity between 4500 and 500 BC (Feeser et al. 2019, p. 1598).

Although the evidence is limited, it appears that human induced environmental changes in the period 1500–1100 BC rendered areas of previously productive farmland significantly less so in parts of Jutland and south Sweden during the 12th to 11th centuries BC. Anthropogenic impacts on the environment appear to be causal, and it is plausible that climate change also played a contributory role, and certainly interplay between the two should be considered. Overall, the centuries-old balance achieved in deforested landscapes in a relatively warm and wet climatic niche was tipped in several parts of this region after 1200 BC, followed by progressively lower levels of anthropogenic activity for at least a century.

Ireland and Britain

Lying in the Atlantic northwest of Europe, Ireland and Britain experienced climate and weather patterns heavily influenced by Atlantic systems even more than the Nordic area. They constitute the most environmentally diverse study area, ranging from the warmer, drier, and flatter region of southern Britain to the mountainous landscape of northern Scotland and the low-lying and wet interior of Ireland. Land suited to arable farming is highly variable but nonetheless present in most parts of the islands, and many substantial river courses connect the inland with the surrounding seas. Animal husbandry was extensively practiced, to the extent that it has been suggested that hillforts were constructed to protect animals because livestock were construed as a major manifestation of wealth and status (McClatchie 2014; O’Brien and O’Driscoll 2017). Cereal pollen and macrobotanical remains indicate low diversity, as with the Nordic area, and a strong reliance on naked six-row barley in Ireland and Britain (Bradley 2007, p. 192; McClatchie 2014, p. 35). In southern Britain, consumption of sheep and cattle for meat alternated in predominance in most communities; pig occasionally matched their proportions but more commonly was quite rare in assemblages, as was typical in the Nordic area. By the Iron Age, the consumption of pigs became exceptionally rare (Serjeantson 2007).

In Ireland, a significant increase in $\delta^{15}N$ in the bones of wild and domestic herbivores indicates woodland clearance and increased pastoralism on a scale that altered the soil chemistry of wooded, unwooded “wild,” and agropastorally managed land during the Late Bronze Age (Guiry et al. 2018). This also reflects mixed farming in subsistence strategies, which accompanied intensified use of farmland. Guiry et al. (2018) also observe that these $\delta^{15}N$ signatures come from the soils in which crops grew, thereby revealing a fundamental anthropogenic transformation of the wider environment by human actions from the beginning of the Late Bronze Age onward.

Proxies of climate change are comparatively rare and widely dispersed, but they are diverse, providing a uniquely valuable multiproxy perspective. There is only one speleothem record covering this period for both Ireland and Britain, and analyses focused on the early rather than the late Holocene. The speleothem comes from Crag cave in southwest Ireland and indicates a period of warming after 1200 BC (Charman 2010, fig. 5; McDermott et al. 2001). While the intervals are resolved to 7–18 years in this speleothem, a dearth of absolute dates from the Bronze Age means that "total uncertainties are greater than 1000 years between c. 2700–5000 cal. BP" and so it needs to be used with caution in this time frame (McDermott et al. 2001, p. 1330, fig. 2; Swindles et al. 2013, pp. 306, 317). The 12th century indicator of warming in this proxy is mainly recognized by correlating observed phenomena with other proxies from nearby (Swindles et al. 2013).

Atlantic conditions also impact Greenland, where a warming 12th century and a cool spike in the 11th century BC were detected in ice core analyses (Kobashi et al. 2011, figs. 1, 3; see also Kaniewski et al. 2019). Klus et al.'s (2018, p. 1167) ice-core study documenting a 7000-year data transect of north Atlantic Holocene conditions revealed that one of two exceptional cold events occurred in the 11th century BC and lasted ca. 29 years. The bar for "normal conditions" in that study was set from 4000–3201 ka, emphasizing the deviation beginning in the later 13th century BC (3.2 ka).

Peat bogs occur frequently in Britain and Ireland. Forming since the end of the last Ice Age, they have been the subject of many local-scale studies. I focus here on more recent synthetic analyses rather than individual studies. Strata have been dated using ^{14}C dating, spheroidal carbonaceous particles, and tephra deposits, or a combination of these (Swindles et al. 2013, p. 305). According to Gearey et al. (2020), data from bogs indicate that mean summertime temperatures peaked 1310–1100 BC before falling ca. 1.5° between 1150 and 960 BC to ca. 12°, which was warmer than bracketing centuries. A model of increased mean summer temperatures and aridity in the 12th century BC followed by decreasing temperature but relatively lower rainfall is indicated in chironomid head research from Ireland, complementing the peat-bog records (Plunkett et al., 2020, fig. 6; Swindles et al. 2013, pp. 316, 317).

A series of Irish bog oaks provide an annually resolved record. Focusing on variable prevalence and age of trees, Turney et al. (2016, p. 75) identify an abrupt downturn in oak numbers ca. 1180 BC as a consequence of "long-term forcing, consistent with a climate-driven shift rather than site specific factors skewing the record." Furthermore, they identify a shift to wetter conditions after 992 BC. Despite the tight chronological resolution of the data source itself, Turney et al.'s modeling of tree ages as a marker of climatic shifts only partly articulates with the other proxies from Ireland cited above. A key issue is the occurrence of a climatic shift around 1180 BC in their study.

Looking at tree-ring data from these same oak series, Baillie argues for a cold period between 1159 and 1141 BC (Baillie 2002). He also notes that this apparent cold spell is most visible in oaks that had grown in bog environments, and this reduced growth is less visible in (archaeologically recovered) oaks that grew on mineral soils (Baillie 2002, p. 380). It remains possible that climate conditions affected bog water levels and hence oak growth rates in that ecological niche, accounting for these 12th century restricted growth markers on oaks there and not from other contexts.

Data from bogs in Dartmoor, southern England, indicate a sustained wet phase between 1395 and 1150 cal BC (Amesbury et al. 2008, p. 91), while Barber et al. (2003, pp. 532–533) argue for climatic deterioration in England and Ireland ca. 1250–1200 BC when "even wetter conditions prevailed" before a late 12th–11th century BC upswing. Langdon et al.'s (2004) study of chironomid head capsules from Talkin Tarn lake sediments in northern England indicates increasing temperatures from 1200 BC. A brief wet horizon around 1100 BC has been recognized in various datasets from Ireland and Britain (Charman 2010, p. 1543; figs. 3d, 6d; Plunkett et al. 2020, fig. 6). A general pattern seen across multiple British datasets shows that a wet period between 1500 and 1200 BC gave way to a drier period from 1200 to 800 BC, potentially punctuated by a brief wet period in the 11th century (Brown 2008, p. 8, fig. 1; Charman et al. 2006; Gearey et al. 2020; Plunkett et al. 2020; Swindles et al. 2013, pp. 316–317). This wet to dry swing is evident in Charman et al.'s (2006) study of lake levels in Britain, and though a degree of regional variability is attested, this pattern also corresponds with Magny's (2004) study of lake levels in central Europe. For Ireland and Britain, data are conflicting as to when and for how long a warmer trend emerged, but there is general agreement that the 12th and 11th centuries were warmer than preceding ones, though that trend may have begun in the 13th century in Ireland.

Fyfe et al. (2013) modeled more than 70 pollen records from Ireland and Britain using a REVEALS model, which did not show a significant change in land use around 1200 BC. Rather, it shows heterogeneity in land use across the different landscapes of the two islands. Drawn from more specific cases, the pollen record from Ireland suggests that tree clearance episodes occurred at a very localized level between 1400 and 1000 BC, often around enclosed sites such as Haughey's Fort, Navan Fort, Mooghaun, and Ballylin (Plunkett 2007, p. 233, 2009). This localized pattern of intensified clearance and land use complements the argument for increased nitrogen content in soils (visible in animal bones) discussed above.

Synopsis

Based on the results of these diverse studies, there is no consistent and clear picture for Europe ca. 3.2 ka. Two trends appear to emerge that differentiate northwest and southeast, potentially related to the relative impact of Atlantic and Mediterranean systems. Although exceptions occur, many of the cited studies identify a warming 12th century BC trend in central and northern Europe and a countervailing trend of lowering temperatures for the Mediterranean ambit. Decreased rainfall is consistently identified across Europe, apart perhaps from the Nordic area, in the 12th century BC. The 11th century BC is more heterogeneous in terms of what the records tell us, but the consistent pattern is a deviation begins between the 13th and 12th century BC that lasts at least a century in each of the five areas examined above. The onset is staggered, but this may well be predicted given the chronological resolution of the records themselves and using absolute dates rather than observed phenomena to cross reference them.

As local environmental conditions occur at the interface between climate and social use of landscapes, this provides a context for specific cultural entities that occupied each area during this transitional period (Weiberg and Finné 2018, p. 591). In the Aegean, Pannonian Plain, Po Valley, and Nordic regions, the climate conditions in which extensive settlement patterns and specific landscape uses developed between 1500 and 1200 BC changed in the following centuries. The exploitation of good climate between 1500 and 1200 BC, perhaps more than the arrival of "bad climate" after 1200 BC, may have fomented problems due to the formation of a dependency relationship. In the Aegean, Pannonian Plain, and Po Valley for example, the pronounced (though not extreme) changes lie within the long-term parameters of Holocene climate. That is, the climate of the 12th century was not particularly extreme, and similar patterns can be detected at various points in long-term records in the same locales when there was no contemporary social disjuncture.

Societal Changes

It has been proposed that 1200 BC marked a change to the networks that had defined the globalized social world of Europe in the third quarter of the second millennium BC. Before addressing social change in specific areas (Fig. 4), I briefly comment on the evidence for a shift in European-scale networks of interaction to provide a wider context in which to consider specific areas.

Metalwork: A Proxy for Networks of Interaction Linking the Study Areas

Two of the most significant things that may affect multiple prehistoric societies simultaneously at large geographic scales are long-distance communication networks that support political economies and climate. The former is primarily measurable through the materials that moved through those networks. For the European Bronze Age, metals are particularly relevant as a proxy for interaction. I focus on metals because they constitute a highly visible resource open to multidisciplinary analysis, objects survive in vast quantities, they were exchanged across the entire geography of Europe, and bronze is seen as the economic engine of Bronze Age societies (Earle et al. 2015; Earle and Kristiansen 2010). This dataset also clearly demonstrates that the study areas were all bound together through craft, esthetic, belief, practice/activity, and resource networks. Although a deviation in our narrative on human–climate relations, metals provide an important general backdrop for understanding how the domino effect of climate change affecting political economies in one area could impact others in the highly networked Bronze Age world. Declining conditions in one area must be viewed on a sliding scale from individual settlements to the macroregional scale of the intersocietal networks that shaped each connected society simultaneously.

Metalwork is informative for understanding networks of interaction in three main ways. As a raw material, we can evaluate the networks through which it was exchanged. As cultural objects, we can explore the networks through which

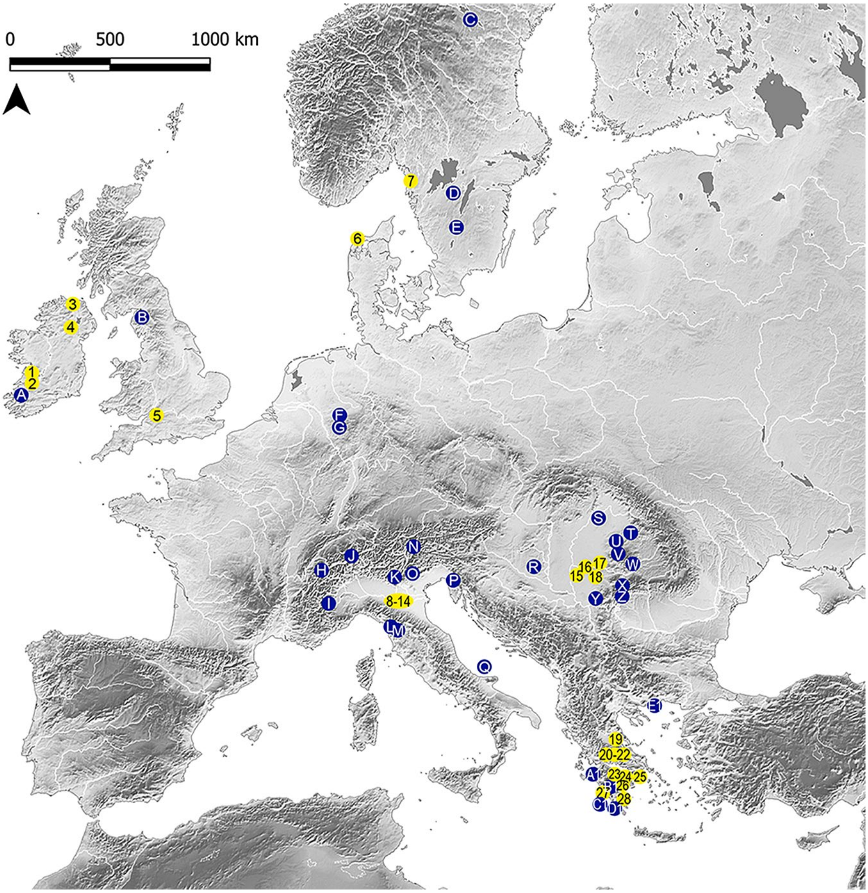


Figure 4. Sampling locations and archaeological sites mentioned in the text. Sampling locations: (A) Crag cave, (B) Talkin Tarn, (C) Lake Blektjärnen, (D) Lake Igelsjön, (E) Store Mosse, (F) Bunker cave, (G) Atta cave, (H) Mer de Glace glacier, (I) Rio Martino cave, (J) Great Aletsch glacier, (K) Lake Ledro and Lake Lucone, (L) Renella cave, (M) Corchia cave, (N) Spannagel cave, (O) Ernesto cave, (P) Savi cave, (Q) RF93-30 marine core, (R) Trió cave, (S) Sarló Hát, (T) Ursilor cave, (U) Fenyves-tető, (V) Scărişoara cave, (W) Lake Ighiel, (X) Lake Brazi, (Y) Poleva cave, (Z) Ascunsă cave, (A1) Kotihi lagoon, (B1) Asea Valley, (C1) Mavri Trypa cave and Gialova lagoon, (D1) Alepotrypa cave, (E1) Skala Marion cave. Sites: (1) Mooghaun, (2) Ballylin, (3) Corrstown, (4) Haughey's Fort and Navan Fort, (5) Tormarton, (6) Bjerre, (7) Tanum, (8) Poviglio Santa Rosa, (9) Montale, (10) Casinalbo, (11) Fondo Paviani, (12) Case del Lago, (13) Case Cocconi, (14) Frattesina, (15) Gradište Iđoš, (16) Csanádpalota–Földvár, (17) Santana Cetatea Veche, (18) Corneşti Iarcuri, (19) Dimini, (20) Orchomenos, (21) Gla, (22) Thebes, (23) Mycenae, (24) Midea, (25) Athens, (26) Tiryns, (27) Pylos and Iklaina, (28) Ayios Vasileios. Basemap is a modified version of a European Environment Agency 2004 map (permalink: 070F2DAD-1AED-4B9B-950F-0047E5ADDF35) used under their copyright conditions

particular ideas related to style and purpose/function of metalwork traveled. As material with mutable value (it can be recycled), how it was disposed of can inform us about its management within a society. We only need a general sketch here to demonstrate how changes in metal consumption reflect 1200 BC as a clear turning point in the economic, craft, and ideological networks that connected Europe.

A general pattern in this 1200 BC horizon across the continent is the rapid spread of new styles of military equipment that, typological details aside, represent a profound increase in transcultural military hardware and associated martial traditions (Kristiansen and Suchowska-Ducke 2015; Molloy and Horn 2020). For example, similar sword types emerged in less than 50 years in each study area (Type Reutlingen and successors), and shield types linked each area with at least two of the others (apart perhaps from the Po Valley).

In Britain, Northover (1982) interpreted trace element patterns in copper alloys as indicative of a fundamental change in the source of metal that was used and/or its management through recycling in the 12th century BC. Metal with this same high-impurity pattern, probably from the eastern Alps, became common throughout western Europe at that time (Rohl and Needham 1998; Williams and de Veslud 2019, p. 1185). Concurrently, continental metalwork forms became increasingly influential in Britain (and Ireland to a lesser extent) and vice versa, marking the establishment of important new long-distance networks through which ideas and materials flowed and disrupted existing insular metal networks. New genetic evidence corroborates this, with networks through which people migrated to southern Britain from the continent emerging after ca. 1500 BC and increasing further in the 12th to 8th centuries (Patterson et al. 2021).

In Scandinavia, fewer distinct sources of copper were being consumed by ca. 1100 BC than in earlier phases of the Bronze Age (Ling et al. 2014, p. 125). There also was a distinct reduction in the amount of tin invested in metalwork objects made in the 12th century and those made in the 11th century, representing either new conventions or resource limitations (Ling et al. 2014, p. 119). By the end of the 12th century, there was a wholesale reduction in the deposition of metalwork in mortuary contexts, which Kristiansen (2018) identifies as reflecting challenges to the supply network.

In the Carpathian Basin, in the 13th to 12th centuries BC, the deposition of metal in hoards increased exponentially. New data confirm that Alpine sources became dominant, though there is also evidence for the increased presence of Cypriot copper at this time (Gavranović et al. 2022; Molloy 2019, pp. 148–149). Metal supplied to sites north of the Po Valley continued to come from the nearby Alpine sources, though there are no published analyses of objects from the few surviving sites south of the river. Metalwork styles were increasingly shared between the Po Valley and Carpathian Basin in the 13th and 12th centuries BC (Molloy et al. in press). A subset of these styles, dominated by weaponry, appeared occasionally in the Aegean in the 13th century and then much more frequently in the 12th century. While local metal supplies remained consistent, this transculturation of weapon forms represents a clear change in consumption patterns and social networks as society was reconfigured after the palatial collapse (Iacono 2019; Jung and Mehofer 2013; Molloy 2016).

The consistent pattern seen in metalwork reveals a sharp change in supply, style, and management from the decades around 1200 BC. On the one hand, this shows continuity of long-distance networks; on the other hand, it shows a narrowing or refocusing of those networks and the political relationships they embodied. It is clear that shifts in the macroscale metal networks of Europe arose from changes to the societies that had formed the powerful nodes that drove long-distance networks.

Mycenaean Greece

Defined by shared material culture, the urban groups of southern Greece are commonly called the Mycenaeans, though there was significant variability in how people in different areas participated in this identity (Feuer 2011). In more densely settled areas, there was a hierarchy of settlements from farmsteads to minor urban centers surrounding a small palace complex, though there was regional variation and different takes on the role and organization of central places in settlement networks (Kramer-Hajos 2016). Some communities participated in selected components of Mycenaean identity but had different political systems and hierarchies, many of whom may not have been under the control of a palace.

A wave of destructions at urban centers ca. 1200 BC has classically defined the collapse of the Mycenaean palatial system (Dickinson 2006; Middleton 2010). This phenomenon has been studied extensively, with proposed causes including climate change, earthquakes, environmental collapse, social revolts, mass migrations, changes in warfare, disease, economic overspecialization, and a cocktail of each of these together in systems collapse models (Cline 2021; Drews 1993; Middleton 2010, 2020a).

The well-known shaft graves at Mycenae were established around 1700 BC, and the famously wealthy tombs there were created in the 16th century. The first signs of Mycenaean urbanism began ca. 1500 BC, and then between 1400 and 1300 BC fortified citadels were constructed at some nascent palatial centers such as Tiryns, Athens (?), Thebes, and Mycenae. Palaces at Pylos, Orchomenos, Dhimini, and Ayios Vasileios were built around the same time but do not appear to have been enclosed. Teichos Dymaion was built in Achaea and was enclosed but lacked a palace (Middleton 2020b). Towns and villages were distributed throughout the landscape, and based on the records from Pylos at least, many in southern Greece were hierarchically ordered within territories that were subject to palatial centers. These palaces themselves had varied successes, for example, Orchomenos appears to have declined by 1300 BC and in the Argolid, the neighboring sites of Mycenae and Tiryns alternated in importance between 1400 and 1100 BC (Mühlenbruch 2020).

Pylos provides our highest-resolution data on the functioning of a specific Mycenaean polity through its well-preserved Linear B text archive. Those records tell us that in the 13th century, there were two provinces and a possible four-level hierarchy of sites (Cosmopoulos 2006). There were no citadels; two administrative provinces with many settlements answered to the authority of the palace while operating largely independently on a day-to-day basis. This archive, combined with a destruction level at the nearby major center of Iklaina, suggest conquest or subjugation of the territory of the latter, as the palace extended its reach to unite two polities only decades before widespread collapse (Cosmopoulos 2019). Pylos was destroyed by fire around 1200 BC, and across the Taygetus Mountains, the palace at Ayios Vasileios was destroyed by fire around 1250 BC (Kardamaki 2017).

In Boeotia, the low-lying Copaic Basin was drained, and the largest citadel in Greece was built at Gla late in the 14th century. This corresponded with the decline of nearby Orchomenos and a destruction horizon at Thebes, followed by rebuilding (Dakouri-Hild 2010, p. 698). These data suggest realignments of power and centrality at the onset of the 13th century.

In the Argolid, the citadel of Midea was built in the heartland of Mycenae and Tiryns around 1250 BC, calling into question the autonomy of citadels as centers of distinct states. Another indicator of change is the visible decline in prosperity but increased emphasis on defensibility at Mycenae after 1250 BC. This was a time when Tiryns thrived, with expanded fortification enclosing its lower town (Mühlenbruch 2020, pp. 124–126). All urban centers of the Argolid were destroyed by fire ca. 1200 BC, as were the centers at Gla, Dhimini, and Tiryns to the north, and Teichos Dymaion in Achaea. In Crete, the already much-diminished palace at Knossos may have suffered destruction in the late 14th century BC, and an administration there using Linear B survived until 1250 BC at the very latest, while the palatial center at Chania in western Crete was destroyed around 1200 BC.

We know from Linear B archives dated to the later 13th century that the societies living in those urban centers had become increasingly hierarchized, and so we find centralized administrations with a Wanax (king?) at the top, followed by Lawegatas, Basileus, Eqetes, along with priests and priestesses, scribes, dependent workers, and a civic body called the *damos* (Middleton 2020b, p. 9). Hierarchies and the use of material culture to construct specific identities in death, particularly the notion of the warrior, demonstrate the relevance of horizontal as well as vertical social differentiation for societies of southern Greece. Surprisingly, we do not yet know if the Wanax referred to in the Linear B tablets from one site was the same individual referred to at other sites, and so how many "rulers" there were, which constitutes a fundamental problem for understanding the political geography of the Mycenaean world (Kelder 2012).

In every century there were clear changes to the political landscape of the Mycenaean world between 1700 and 1200 BC, and the case of the Pylian state at least strongly implies that conflict and conquest were a part of its developmental history. Destructions of urban centers in the middle of the 13th century at Thebes, Mycenae, and Tiryns point to a regular cycle of conflict, and such destruction cannot be explained away as natural disasters (Hinzen et al. 2018). There was no stable, typical, or "classic" Mycenaean world, but rather a landscape of competing centers that were constantly in a process of becoming. Hindsight may highlight the destructions of 1200 BC as the end of a linear social trajectory; taking the evidence for 12th century nucleated settlements more fully into account, change was clearly part of unpredictable developmental arcs.

It was essentially the palatial system with its attendant entourage of craftworkers, scribes, and priestesses that collapsed. This was materially characterized by the loss of Linear B writing, sophisticated art, canonical palaces with central hearths, monumental civic and mortuary architecture, and organized military systems. The fiery events that marked the fall of each of the palaces took place within a short period of time (Middleton 2020b, p. 11). In what followed, there was a rejection of palatial architecture in rebuilding activities at sites such as Mycenae, Tiryns, and Midea, yet these places remained foci of power for decades after the loss of the palatial administrations. There was little appetite among the surviving residents of the Argolid to reconstruct the palaces, either materially or their underlying ideologies.

It was in the context of this fundamental reorganization of society in the wake of a period marked by wars and the loss of life, property, and stability that the climate became increasingly arid and the agricultural system dependent on predictable rains potentially became strained. The palynological evidence shows that in some areas this was associated with a contraction of land use, and survey evidence shows the spatial extent of occupation of many landscapes declining. Notably, in Achaea the palynological record from Kotihi lagoon shows little change; we know this area prospered until close to the end of the millennium.

The completeness of collapse as an unfolding circumstance can arguably be understood as the failure of leaders at urban centers to reestablish stability and stop the depopulation of their areas. This material and ideological disinvestment in central places and their societal frameworks took place in the two to four generations after 1200 BC. For a period, the loss of palatial authorities may have facilitated increased prosperity in previously non-palatial areas, including Achaea, Corinthia, Phokis, or the Euboean Gulf, and even stimulated new forms of commerce, but this brief prosperity declined around 1050 BC (Kramer-Hajos 2016, p. 153, 2020; Moschos 2009; Murray 2017; Souyoudzouglou-Haywood 1999). The failures of the 12th century leaders to effectively reestablish prosperity was a greater signature of system-wide collapse than the destruction of palaces, which had existed for one to two centuries in most cases and were one, albeit an important one, component in settlement networks.

For many areas, the changing political and settlement systems may be seen as a return to forms that had preceded the period of the palaces and, indeed, may have continued in tandem in non-palatial areas. We might envisage a population recovering from a period of turmoil reverting to simpler and smaller forms of social organization that "worked" for non-palatial communities, but these were then all beset by increasingly arid conditions. Although speculative, it is plausible that the palatial system rewarded specialization rather than diversification in land use in their hinterlands, and so buffering mechanisms were weakly built into the political system. When that collapsed and the territory of polities no doubt contracted, then this required an overhaul of land-use conventions. The increase in aridity narrowed the options and subsistence and/or surplus buffering mechanisms further. It may have been that the path back to larger and complex polities in the ebb and flow of Aegean urbanism, which dated back to the beginning of the second millennium, rather than a rejection of this lifeway, was ultimately truncated in the 12th century BC.

In the surrounding area, settlement along the Vardar-Axios River and plains around Macedonia in the north show clear continuity from the 12th to 11th centuries (Bulatović et al. 2021; Ruppenstein 2020; Triantaphyllou and Andreou 2020). Indeed, settlement and cemetery records suggest the area prospered and hosted migrants from farther north, potentially people leaving the Pannonian Plain. The hints of different impacts of climate change seen in the Mavri Trypa and Skala

Marion caves may be of relevance, as seen also in the relatively unchanged anthropogenic pollen markers in northern Greece for these centuries (Weiberg et al. 2019). In Crete, a broadly similar trend occurred, where a 13th century decline in settlements was reversed around 1220 BC, with many defensible villages established and thriving into the first millennium (Gaignerot-Driessen 2016; Langohr 2020; Nowicki 2018; Wallace 2018).

The Pannonian Plain

Our knowledge of settlements between 1500 and 1200 BC in the Pannonian Plain has changed dramatically in recent years. The largest prehistoric settlement in Europe prior to the first millennium BC—an enclosure of more than 1750 ha—has been defined at Corneşti Iarcuri (Harding 2017; Heeb et al. 2017; Szentmiklosi et al. 2011). This site was part of a newly discovered network of mega-fort sites in the eastern Pannonian Plain that are characterized by their exceptional size, such as Santana Cetatea Veche, Gradište Iđoš, and Csanádpalota–Földvár (Gogâltan and Sava 2010; Molloy et al. 2020; Sava and Ignat 2016; Szeverenyi et al. 2017). Along the Tisza River, a cluster of more than 100 large and usually enclosed sites, the Tisza site group, has recently been identified (Molloy et al. n.d.). Settlements are commonly located along, or set back from, major water courses and broadly mirror a trend toward wetlands and rivers also seen in the Po Valley (Dalla Longa 2019, p. 101). They occupy some of the lowest points in the flat Pannonian Plain landscape, many at the base of terraces or straddling the lower slope and its base, and they are typically situated adjacent to or are transected by minor waterways (Molloy et al. 2020, p. 6). While (probably winter) rainfall remained higher than it was during the height of the MBA settlement network, low-lying settlement locations demonstrate that water levels were not a major flooding threat. The occupation span of these sites remains to be firmly anchored. Although we know that the earliest sites were built ca. 1600 BC, there was a major investment in construction between 1500 and 1400 BC, a destruction horizon ca. 1300 BC, and limited evidence for occupation after 1200 BC at excavated sites. The initial growth of settlements took place when cooler conditions with higher wintertime precipitation have been modeled. The growth in building activity around 1400 BC coincides with a modeled increase in temperature and aridity, and reduced activity and/or abandonment of sites followed a warm/arid peak and continued high aridity after 1250 BC. Arguing for a collapse, on current data, remains problematic, but in comparing settlement densities in the 13th versus the 12th century, a striking disparity emerges.

While tell-centered polities represent complex social entities in the local MBA, very few sites of this period are known from the area that the Tisza site group occupied in the LBA. The dense distribution of large sites in the LBA constitutes an extensification of land use compared to the MBA, though we may also predict intensification of land use for food production, even in the non-occupied parts of the characteristic enclosures. This new mode of utilizing spaces may indicate changed environmental conditions that could support denser settlement than in preceding centuries, in turn suggesting that a LBA-specific form of human-landscape relations emerged. As the $\delta^{18}O$ and $\delta^{13}C$ data suggest, this was apparently a much less variable and slightly cooler and less wet period than the final centuries of the MBA. Settlement location choices relative to climate may mirror Magny's argument for northern Italy where societies developed "a peculiar socio-economic organization" dependent on humid conditions and exploited a particular niche hydrology that promoted habitation on the fringe of wetlands (Magny et al. 2009, p. 586).

Monumentality took on a new relevance in these settlement systems when we compare their scale of tens to hundreds of hectares to the preceding settlement forms that include tells that rarely extended to 10 ha (Nicodemus and O'Shea 2019). It is apparent that a large footprint was a primary concern in the LBA, as the largest settlements represented massive investments of labor. This new system emerged at the same time as changes in cemetery locations and rituals, so that by 1400 BC, there was an almost exclusive shift to cremation burials in flat cemeteries in tandem with excarnation or other modes of manipulation of the un-cremated remains detected at all excavated settlements. A new ceramic stylistic tradition, commonly called Belegiš II, developed by ca. 1400 BC and came to be used across an unprecedentedly large area (Cardarelli et al. 2020; Molloy et al. in press). Its presence marked the narrowing of diversity in ceramic markers of cultural distinctiveness in the east and south Pannonian Plain, signaling widening participation in a common cultural norm. The overall picture for the LBA is one of a newly established political and social system that was manifested across most fields of social practice and covered a substantial portion of the Pannonian Plain.

Only four LBA fortified sites have been excavated and dated, thus, far. Following a building spurt in the 15th century, a possible horizon of conflict is evident between 1400 and 1300 BC when destruction horizons occurred at Santana, Gradište Iđoš, and Corneşti Iarcuri (Gogâltan et al. 2019; Lehmpuhl et al. 2019; Molloy et al. 2020). There was less intensive occupation at Corneşti Iarcuri after this, and Santana may have been abandoned. Other sites appear to have been abandoned slightly later, between 1250 and 1150 BC at Gradište Iđoš and Csanádpalota–Földvár, for example. In the southeastern plain, almost all cemeteries were abandoned after 1200, with a lower visibility of burials dated to the 12th to 11th centuries (Bukvić 2000; Duffy et al. 2019; O'Shea et al. 2019; Petrović 2007; Todorović 1977; Vranić et al. 2002).

Settlement evidence is much reduced in general between 1200 and 1050 BC in the southern Pannonian Plain, and monumental central sites of any kind are unknown. While systematic survey is rare, Bóka (2012, fig. 5) and Száraz (2017) show "Gava period" sites were well distributed in the Körös area and Zala County in Hungary, respectively. For the Körös microregion, just north of the above fortified sites, this Gava typo-chronological period is framed as 1200–900 BC, and so shifts within this bracket are insufficiently clear. In Zala County, the number of sites fell from 122 sites dated broadly to 1300–1100 BC to 22 sites in 1100–900 BC. There remain significant problems with dating ceramics from survey finds and some surveys do not effectively disaggregate material from 1500 to 1000 BC (Artursson 2010; Bóka et al. 2017; but see Duffy et al. 2019).

MBA settlements favored naturally raised areas close to rivers with sufficient surrounding farmland. One explanation for change in the LBA is that the reduced rainfall coupled with reduced variability on a decadal scale apparent in hydroclimate proxies rendered large tracts of previously uninhabitable or undesirable areas more predictably accessible and valuable. This landscape is remarkably flat, and small changes in the water table can significantly impact potential land use. The close relationship between site locations and minor waterways running through or adjacent to them may also help explain their abandonment, should those waterways have become less active as aridity increased in 13th to 12th centuries. French's (2010) work in the Benta Valley farther northwest in the plain suggests precisely this phenomenon took place and further analyses are required to test this in the area of the Tisza site group.

Around the Pannonian Plain to the north and east, new settlements in the hills were commonly fortified, but they were as a rule much smaller in extent than the LBA forts. In the Transylvanian Plateau, the Noua and Wittenburg cultural traditions came to an end in the 14th to 13th century BC (Quinn et al. 2020, pp. 51–53). A new wave of settlement building there was contemporary to increased use of Gava-type pottery, closely related to the Belegiš forms used in the Pannonian Plain. Over 30 "Gava settlements" are known in Transylvania alone, dated broadly to 1200 to 900 BC; the majority are east of the Apuseni Mountains, away from the Pannonian Plain (Bălen 2013, pl. 1). These Transylvanian sites occupied a different topographic and environmental microclimate, away from major travel corridors and in more naturally defensible topographic positions. Several of those built after 1050 CalBC were very densely occupied, for example those at Căuaş-Sighetiu and Teleac (Kienlin et al. 2012; Metzner-Nebelsick 2010, 2012; Uhnér et al. 2019). By ca. 1050 BC, there are signs of a resurgence of enclosed settlements in the Pannonian Plain, though these are of a much-reduced size, and in some cases these occur as small enclosures within the ruins of much larger LBA forts (Molloy et al. 2020).

To the south, new defensible and open settlements emerged in the 12th century BC in the Morava and Vardar-Axios Valleys leading to Greece; they were characterized by the adoption of Carpathian-style channel-decorated pottery (Bulatović et al. 2021). As the Pannonian Plain became depopulated, its material culture traditions were increasingly influential elsewhere, suggesting an element of outward, no doubt gradual, migration.

With abandonment of the mega-forts by ca. 1200 BC, there was an exponential increase in the practice of hoarding somewhere between 1300 and 1100 BC (Gogâltan and Rezi 2019). There are many complex discussions about the purpose of hoarding, but a common strand is that they were a crisis response, whether hiding wealth from attackers or seeking to propitiate divine forces in the face of increased social challenges (Bradley 1990; Dietrich 2014; Fontijn 2013; 2019; Turk 2001; Turk and Čerče 1996). This latter may well include changes in the predictability or nature of weather patterns, as seen in the hydroclimate data for this same window of time. It is relevant that most hoards were deposited in or close to watercourses. It is conceivable that the increase in hoarding from the 13th century on was the kind of "doubling down" on ritual practices argued to be a response to extraneously introduced society-wide crises, such as climate change, showing past awareness that conditions were changing (Johnson 2017). These same items of metalwork are also indicative of changes in military practice, with the invention of shields, greaves, and possibly helmets and new forms of sword and spear emerging in the 13th to 12th centuries. These represent fundamental changes in the nature of warfare in Europe (Molloy and Horn 2020).

Overall, the system in place between 1400 and 1200 BC supported the presence of densely spaced, large, and enclosed sites in the southern Pannonian Plain indicative of a substantial population. Whatever changed, it was sufficient to render that system unsustainable, and areas of the landscape that had supported large populations ceased to do so.

The Po Valley

The density, and complexity, of settlement in the Po Valley between 1500 and 1150 BC was unprecedented there. Settlement was characterized by Terramare sites defined as "quadrangular settlements surrounded by an artificial embankment and ditch into which the waters of a nearby river or natural canal were re-routed" and a smaller number of Palfitte sites, which were water-side pile dwellings (Cavazzuti et al. 2019a, p. 625). These communities shared material culture, craft, domestic, and mortuary traditions. In the mountains to the north and south, copper deposits were exploited when the Terramare system was at its height (Ling et al. 2014, 2019). Although not all were occupied at the same time, as many as 220 Terramare sites have been identified (Cardarelli 2009; Cavazzuti et al. 2019a, p. 625; Kristiansen 2016, p. 172).

There was a rapid increase in population in the final stages of the MBA at a rate that cannot be accounted for by local population growth, and it has been speculated that migrants from the Pannonian Plain contributed to this (Cardarelli 2009; Molloy et al. in press). Incremental growth of population is documented in some areas, primarily north of the Po River, suggesting that even if migration was important for the emergence of the Terramare system, it was unlikely to have been from a sole source or a single wave (Dalla Longa 2019).

There was a trend to locating sites along water courses, characterized as a "systematic wetland-oriented occupation strategy" (Dalla Longa 2019, p. 101). The very earliest sites that might be called Terramare were settled ca. 1650 BC, though they came to be more commonly constructed after 1500 BC, and these early sites rarely exceeded 2 ha (Cardarelli 2009, p. 456; Dalla Longa et al. 2019, p. 7). After this long early phase where sites occupied the highest tracts of land, there was a shift to lower tracts sometime prior to 1350 BC, as documented in site distributions in the Valli Grandi Veronesi north of the Po River (Dalla Longa et al. 2019, p. 7). In the next stage of development, there was a move toward occupying an even greater diversity of topographic locations, often in low-lying contexts and along rivers (Dalla Longa 2019, p. 102). The high-quality survey data from Valli Grandi Veronesi reveals that settlement numbers were stable during the 13th century, potentially increasing slightly in some areas by the end of the century and into the first half of the 12th century (Dalla Longa 2019, p. 105). Close to where the plain meets the Alps in the north, a slight reduction in site numbers began in the 13th century (de Marinis 2009, p. 536).

In this period, some larger Terramare sites emerged north and south of the Po at Fondo Paviani (16 ha), Case del Lago (22.5 ha), and Case Cocconi (20 ha, but possibly 60) (Blake 2014, p. 117). It has been argued that these sites were primary centers in local polities that included smaller Terramare settlements (Cardarelli 2020). The expansion in number and size of sites must have equated to a reduction in the potential buffering capacity of the landscape due to the expansion of agriculture to support growth.

In the northern Po Valley, there was a "drastic reduction in the number of settlements and a consequent rearrangement of their distribution," with numbers falling from their peak in the 13th century to less than one quarter of that number by the mid-12th century BC (Blake 2014, p. 118; Cardarelli 2009; Dalla Longa et al. 2019, fig. 5). For those settlements that survived after 1150 BC, they continued to occupy riverine routes, but in the Valli Grandi Veronesi, they were located on alluvial ridges or wide terraces. This includes new and established settlements (Dalla Longa 2019, p. 104). Some settlements continued to thrive into the mid-12th century and then fail, such as Fondo Paviani. Other important sites emerged or were established when new networks developed, including the settlement at Frattesina, which took a leading role in local power relations and was well integrated into long-distance networks from the late 12th century (Cavazzuti et al. 2019a; Iacono 2019). Nonetheless, recent studies of personal mobility indicate that there was a contraction in networks after 1200 BC, with the Frattesina community exhibiting lower personal mobility than earlier Terramare groups (Cavazzuti et al. 2019a, b).

South of the Po Valley, a decrease in settlement numbers in the 13th century was commensurate with an increase in site size. This was due to a progressive concentration of population in larger settlements as hegemonies increased (Cardarelli 2009, p. 466, fig. 6). In this part of the Po Valley, virtually all settlements were abandoned by 1150 BC. This indicates a substantial loss of population, as many as 120,000 people in Cardarelli's (2009) modeling for the entire Po Valley. However, the boundaries of Terramare relative chronologies are still debated, and they are anchored on a very small number of absolute dates, set out, for example, by Cardarelli (2014). This has implications for correlating climate and social change, particularly if observed changes in the two datasets are the factors used as anchor points.

The palynological, macrobotanical, and faunal evidence discussed above indicate that there was an increasingly complex relationship between society and the landscape from the 14th century onward, with human and climatic factors shaping almost the entire landscape. It is not clear if population growth characterizing the wider establishment of the Terramare complex around 1500 BC was due to a new approach to managing agriculture in a flat riverine landscape or if minor changes in the climate had a beneficial impact on the local environment supporting more productive use of the landscape. In either case, the rapid and sustained growth suggests a dependency relationship between population, political structures, and agricultural systems. The settlements themselves, and presumably their local ecology and/or defensibility, was dependent in many cases on small water courses that fed the surrounding ditches. As with the Pannonian Plain, it appears that several aspects of the Terramare network were dependent on a particular balance in hydrology, from the settlements themselves to the exploitation of low-lying and wetter parts of the landscape.

While increasing aridity may well have impacted agriculture, it was also likely to have impacted the entire ideology and character of communities and their relationship to wetlands. This may have extended to the very definition of settlements themselves with their surrounding ditches. As with the Pannonian Plain, the possibility that a switch from conditions that had been considered predictable to a drier climate would impact participation in social institutions or trigger conflicts is salient, if difficult to measure. Johnson argues that the social infrastructures enabling increasing prosperity and stability may give rise to a swelling elite, and factions within this, with constantly shifting alliances arising in balances of power within and between polities, what Middleton calls "competing hegemonies" (Johnson 2017, p. 53; Middleton 2020b). For the Po Valley, the very things that gave rise to a prospering elite in the 13th century appear to have then undermined that stability as their ranks grew and competition increased after 1200 BC. Such competition is arguably visible in the rapid changes and growing investment in panoplies of weapons at precisely this time. The nature of the Po Valley boom and bust contrasts with other areas of Italy that show more incremental growth and stability throughout the Bronze Age (Blake 2014; Capuzzo et al. 2018; Iacono 2019; Ialongo 2018; Roberts et al. 2019).

The Nordic Area

Beginning around 1600 BC, the Nordic world became well connected to the Pannonian Plain and the Po Valley, just as the settlement networks in those areas were rapidly transforming, and ideological borrowings from the Aegean world and metal resources from Britain attest to external connections of the mid to late second millennium BC (Kaul 2013; Ling et al. 2014; Melheim et al. 2018; Vandkilde 2014; 2016). By 1500 BC, "an original Nordic culture emerged, linked to a new more hierarchical organization of society and landscape" (Earle and Kristiansen 2010, p. 23). Social organization in the Nordic world was markedly different than in the areas explored above. Settlement was defined by multi/extended-family households in long houses that commonly stood alone, though in some areas these were densely spaced in the landscape. As prosperity and population increased in the 15th century, so too does the evidence for trade in metals and consumption of prestige goods, representing an expansion in exchange networks (Ling et al. 2014, 2018).

The area of Thy is both well investigated, and traces of affluent communities are well preserved archaeologically. This area was among the most materially wealthy in Europe. It may have been close to, or even exceeding, its carrying capacity after 1300 BC, with an estimated population comparable to the preindustrial period (Ling et al. 2018, pp. 495, 498). Demonstrating the prosperity of this region, Kristiansen (2018, p. 125) argues there was an increase in deposition of swords and barrow construction between 1300 and 1100 BC, which may be read as conspicuous consumption, although Kristiansen sees this also as evidence for increased prevalence of violence in society. However, during the 12th century barrow building in Thy ended, and the construction of very large farmhouses became a rarity (Kristiansen 2018, p. 128).

Ling et al. (2018) argue for a "maritime mode of production" as a dominant element in political economies of the Nordic world. In this model, population surplus was converted into trading, raiding, and colonizing ventures. Their model also envisages expansion of maritime activities and opportunism, such that martial strength was a key factor enabling development of prosperity while at the same fueling intense competition between political units. Certainly, the strong focus on maritime and martial symbolism in Scandinavian rock art complement such a model. It remains possible, if speculative, that climate change after 1200 BC affected this maritime mode of production that depended on favorable sea conditions. For example, there appears to have been a lowering of sea levels indicative of changing conditions (Søgaard et al. 2018, p. 219).

House designs follow a Neolithic heritage, and sizes remained at their peak size until 1500 BC, after which they began to decrease in size (Artursson 2010). Between 1300 and 1100 BC in southern Jutland, the size of most houses was reduced to less than 200 m^2, and their frequency in the landscape significantly decreased (Bech and Rasmussen 2018, p. 35, fig. 2.C; Kneisel et al. 2019, p. 1610). To the north, in Thy, houses continued to be built in large proportions in the 12th century, but after that the numbers and sizes dropped off considerably (Bech and Rasmussen 2018, pp. 37–39, fig. 2.8, fig. 2.C). This pattern is seen in the limited datasets from the wider area; after 1100 BC houses became smaller and fewer and there was less metalwork deposition, interpreted as a diminution in the wealth of the area and political hierarchies (Artursson 2010, p. 98; Earle and Kolb 2010, p. 68).

In Tanum, Sweden, rock art depicting ships indicates intense use of the coastal landscape, though the settlement density there was perhaps two houses per km^2 at its height (Ling et al. 2018, p. 499). In Rogaland in southern Norway, some basic data are available, and we see the number of houses built between 1300 and 1000 BC was significantly smaller than the blocks of centuries bracketing this (Bech and Rasmussen 2018, fig. 2.13).

There is no consistent pattern of change pivoting around 1200 BC in the Nordic world, but the 12th century was clearly a time of change leading up to the transition to Nordic Period IV, which was a markedly poorer phase materially. Rogaland, southern Jutland, and Tanum all experienced a decline in visible population during the 12th century, but the change was more gradual in Thy, and it may be later in the 12th century before population and prosperity declines were more strongly felt. In each area, the character of change was less dramatic than in the previous three areas and may be seen as a reduction in investment in resources and rationalization of systems, not a collapse in a sociopolitical sense. The severity of this transition on prosperity, however, is marked in the abandonment of monumental tomb building, substantial reduction in the quantity of metalwork going out of circulation through votive offerings, and a further reduction in the relative size and frequency of houses. This represents a striking shift in expressions of elite power and prosperity and indeed a substantially reduced visibility of actions demonstrating power or wealth in society by 1100 BC.

Changes in mortuary rites also occurred between the 12th and 11th centuries BC, with a wholesale increase in cremation and the introduction (probably from central Europe) of urn burials. A recent small-scale study of strontium isotope markers of mobility in cremation burials indicates limited mobility in the centuries prior to 1100 BC and a marked increase in inward migration into Denmark after that point (Reiter et al. 2021). This is a further marker of the schism dated broadly to 1100 BC.

Social challenges that developed throughout the 12th century culminated by its end with clear changes in land use, wealth, ritual, and political management. Social change clearly articulated with environmental degradation, yet no major climate change markers have been identified. Although perhaps straining the evidence, some areas appear to have experienced reduced rainfall, and all seem to have experienced warmer temperatures, which could have exacerbated aeolian soil erosion that had been triggered by anthropogenic activity. Of all the study areas, the potential for minor climate change to have severely impacted a highly socialized landscape/environment appears higher in the Nordic world.

Ireland and Britain

Ireland and Britain have high-quality environmental and ^{14}C data available, yet our knowledge of the development of settlement traditions over time is fragmentary. The dearth of village sites and typically invisible surface markers of structures means that discovery of houses has often been “accidental” through developer-led archaeology. While this work generated many new radiocarbon dates, observing patterns in terms of frequency or scale of settlement is difficult because many sites were randomly identified and social factors influencing their distribution are difficult to measure.

The general pattern is one of dispersed houses that would have been home to small, probably nuclear, family units. Hillforts capable of housing multiple families increasingly became a feature of some later Bronze Age landscapes after 1200 BC in Ireland and later in Britain (O’Brien and O’Driscoll 2017). Forts such as Dún Aonghasa, Toor Mor, Fermoyle, and Rathnagree constitute one form of central site in the 12th century BC, though it is unlikely such sites were a focus of extensive settlement networks or home to large populations. This is evident through the sparsity of structural features documented from this period within them (Lock and Ralston 2019; O’Brien and O’Driscoll 2017). As a site type, hillforts could only temporarily accommodate a very small proportion of the overall population, and so unlike the Po Valley or Pannonian Plain, their size and frequency are not ideal proxies for evaluating social organization, settlement history, or population levels.

In Ireland the presence of hillforts is indicative of new forms of communal architecture that served as a centralizing focus in settlement distribution, with nucleation around these sites sometimes suggested in the palynological record (Plunkett 2007, p. 233). Hillforts may thus have created a form of site clustering rather than strictly centralization, drawing homesteads away from other locations. Unfortunately, surface invisibility of structures and the rare use of pottery in many parts of the islands hampers surface survey investigation and settlement modeling.

The evidence from $\delta^{15}N$ isotope analysis of animal bones in Ireland discussed above indicates intensification of farming practices, also evident in some of the pollen records. This would accord with a centralizing role of hillforts seen in the increasing shift from dispersed to loosely clustered settlement regimes in some areas after 1200 BC. The increase in hillfort building in Ireland observed by O'Brien and O'Driscoll (2017) in the 13th century occurred around the time of a warm peak identified in climatic records (Gearey et al. 2020). However, based on the modeling of ^{14}C dates in Ireland, Ginn and Plunkett (2020) argue for a lull in many markers of anthropogenic activity, including settlement numbers, bottoming out in the 13th century. This was followed by a resurgence beginning ca. 1200 BC that peaked by 1050 BC close to the island's previous maximum between 1600 and 1400 BC (Ginn and Plunkett 2020, pp. 47–51).

For Britain, a different pattern is seen in the south of the island. It has been argued that there was an increase in the frequency of settlements after 1500 BC, and these often include more substantial domestic structures than in the earlier Bronze Age (Bradley 2007, pp. 181–182; Brück, 2019, pp. 115–162). There was a marked increase in the range and number of identifiable site types in both islands and of site frequency after 1150 BC, including middens as gathering places. Brück (2007, p. 25) also notes that the range, quantity, and quality of artifacts recovered from LBA (ca. 1150–750 BC) sites in Britain is higher than in the preceding centuries.

The site of Grimspound in southwest England, established in the 15th century BC, had a stone enclosure surrounding a small, enclosed village or high-status settlement. The earliest ringworks—defensible, enclosed sites not in prominent topographic locations—such as Thwing and Worcester also date to this period, with the site type becoming more prominent in the early first millennium (Bradley 2007, pp. 193–208). In southern and eastern England, extensive co-axial field systems were a feature present since the earlier Bronze Age, and they continued to be built and used after 1500 BC. They then became more commonly associated with isolated or occasionally clusters of houses and reveal control and stability in landscape management. In southern Britain, while evidence for occupation of fortified communal central places like hillforts is all but absent in the 12th to 11th centuries, open landscapes were increasingly demarcated by built features and contested. Linear earthworks began to define territories after 1200 BC in southern England, in some areas replacing field systems as a means to divide up landscapes (Bradley 2007, p. 210). At Tormarton, the execution of at least five males who were then unceremoniously thrown into such a ditch indicates these changes in land demarcation may have been a source of conflict (Osgood 2005).

Bradley has described how the entire cultural landscape of lowland Britain in the 12th century "assumed a quite uniform character" (Bradley 2007, pp. 210). Most settlements were not enclosed, and it became common to find small clusters of houses with ancillary buildings. Our knowledge of settlement around 1200 BC beyond southern and eastern England is less developed. While field systems and long ditches existed in the south, farther north settlement density and the presence of fortified sites or clusters larger than hamlets is as yet unknown before the turn of the millennium (Bradley 2007, p. 196). The only known unfortified village-sized settlement in the islands is Corrstown in northern Ireland, which was established around

1500 BC, thrived in the 14th century, and appears to have gone into a final decline after 1200 BC (Ginn and Rathbone 2012).

With only nominal tree clearance horizons noted, it is apparent that anthropogenic stressors on the environment were minimal and did not relate to soil exhaustion as they had in other regions discussed. In both islands, settlements occupied most environmental niches in the landscape, ranging from the fertile plains of southern England to rugged Atlantic islands off the coast of Ireland. Some may have been more exposed to climatic change impacts than others, for example, the upland settlements of southwest England (Turney et al. 2016).

Given the paucity of ceramic finds and limited settlement evidence between 1200 and 1000 BC, metalwork was a key source. Apart from the shaft graves at Mycenae, the densest concentration of goldwork in Europe has been recovered from Ireland and is dated to the later Bronze Age. This material is outstanding in terms of quality as well as quantity (Eogan 1994). It is salient that when some continental centers of influence were contracting, Ireland and Britain became influential and wealthy centers, extending their influence into the continent as seen in metalwork styles. Specialist workshops were supported, and prestige economics expanded as part of the reorganization of society after 1200 BC. While particularly high-status settlements are rarely recorded, the material culture attests to their existence and the forms of wealth their occupants created. The general narrative seen in metalwork is one of continued high-level exchange of objects, raw materials, and ideas in long-distance networks in the 12th and 11th centuries (Roberts 2013). There was a decline in the deposition of bronze objects in hoards after 1200 BC, but this was accompanied by an increase in deposition of gold hoards, more than 25, during the Bishopsland phase in Ireland. The continued circulation (not deposition) of bronze tools and weapons may indicate stable conditions, if we accept the theory that scrap hoards were in some venues a form of response to crises.

Despite local-scale variability, the overall pattern for these islands suggests wetter conditions came to an end around 1200 BC followed by warmer and drier conditions. In this niche, settlement numbers increased and remained consistently higher than the previous two centuries. A similar growth in settlement numbers (and occupied footprints) is noted in the south of France, also beginning ca. 1350 BC and peaking by 1050 BC, suggesting favorable conditions were more widespread in parts of western Europe affected by Atlantic weather systems (Berger et al. 2019, p. 792). The prosperity seen in the islands represents an important disjuncture in itself and is something of a departure from immediately preceding centuries, particularly in Ireland. We can identify centralization, thriving prestige good economies, and expanded regional interaction, each of which can be read as a positive change. However, the increased use of fortification of central places and division of landscapes, along with new developments in weaponry and warfare—many coming from the continent—may indicate that social changes after 1200 BC were not universally beneficial to the wider populations.

Social Change Discussion

The year 1200 BC was a broad focal point for changing human–climate–environment relationships in societies across Europe. Seen in isolation, there is a disjuncture in many societies if we view a snapshot of them ca. 1200 and another ca. 1100 BC. In each case, this break is sharper than seen across the preceding blocks of centuries, and in several areas it is associated with migration out of previously prosperous areas. The timing, pace, regional biases, and general nature of social transformations do not support climate change as a trigger of hyperresponsive social changes, including collapse. Indeed, areas bordering our study areas such as northern Greece, Transylvania, southern France, Sardinia, among many others, exhibited few physical markers for crises in the 12th century, and they clearly prospered during this window.

The lack of continued or resurgent complexity in the 12th century better correlates with the timing of peaks in the climate data than crises defined in archaeological datasets during the 13th century in the Aegean, Po Valley, and Pannonian Plain, at least. Arguably, landscape resilience itself (e.g., in light of deforestation), lifeways and culture-specific agricultural conventions fell victim to lock-in effects and inflexibility in the face of changing situations. In already fragmented political worlds rife with internal conflicts at a time of exceptional reorganization, communities appear to have been ill-equipped to reorganize at sufficient scale and pace to reestablish large, multilocal political entities. In the Aegean, for example, earlier centers of power were reoccupied but poorly repaired at a time when there was a rapid growth in the proportion and distribution of weaponry of exogenous design. There, and in other areas discussed above, we may detect a "perfect storm" of distinct contemporary challenges or cascading stress factors in various social arenas rather than a singular stimulus (Cline 2021; Knapp and Manning 2016, p. 137). While crisis and change were common in several areas, the underlying processes need not have been the same. The gradual breakdown of old metal networks that had supported social relationships and the emergence of new networks in the 12th century demonstrate change beyond the scale of any individual society. There can be little doubt that collapse or decline of societies in influential regions of Europe with complex economic systems was an important factor in these shifting networks, creating a domino effect shaping even those areas that were ostensibly more stable. This created opportunity as well as crisis, as seen in Atlantic Europe or the growing dominance of (probably) eastern Alpine copper exports across Europe as the influence of powerful political players in exchange networks lying on their fringe declined. Control over the flows of resources in such networks was open to manipulation by those seeking to profit from them, and so ironically the increased flow of materials out from a source region may reveal weakened political control.

At an organizational level, in the Aegean and possibly the Po Valley, Pannonian Plain, and Nordic area, 13th century infrastructures may have had capacity to accommodate, or at worst rebound from, challenging conditions when growth and consolidation were actively occurring. They had well-organized political systems that drew societies together with a degree of common purpose as they expanded their resource base. Removing that organization, cooperation, and/or hegemonies in the wake of political collapse left societies more exposed to a variety of risks by the 12th century BC. As political territories and populations contracted, so too must have the buffering mechanisms of societies that had previously been in control of more diverse landscapes and labor resources. Though somewhat functionalist, we can see that meeting subsistence needs at a local scale may have superseded surplus production capacity after 1200 BC.

Even if we do not blame climate or environmental change overtly for these transformations, we can highlight the precariousness of situational dependencies in the societies studied. The climate conditions that prevailed in each region between 1500 and 1200 BC provided the context for specific societies to grow and modify their environment. It can reasonably be argued that in Mediterranean Europe and its hinterland, specific cultural configurations between 1500 and 1200 BC thrived at the interface between social expectation and landscape productivity. The niches they depended on may have exposed them to risks of a rigidity trap in which social organization was anchored in specific forms of landscape specialization (Haldon et al. 2020, p. 30). There was little built-in buffering capacity by political entities because they rarely extended across multiple environmental zones. This placed them in a "socially and technologically produced condition of vulnerability" or self-created fragility (Arponen et al. 2019, p. 7; Yoffee 2019). The brief review of agricultural practices above indicates continuity in species exploited, which is unsurprising given the very long history of use for most of them. There are nonetheless indictors that management strategies and preferences changed, suggesting disjuncture in some regions, which relates to society-specific ways of harnessing material and labor resources.

In the Nordic region, crisis may have been driven by intensive forms of landscape exploitation that left them exposed to even mild fluctuations in climate, leading to the documented soil exhaustion in a classic environmental overshoot model (Cumming and Peterson 2017; Kristiansen 2018). While ostensibly anthropogenically driven, it remains plausible that a fine balance struck for centuries made the region susceptible to even minor climatic shifts. Although the limited records do not suggest substantial changes in rainfall, the apparent increase in temperatures may have increased the exposure of soils to aeolian erosion. For four of the regions discussed, it is surely relevant that the societies that emerged between 1500 and 1200 BC exhibited more complex political states, long-distance networking, and dense settlement patterns than at any time before this in their history. The evidence from Ireland and Britain is equivocal, but the broad pattern appears to be a countervailing trend with modest anthropogenic activity between 1500 and 1200 BC followed by an upswing in conditions and activity in the 12th century toward an 11th century peak.

Discussion

Could climate change have led to rapid social changes, including societal collapses, around 1200 BC? On balance, this appears to be asking the wrong question in light of the nature of available data and current thinking on collapse and resilience in past societies, both of which are best applied in multidecadal frameworks. If we ask more generally whether climate change was an uncommonly acute factor shaping social change in the later Bronze Age, then the data indicate it played a highly influential, and frequently detrimental, role over the span of multiple human lifetimes.

In different parts of Europe, there was a broad correlation between societies most affected in the 12th century (decline in size, number, and status of central sites and regional depopulation) and previous levels of complexity. The Aegean, Po Valley, Pannonian Plain, and Nordic lands incorporate landscapes that had once sustained the most flourishing societies in Europe. That these were subsequently largely abandoned even as neighboring regions sustained stable population levels is remarkable. This may suggest that the landscapes themselves were no longer attractive, whether that was social taboo or environmental conditions or both. Certainly, the finely balanced relationship between wetlands and farmlands in the Po Valley and Pannonian Plain or the dependency on rain for water in the Aegean left them exposed to change, which required varying degrees of labor or innovation to manage.

The Bronze Age world was a highly competitive environment where wealth, status, and power were writ large in the urban and fortified complexes, in the use of valued objects to display identity, and in the constant need to resource long-distance relations. This is perhaps epitomized by the amber route or metal exchange networks that connected all corners of Europe in the Bronze Age. Climate and environmental challenges may be seen as force multipliers within an already competitive and potentially precarious system in which access to wealth resources was a fundamental of political economies (Earle et al. 2015). It is no surprise that the Aegean, Po Valley, and Pannonian Plain, which had been innovators in conflict and competition—from the building of massive forts to creating complex new combat systems—were the areas least well equipped to respond to exogenous forces and intensified internal competition. Their very complexity was predicated on power balances within and between centers of power and external relationships through which materials flowed.

Societal complexity accelerated in many parts of Europe between 1500 and 1200 BC. In four of five societies examined, this was marked by the increased density of settlement and use of the built environment to both physically and ideologically demarcate landscapes. These structures and enclosures were material markers of new forms of land ownership and definition of territories. In the Aegean and Po Valley in particular, it is evident that political boundaries were in a constant state of flux, fueled by competition and conflict. Together with the increased circulation of prestige goods such as amber and potentially livestock, control of property of various sorts was fundamental to the beliefs and expectations of these societies. The social crises that came to a head in the decades around 1200 BC led to abandonment or wholesale reconfiguration of the built landscape and the use of built spaces to demarcate ownership, hierarchies, and territories. In the Aegean, some fortified centers were resettled, but monumental architecture, and notably palace buildings, were not replaced or even substantially repaired, while areas that had previously become marginal began to thrive until the 11th century or later still in the case of Crete.

In the southeast Pannonian Plain, change was the most striking, with virtually all monumental settlements abandoned en masse sometime between 1250 and

1150 BC. The settlement collapse in the Po Valley was no less dramatic, with hierarchical relationships and networks that had encompassed the entire landscape vanishing, even if some enclaves in the north survived before a new vitality slowly emerged from the 11th century. While the Nordic case is less sharply defined, reduced investment in monumental tombs and new house construction occurred throughout the 12th century and became more pronounced in the transition from Period III to IV ca. 1100 BC. The reconfiguration of landscapes in Ireland and Britain was most pronounced in the former, with increased use of monumental settlements that potentially played a centralizing function. The 12th century heralded a period of innovation and increased long-distance networking, most visible in metalwork. In all five areas, the world of 1200 BC looked remarkably different than that of 1100 BC.

Such profound changes to settlement and mortuary conventions alongside local exchange and long-distance networks indicate that the value and belief systems underpinning community relations were being fundamentally reconfigured in the 12th century. In this, Climate change was incrementally deviating from conditions of ca. 1500–1200 BC. This climate scenario was interlinked in some cases, notably the Po Valley and Nordic area, with anthropogenic stressors on the environment. While the climate data are at times frustratingly equivocal, the general trend was a substantial drift toward the margins of the Holocene parameters unfolding between 1200 and 1000 BC. This suggests we could reasonably envisage a situation whereby more susceptible areas were exposed to crises before neighboring areas. That is, for people within a given region, climate and environmental change were unequally experienced in real time as they unfolded. This is seen, for example, in the varying fortunes of settlements over the course of the 12th and into the 11th centuries BC in southern Greece, the northern versus southern Po Valley, and varied landscapes of the Nordic area in particular.

This provided reasonable grounds for some people to take advantage of their relative prosperity in power relationships. The data may better support a model of societal responses to unequal climate pressure exacerbating or directly causing social stressors than climate change itself being a cause of stress at a regional level. The case for increased conflict may be made for the Aegean where innovations in weapons and warfare took place during the 12th century as well as the Po Valley, which was one of the areas that drove the innovations adopted in the Aegean. For Ling et al.'s (2018) maritime mode of production model, changes in settlement systems and management of metal in the Nordic world appear to correlate well with an implosion of that system. Whether through access to less-affected landscapes or other resource bases, the key point is that change must have been unequally experienced. Such a scenario recognizes the structuring conditions of climate change, but its societal impact is dependent on the role of choice, belief, and human agency.

Accepting the problems of correlating the chronologies of climatic and archaeological data, the trend in most areas is that climate change occurred in the wake of major social disjunctures. On the basis of current chronologies, it simply cannot have been a primary catalyst of change. Recent work in the archaeology of collapse emphasizes this need to understand "what happens next" as a key to understanding how a period of crises was marked and becomes archaeologically recognizable

(Haldon et al. 2020, p. 32; Middleton 2017b). My argument is that climate and environmental changes impacted societal resilience. What is evidently a collapse in some of the study areas may have otherwise been another of the disruptions that marked the ebb and flow of those societies in long-term perspective. That is, the collapses or crises-driven changes around 1200 BC are marked more sharply by developments in following decades than by the change horizon itself and its immediate aftermath.

This comparative study of contemporary societies revealed that each experienced a sharper break after 1200 BC than can be recognized in each area for the preceding blocks of centuries. This took the form of a centennial-scale shift marking the 12th to 10th centuries as different from the 16th to 13th centuries BC. It was demonstrated that proxies from across Europe reveal climate change in the 13th to 11th centuries BC. This in principle extends the evidence for a 3.2 ka event impacting societies beyond the Mediterranean and into Europe. We require considerably more well-dated proxy data to systematically build such a regional perspective by taking closer account of variability at local scales. It was necessary to focus on sample societies from distinct cultural configurations of Europe, and so more extensive analysis in any one of these areas would require treatment of many more archaeological datasets as well as further climatic ones. Such future work would benefit by integration with analysis of more closely constrained faunal and macrobotanical studies that may reveal changes in agricultural risk management—a marker of real-time climate crisis response.

The recent call by Burke et al. (2021) for an explicit archaeology of climate change is salient here, alongside the ongoing development of the history of climate and society (HCS), as defined by Degroot et al. (2021). This not only requires pushing back deeper into prehistory to establish a *prehistory* of human–climate interactions, it requires particularly archaeological contributions that can target environmental and societal changes together in the same context (e.g., Dibble and Finné 2021; Nicoll and Zerboni 2020). There is a profound need for comparative regional perspectives during periods of known climate change, even if the resolution diminishes when we step back in time and away from ideal datasets/regions of historical times. Although this has been a broad single-authored overview of diverse studies, it emphasizes the need for truly multidisciplinary collaborative endeavors in future work that bring climate and social scientists together on an equal footing. This is not merely closer integration of datasets, it requires a more equal approach to the same problem that has in the past been biased through imbalances in funding between STEM and AHSS subjects.

Conclusion

This paper has explored a particular prehistory of human–climate interactions focused around 1200 BC in Europe. The case was made that a tendency to draw together paleoclimatic and archaeological datasets in the context of collapse studies not only risks confirmation bias, it truncates how we measure the relative impact of climate on societies over time. This is essential if we are to disentangle causation from correlation when we identify turning points. Equally, the comparative regional approach of this study looked beyond the specific social dynamics of each contemporary society to a scale where extraneous factors impacting each may better be evaluated, which included but was not limited to climate change.

A broad range of results from paleoclimatic and environmental studies have been evaluated, considering work on proxies as varied as lake and marine cores, speleothems, bodies of ice, bog deposits, tree rings, pollen, and chironomid head capsules. Though using a heterogeneous *potpourri* of datasets that do not lend themselves to a neat comparative approach, there were clear correlations in how these data were interpreted to reflect climatic and/or environmental conditions in our periods of interest. In broad terms, a particular temperature-wetness niche is detectable in the 16th to 13th centuries BC, followed by increased aridity in the 12th century in most of the studies discussed. A broadly north–south divide was observed in temperature proxies, with evidently increasing temperature in the decades around 1200 BC throughout much of continental Europe and the Atlantic islands, while in the Mediterranean the evidence was indicative of cooling trends. In all regions, a distinct shift was detected in the decades around 1200 BC, irrespective of the precise nature of that shift. Although this was in no case extreme, climate data regularly reached the margins of Holocene conditions for each region.

There also were sharp social changes evident in this same time frame in each of the regions studied, demonstrating correlation. In several areas, climate change was identified as a force multiplier that exacerbated pre-existing social problems that were culminations of well-defined trends predating any markers of climate change. The more vexing issue of causation requires a centennial perspective on each area that takes account of particular social dynamics. Consequently, no universal model of climate as a primary driver of social change in later Bronze Age Europe encompassing the entire geographic scale of this paper was posited.

The collapse of Aegean palatial systems (specifically) around 1200 BC was viewed in relation to initial signs of continuity and resilience in population levels and settlement locations in the 12th century, prior to decline at most sites before the end of that century. Increasingly arid climatic conditions are documented in most proxies for Greece during the 12th century. A possible arid spike occurred in the later 13th century that may correspond with the onset of increasing aridity in the Carpathian Basin to the north. In that area, the mega-fort horizon that had defined the LBA in the southern Pannonian Plain declined between 1250 and 1150 BC, followed by massively reduced anthropogenic activity in the surveyed parts of the southern plain until ca. 1050 BC. A similar arid phase in the Po Valley appears to have begun at the same time as in the Aegean, and there was a widespread abandonment of settlement and depopulation between 1200 and 1150 BC. In the Nordic area, soil exhaustion and deforestation in researched areas relates to anthropogenic activity after 1500 BC, and though climate change proxies revealing conditions ca. 1200 BC are limited, they imply a minor change in hydroclimate and temperature. How this impacted, or articulated with human activity to impact on, environments is unclear, but by ca. 1100 BC there was a major reduction in anthropogenic signatures in the landscape. A contrary picture appears probable for Ireland and Britain, with reduced rainfall correlating in time with an increase in anthropogenic activity, centralization around hillforts in some places, and increased interaction with continental

Europe. These studies show that changes after 1200 BC were highly varied and contingent on the local social, political, and economic conditions. The broad regional picture of this review paper necessarily generalizes complex conditions extending across Europe, yet the plausibility of a 3.2 ka climate event impacting prehistoric European societies has been demonstrated.

A bias toward areas with robust archaeological chronologies and comparatively rich datasets has also biased selection to societies with particular forms of social organization and exploitation of landscapes. Some further studies that may reveal countervailing trends were noted. The comparative regional approach shifted our focus from the specific conditions internal to any given society, and this was augmented by a consideration of changes in long-distance networks in which each society participated. This emphasized the evolving interplay between internal and external factors shaping these societies in comparative perspective. As climate acts at a larger spatial scale than the footprint of each study area, turning points in several contemporary societies should be predicted if climate change was impactful. This was shown to be the case, even if the nature and extent of change was shaped by the conditions of each society. Catastrophist perspectives were rejected, and it was emphasized that change unfolded at a multigenerational scale that was shaped distinctly by human choices, resulting in heterogeneous trajectories.

The potential for archaeology to inform paleoclimate research in long-term perspective was demonstrated through the cases of the Pannonian Plain and Po Valley in particular. Specifically, the shift to wetter and cooler conditions in the 16th–15th centuries BC in these low-lying and flat landscapes known to be high flood-risk environments accompanies a massive, unprecedented growth in both areas. This was shown to be important for understanding how the weather patterns reflected in paleoclimatic signatures translate into environmental conditions and their impact on human exploitation of landscapes. As an apparent paradoxical relationship, looking to long-term trends in such high-sensitivity areas has potential value for calibrating the “meaning” of climatic markers using archaeological patterns.

A key lesson for today, if we may take one from the 3.2 ka event in Europe, is that social institutions in human–landscape relations are paramount in negotiating climate change. Looking to the study areas in regional perspective, crises within intense sociopolitical/cultural configurations such as Mycenaean Greece or Terramare northern Italy were not experienced by their near neighbors. On the one hand, they arguably occupied particular niches, exposing them to specific climate change stressors, but on the other, the relationship between political complexity and change is marked, and depopulation shows this was not simply a regression of political systems or archaeological visibility of people. Humans then as today are not passive victims; they are active agents in their changing world. Political fragmentation, conservatism in land-use strategies, and societal inflexibility are all evident during the crises of the 12th century. It could be argued that economic instability was the ultimate outcome of climate change in the 12th century, but I would argue the above evidence indicates that collapse of belief and political buy-in of the base population was more destabilizing and ultimately devastating.

It was also shown that the 3.2 ka horizon in Europe is highly suitable for exploring human–climate relations in prehistory at a regional scale due to the quality of both archaeological and paleoclimatic data. Cognizant of the deep-time but spatially narrow focus where palaeoclimatology models are most reliable, this study has provided a spatially extensive and chronologically narrow approach, giving an alternative viewpoint to both datasets.

Finally, in response to the core question of this paper—can a 3.2 ka climate event be linked to crises in multiple contemporary but distant societies—I would argue that the simple answer is yes. Yet this paper is replete with caveats as to why this simple answer is misleading. It was shown that climate change was not universally catastrophic and only certain societies suffered while others thrived. In no case can climate change be identified as a society-killing phenomenon when archaeological data are taken adequately into account. In removing the concept of climate victims (following Middleton 2017a), the societies studied illustrated how the structuring conditions of climate change were ultimately quite different depending on the nature of each society. As a consequence, climate change was unequally experienced at a regional scale, and this inequality of impact extended to heterarchical or hierarchical relations within these societies. So, a fairer but less concise answer may be that climate change undermined the organizational logic of specific social systems that were in the process of reorganization after a period of unsustainable growth, thereby leading to a collapse in belief and participation in those systems.

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