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Review

Human adaptation to Holocene environments: Perspectives and promise from China

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ABSTRACT

This paper reviews recent archaeological research on human-environment interaction in the Holocene, taking continental China as its geographic focus. As China is large, geographically diverse, and exceptionally archaeologically and historically well-documented, research here provides critical insight into the functioning of social-natural systems. Based on a broad review of the field as well as recent advances and discoveries, the authors reflect on research themes including climate change and adaptive systems theory, spatial and temporal scale, anthropogenic environmental change, risk management and resilience, and integration of subdisciplines. These converge on three overarching conclusions. First, datasets relevant to climate change and ancient human-environment interaction must be as local and specific as possible, as the timing of environmental change differs locally, and the human response is highly dependent on local social and technological conditions. Second, the field still needs more robust theoretical frameworks for analyzing complex social-natural systems, and especially for integrating data on multiple scales. Third, for this work to contribute meaningfully to contemporary climate change research, effective communication of research findings to the public and to scientists in other disciplines should be incorporated into publication plans.

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1. Introduction

As global climate changes rapidly, research into past human-environment interaction has attracted great interest, and the potential contributions of archaeologists to contemporary climate change research are now widely recognized (d'Alpoim Guedes et al., 2016; Fisher and Feinman, 2005; Lane, 2015; Rick and Sandweiss, 2020; Rockman and Hritz, 2020; Stephens et al., 2019). The public and policymakers have a particular interest in the instructive value of studies on paleoclimatic shifts and the purported collapse of past civilizations (e.g., Coombes and Barber, 2005; Robbins Schug et al., 2019; Wang et al., 2016), including how human behavior transformed landscapes and either helped or hindered adaptation to climate change. This paper will address the state of research on these themes in continental China, a vast and geographically diverse area with important contributions to make to the global archaeology of climate change.

We believe a regionally specific approach is fruitful because of both its geographic focus and its methodological breadth. Such an approach can address questions of local interest, such as the rise of urbanism, the origins of metallurgy, and the spread of specific domesticates, as well as those of global interest, such as the limits of human adaptive potential, the interaction of social and biophysical environments, and the role of technology in social complexity. The authors also intend to illustrate how the archaeological subdisciplines articulate with each other, and how cross-disciplinary work is essential to building a fuller picture of past human-environment interaction.[1]

1.1. Geographic and temporal context

Though far from a comprehensive review of the entirety of Chinese archaeology, we hope this paper will serve as a resource for students and scholars working in other parts of the world who are interested in global connections and comparative research. To that end, Fig. 1 and Table 1 provide an overview of regions, geographic features, time periods, and archaeological cultures mentioned in the text.

The vast majority of archaeological research in China has concentrated on the middle and lower reaches of the two largest rivers in China, the Yellow and the Yangzi (Yangtze) Rivers. These watersheds contain most of China's arable land, and as a result, the greatest population density during the Holocene, the fastest contemporary urbanization and economic development leading to archaeological exploration, and consequently the majority of China's published archaeological sites.

Surrounding these are areas that became integrated into various dynastic spheres of influence and governance over the past two thousand years. In the south, Lingnan was one of the last refuges for hunter-gatherers in the Late Holocene, and later the entrepôt to the South China Sea (Allard, 1997; Chi and Hung, 2008; Hung and Zhang, 2019). The low-density communities of the southeast coast practiced terrestrial and marine hunting, fishing, and foraging, eventually supplemented by rice and pig husbandry (Chi and Hung, 2008; Jiao, 2013). To the southwest, the Yungui (Yunnan-Guizhou) Plateau is a mountainous region with deep valleys that supported intensive rice cultivation in human-made paddy soils (Yao, 2016; Yao et al., 2015). In Northeast China (Dongbei), cold temperatures and low rainfall have limited the agricultural productivity in many areas (Nelson, 2002). To the west are the "Inland Frontiers" of Inner Mongolia, the Hexi Corridor, the Tarim Basin, and the Dzungaria, historically contested by agro-pastoralist kingdoms and China's empires (Di Cosmo, 1994). Settlement of the arid, high-altitude Qinghai-Tibet Plateau was made possible by a range of behavioral adaptations, including hunting and foraging, vertically transhumant pastoralism, husbandry of millet and eventually wheat and barley, and exchange with lower-altitude communities (Hein, 2018).

1.2. Definitions and themes of this review

Much of the research presented here relies on an ecological framework, including certain shared concepts, such as resilience and risk management. Resilience, as defined by ecologists, refers to the amount of disturbance a system can endure and still remain in its original state (Holling and Gunderson, 2002). Particularly, resilience theory's emphasis on "reorganization" rather than "collapse" can help archaeologists better conceptualize historic and prehistoric social change. Risk, in this case, is variability in outcome, along a probabilistic distribution (Stephens, 1990). Risk management strategies (e.g. diversifying crops) increase system resilience (Marston, 2011), but are highly context-dependent, specific to the local socioecological system, available technology and domesticates, and environmental conditions (Chen et al., 2020).

In addition to archaeological applications, these concepts can be used to re-interpret China's two-millennia-old tradition of official histories, and several recent meta-analyses take advantage of the growing corpus of paleoenvironmental data alongside historical data to examine adaptive trends in Chinese history (Fang et al., 2019; Lee et al., 2017; Wei et al., 2015; Zhang et al., 2006; Zhang et al., 2007). Resilience is a particularly useful construct for dissecting the dynastic cycle, by reframing it as an anthropological research question and identifying the social factors involved in the dissolution and reconstitution of various dynasties (Liu and Feng, 2012; Wu and Liu, 2004). For instance, recent studies at the site of Sanyangzhuang have attempted to connect village life to larger trends at the end of the Western Han dynasty (206 BCE—9 CE) as a means to understand the strengths and weaknesses of dynastic governance, and how reorganization of political systems influenced changes at a local material level (Kidder et al., 2015; Kidder et al., 2012; Zhuang et al., 2016).

These ecological concepts can also inform our interpretation of archaeological data, especially relating to human responses to climate change. In 2018, the International Commission on Stratigraphy codified the current geological age as the "Meghalayan," a subdivision of the Holocene epoch defined by paleoclimate changes related to widespread aridification at approximately 2200 BCE, often designated the 4.2 ka BP event (Cohen et al., 2018). However, the significance for human civilization of the megadrought at 4200 years ago is debated (Middleton, 2018): it has been implicated in the collapse or transformation of numerous societies around the world (e.g., Anderson et al., 2011), including Neolithic cultures in and around Central China (Wu and Liu, 2004), though many have argued against a climatological explanation for these transformations (Dong et al., 2013; Drennan et al., 2020; Jaffe et al., 2020; Jaffe and Hein, 2020; Shelach, 2009). The lack of scientific dating of many sites in China is also a principal methodological concern in drawing causal connections, or even correlations, between social and climatological events (Jaffe et al., 2020; Liu et al., 2020c).

Meanwhile, another concept, the "Anthropocene," has been more broadly employed since being introduced by climate scholars (Bauer and Bhan, 2018; Bauer and Ellis, 2018; Crutzen and Stoermer, 2000; Smith and Zeder, 2013). Various opinions have been put forward concerning when this proposed epoch began:

1) the Industrial Revolution, defined by harm to the environment from fossil fuel combustion (Nriagu, 1996), habitat depletion and resource overexploitation (Kidder and Zhuang, 2015; Rosen et al., 2015), and epidemiological transitions (Omran, 1971; Omran, 1983);
2) the beginning of the nuclear age, a more recent and specific geological event (Waters et al., 2016; Zalasiewicz et al., 2015);
3) coincident with European colonization of indigenous lands, especially in the Americas, a framing which questions the universality of a Euro-centric narrative, points to colonialism as the root of today's environmental problems, and mobilizes the Anthropocene concept

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[1] To reflect the collaborative nature of this paper, after the corresponding author, authors are listed as: section lead authors in alphabetical order, followed by contributing authors in alphabetical order.

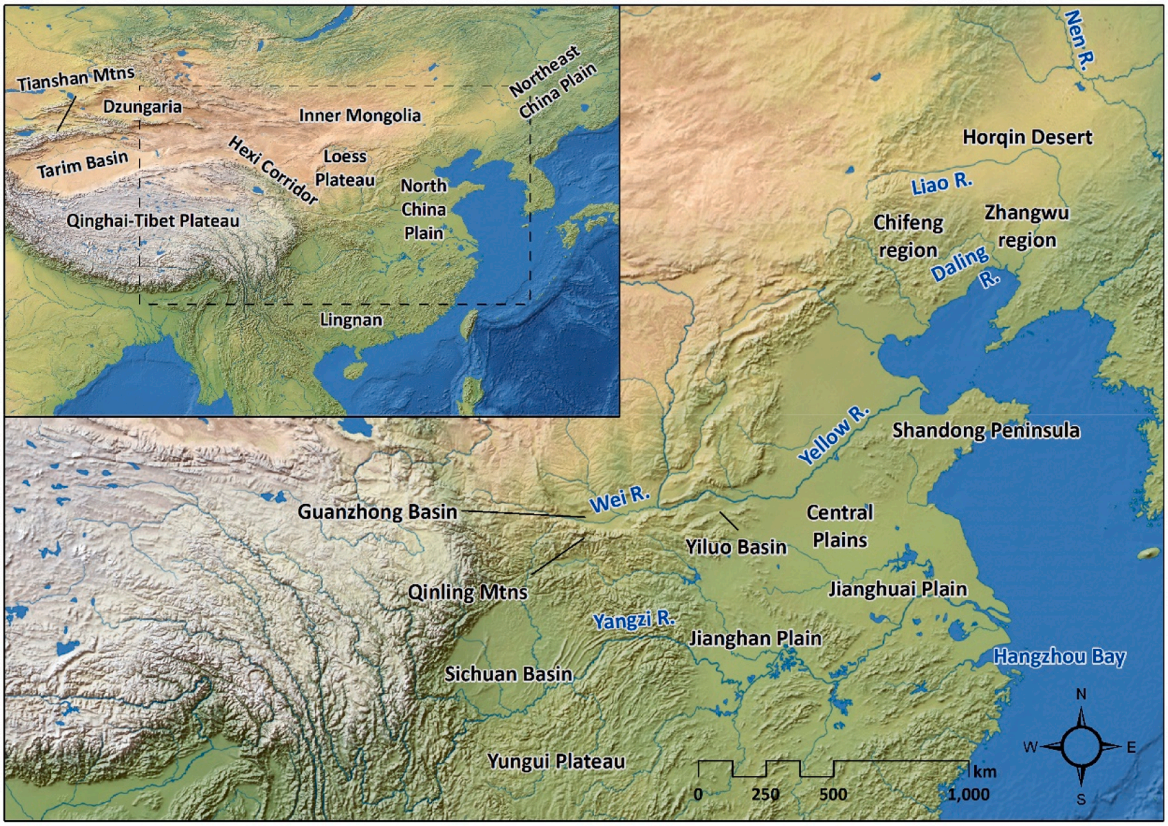

Fig. 1. Major geographic regions and features of continental China, including those mentioned in the text. (Made with Natural Earth. Free vector and raster map data @ naturalearthdata.com.)

Table 1
Time periods and archaeological cultures mentioned in the text. Archaeologically derived/prehistoric dates are cited, and may differ slightly between authors.

Time period	*Archaeological culture/period (region)*	*Chronological dates*
Neolithic	Yangshao period (Yellow River Valley)	ca. 5000–3000 BCE[1]
	Liangzhu culture (Yangzi River Delta)	ca. 3300–2200 BCE[2]
	Longshan period (Yellow River Valley)	ca. 2600–1900 BCE[3]
Bronze Age	Erlitou culture	ca. 1900–1550 BCE[4]
	Erligang culture/early Shang dynasty	ca. 1600–1300 BCE[4]
	Yinxu/late Shang dynasty	ca. 1300–1050 BCE[4]
	Western Zhou dynasty	1046–771 BCE
Iron Age (from 5th c.)	Eastern Zhou dynasty/Spring and Autumn period	771–476 BCE
	Eastern Zhou dynasty/Warring States period	475–221 BCE
Dynastic period	Qin empire	221–206 BCE
	Western Han dynasty	206 BCE–9 CE
	Eastern Han dynasty	25–220 CE
	Tang dynasty	618–907 CE
	Song dynasty	960–1279 CE
	Jin (Jurchen) dynasty	1115–1234 CE
	Yuan dynasty	1271–1368 CE

[1] Jaffe and Flad (2018).
[2] Jaffe et al. (2020).
[3] Luan and Wagner (2009).
[4] Shelach and Jaffe (2014).

for anti-colonial aims (Davis and Todd, 2017; Lewis and Maslin, 2015); and

4) the start of longer-term anthropogenic geological processes (Fuller et al., 2011b), e.g., atmospheric lead and copper pollution deposits detectable beginning in the Bronze Age (Hong et al., 1994, 1996), changes in land use and niche construction with the domestication of plants and animals (Boivin et al., 2016; Smith and Zeder, 2013; Stephens et al., 2019), or the transformation of the hydrology, geology, and ecology of watersheds such as that of the Yellow River (Zhuang and Kidder, 2014).

Despite the lack of agreement on a definition, the use of Anthropocene to represent human impacts on the environment has achieved broad appeal. Although, as reflected in the third definition, some have questioned whether the Anthropocene adequately recognizes unequal responsibility for human-induced environmental changes (Bauer and Bhan, 2018; Morrison, 2018), or critiqued the debate as “dithering” (Hornborg, 2017; see Kosiba, 2019: 450 for further discussion), as Johnson and Earle (2000: 24) state, “the more we learn of history, the more we come to see the environment as an artifact of human activity.”

2. Study of the geophysical environment

2.1. Geoarchaeology

Millennia of economic and sociopolitical processes have made China one of the places on Earth whose environment has been most thoroughly transformed by human action. This history is recorded in paleoenvironmental archives, which reveal phenomena such as anthropogenic soils, increased rates of erosion, ancient pollution, variations in the extent and severity of fire, plant and animal translocation and extirpation, modification of waterways and the water table, and the emergence of anthropogenic landforms.

Anthropogenic soils are prevalent throughout China and have a long history of development and use (Gong et al., 1999; Storozum et al., 2018). In the south, in Lingnan and the Jianghuai plain, where rice agriculture is common and sedimentation rates are much lower, ancient rice paddies have been in use for thousands of years (Cao et al., 2006; Kölbl et al., 2014; Yasuda et al., 2004). The successive use of these rice paddies has created anthropogenic soils that are remarkably resilient to changes in climate and environment, and also exhibit significantly different characteristics from the surrounding natural soil. To the west, in the arid areas of China, there are some examples of human-altered desert soils, though more work needs to be done here (Li et al., 2019). In northern China, most of the anthropogenic soils should be found in arable zones. However, in the North China Plain the vast majority of the former agricultural landscape has been buried by massive Yellow River floods over the past 3000 years (Shi et al., 2010), only occasionally exposed at locations like Sanyangzhuang (Storozum et al., 2018).

China's Yellow River is one of the most anthropogenic fluvial systems in the world. Beginning at the latest in the Han dynasty, erosion rates began to increase and give the river its characteristic yellow color, and the river course began its periodic shifts (Yuan, 2021). In particular, geological coring on the North China Plain and excavations in the valleys of the Loess Plateau reveal that sedimentation rates have increased dramatically since the development of iron technologies and the migration of people into the Loess Plateau to conduct agriculture (Milliman et al., 1987; Ren, 2015; Ren and Zhu, 1994). This increase in the amount of the sediment load of the Yellow River significantly altered the sediment flux of the river, creating a "hanging river" phenomenon, whereby the main course of the Yellow River is elevated precariously over the North China Plain. When the Yellow River breaches its banks, as it has done dozens of times throughout the past 3000 years, the river floods catastrophically (Chen et al., 2012).

China was also home to one of the most technologically advanced metallurgical industries in antiquity. At one point, the Tang dynasty (618–907 CE) likely accounted for over half the world's metal smelting (Hong et al., 1996). This consequently left behind many traces of heavy metal pollution that are now being found in lacustrine records throughout China (Jin et al., 2013; Yan et al., 2010). For instance, in Yunnan, around 600 years ago during the Mongol Yuan dynasty (1271–1368 CE), heavy metal pollution exceeded even modern pollution multiple times over (Hillman et al., 2015). Geoarchaeological investigations at the city of Kaifeng have also revealed that heavy metal pollution from nearby industries dating to the Song dynasty (960–1279 CE) left behind highly toxic anthropogenic sediments that gradually became integrated into the urban soils (Storozum et al., 2020b). (See next section.)

2.2. Archaeometry

"Technology" (broadly defined) constitutes a suite of practices that have fundamentally transformed the environment throughout human history. Some environmental signs of human activity, such as lead and copper deposits in ice cores, are unintended byproducts of material production processes. Such processes depend on great quantities of fuel, produce tons of consumable goods that become trash, and generate waste byproducts that leave harmful residues. Archaeology can contribute to an understanding of the late Holocene Meghalayan, or Anthropocene, by modeling these impacts, and can contribute to modern environmental remediation through survey and ground-truthing of pollutive production sites with elevated heavy metal concentrations. Furthermore, China is an ideal place to study such impacts, as it is not only an expansive land mass with historically large populations, but was also a pioneer in several energy-dependent ancient technological innovations, including the casting of iron (Han and Chen, 2013). It is therefore useful to approach the cultural history of China through an ecological-technological lens. Changes in technology as reconstructed from environmental evidence may also reflect the interaction of human agency, environmental conditions, and various forms of social organization (Womack et al., 2021).

As an example, research into the development of state-level society in Bronze Age China is becoming increasingly reliant on archaeometric analyses of ancient technologies, particularly archaeometallurgy. Metallurgical production in antiquity had two major environmental impacts: 1) deforestation for fuel and 2) pollution from smelting and melting activities resulting in toxicity of water (Li et al., 2017a; Li et al., 2011; Lin et al., 2016), sediment (Zhang et al., 2017), and atmosphere (Hong et al., 1994, 1996). According to the Chinese government, one sixth to one fifth of China's arable land today is contaminated by heavy metals (China MEP, 2013; Hillman et al., 2015; Wong, 2014), some of which is legacy pollution from metallurgical activities since the Bronze Age.

In addition, archaeologists have focused on identifying the extraction, production, and use of raw materials to reconstruct sociopolitical and paleoecological processes. For instance, during the Erligang (1600–1300 BCE) expansion, local smiths across the Central Plains casted a variety of culturally-specific shapes from imported ingots, using copper ores possibly from the Qinling Mountains (Chen et al., 2019: 134), or from other sources such as Panlongcheng and the Yangzi River Valley, though the emerging picture of the exchange network of raw materials and finished vessels is increasingly complex (Liu et al., 2019c). Meanwhile, as outlined by Mei Jianjun and colleagues (Chen et al., 2016a; Linduff and Mei, 2009; Mei et al., 2015), a renewed focus on regional typologies and alloying styles for bronzes, as well as accompanying infrastructure such as crucibles and molds (Chastain, 2019; Chen et al., 2009; Liu et al., 2013), holds further promise for high-resolution reconstructions of the socioeconomic organization and mineral resource trade networks of the economy during the Shang dynasty (1600–1050 BCE).

Industrial production of metal also requires massive amounts of fuel, though fuel for specific metallurgical processes varied greatly (e.g. timber charcoal vs. dung charcoal vs. coal). In the 12–13th centuries CE (during the Jin dynasty in Hebei Province), for instance, combustion of metallurgical coal and coke for silver smelting was likely first adopted after rampant deforestation greatly reduced the available timber charcoal (Liu et al., 2019d). Promising recent work attempts to discern fuel sources by identifying carburized timber cell structure for charcoal, or minor elemental constituents such as potassium and sulfur in the slag byproduct associated with coal (Li et al., 2018). Field methods employing volumetric excavations to record fuel:slag ratios could also assist in the reconstruction of paleoecology (Kaufman et al., 2021).

An additional area of research on technology that is relevant to human-environment interaction is the study of the production of building materials. Previous settlement studies in China have addressed socioeconomic change, subsistence, craft specialization, site features, and statehood (e.g., Chifeng, 2003; Falkenhausen, 2018; Li and Liang, 2018; Liu, 1996; Liu et al., 2004; Liu and Chen, 2012; Underhill et al., 2008; Wu and Liu, 2004; Beijing Daxue et al., 2015; Guojia Wenwuju, 2007; Guojia Wenwuju, 2018; Horsley et al., 2009), but there is much work to be done on the long-term environmental impact of settlement construction and urban landscapes in China.

While pyrotechnology for making ceramic cookware dates to as early as 20,000 years ago (Wu et al., 2012), manufactured building materials such as plaster, brick, and tile only appeared much later. The use of fire to treat house floors and walls existed by 3000 BCE or even earlier (Henan, 2002; Zhonguo and Shaanxi, 1962; Beijing Daxue et al., 2015; Henan et al., 2015), evidenced by burnt wattle and daub. The earliest known manufactured building material was found at Dadiwan, where kiln-processed silicates (ginger stone and Aga soil) were used to produce a hard mortar for the flooring of the F-901 "palace" (ca. 3500–3000 BCE) (Li et al., 2013b). Another early example is the use of lime powder for house floors and walls used during the Longshan period (2600–1900 BCE), manufactured in kilns (Qian et al., 2009; Xibei and Shaanxi, 2005), as well as ceramic pipes (Sebillaud, 2016). Later, flat tiles are found in the early urban center of the Zhengzhou Shang city in Henan (Li et al., 2007).

Eventually, manufactured building materials became associated with the growth and expansion of political power. The earliest possible evidence for ceramic roof tiles in China comes from Bronze Age sites including Taosi in Shanxi (2300–1900 BCE) (He, 2018) and Qiaocun in Gansu (c. 1900 BCE) (Gou and Wang, 2010), with indisputable use of fired ceramic roof tiles at the site complex of Zhouyuan, the birthplace of the Western Zhou dynasty (1046–771 BCE) (Shaanxi, 1979). Many hollow bricks were found in the nearby Western Zhou settlement of Zhougongmiao (Xu, 2006). A standardized building tradition is evident at the State of Qin's capital of Yongcheng (400–300 BCE) (Guo, 2016), and throughout the Qin Empire (221–206 BCE), including at the massive palace site at Xianyang (Qindu, 1976; Tang and Loewe, 2015). Demand for building materials was also associated with large migrations of households into the capital (Shaanxi kaogu et al., 2013; Sima, 1997), brick tomb construction (Luoyang, 1959; Nickel, 2015; Shaanxi and Shihuangling, 1988), and the need for canals, roads, and granaries to sustain urban populations (Nylan and Loewe, 2015). As today, construction was "one of the leaders in deterioration of [the] environment by depleting resources" (Devi et al., 2017: 156).

2.3. Landscape, spatial, and settlement analysis

Because the diachronic investigation of human-environment relations requires a large quantity of spatial data, China's impressive amount of available archaeological material makes it a key contributor to research on this topic. Important foci include changes in land use and food production, population growth, construction of anthropogenic landscapes, and associated social changes. For example, on the topic of food production, spatial analysis that addresses the transition to farming in Northeast China belies the neo-evolutionist model of linear social development (see Jia, 2008: 11). Rather, the variety of subsistence "mixes" coexisting in Northeast China from the early Neolithic (10,000 BCE) (Wang and Sebillaud, 2019) to the Bronze Age (around 1000 BCE) shows complex and evolving economic strategies, which are not captured by the dichotomies of sedentism vs. nomadism, or foraging vs. farming. Some scholarship has focused on the ways that environmental change may have caused, encouraged, or constrained cultivation, animal management, and agriculture (e.g., d'Alpoim Guedes et al., 2016). More work might attend to the effects of agricultural technology on landscapes, following the literature on niche-construction (Boivin et al., 2016; Fuller and Qin, 2010; Laland and O'Brien, 2010; Odling-Smee et al., 2003; Rowley-Conwy and Layton, 2011; Smith, 2011; Zeder, 2012a). (See Paleoethnobotany below for a more detailed discussion of these transformations.)

Many topographic features of the Chinese landscape are anthropogenic, having been created by both intentional and unintentional human action, often related to subsistence technologies. These processes demonstrate the role that political and social organization have in the human impacts on the landscape. Such ancient anthropogenic transformations included considerable physical reconfiguration of the landscape. For example, the "Horqin desert" in Northeast China, although it has changing boundaries, commonly refers to the transitional area between Inner Mongolia and the Northeast China Plain, totaling an area of 500,000 km^2 (Yi et al., 2013; Zhao et al., 2013). A vast lake until the middle Neolithic, through desiccation the region gradually became marshes and hollows, and eventually formed an expansive steppe zone, a rich pastureland that has been in use for centuries. The forest was converted to agricultural land over the course of the last millennium to support a fast-growing sedentary population, and has now become flat "sandy land," a patchwork of fields and salty desert, with evaporating lakes in constant aeolian erosion and drought (Sebillaud et al., 2019, 2021). Similarly, study of the Hani mire in southeast Jilin Province has revealed the periodicity of natural and anthropogenic fires destroying the forest, and its subsequent regeneration (Li et al., 2013a). The Jiang-Huai and Jianghan Plains, much wetter landscapes, were bisected by anthropogenic canals since at least the Song dynasty (Needham and Lu, 1971).

The nature and speed of local anthropogenic landscape changes are often complex and localized, so as the macro-processes become clearer, a more small-scale analysis is needed of anthropogenic transformation of local ecologies. Such local changes include the creation of agricultural fields such as rice paddies (Hu et al., 2013; Qin et al., 2006; Rosen et al., 2017; Zheng et al., 2009; Zong et al., 2007), the creation of artificial hydrology such as irrigation networks (Li et al., 2017b; Liu et al., 2017a; Storozum et al., 2018) and fish ponds (Nakajima et al., 2019), and earth-moving to create terraces, ditches, and walls (Xie, 2018; Xie et al., 2015; Xie et al., 2017). For instance, at Kaifeng, the interior city is at a lower elevation than the surrounding plain, because the walls around the city prevented sediment build-up in the city limits (Storozum et al., 2020a); similar landforms can be found throughout the North China Plain.

As the above examples show, recent scholarship has thoroughly critiqued dichotomies of culture and nature, and instead focused on the ways in which things, people, animals, and the environment are interconnected in networks of interdependency (Knappett, 2013; Kosiba, 2019). The construction of settlements and new landscape features are particularly important aspects of the place-making that occurred throughout the Holocene, as populations increasingly invested in agriculture and lived in urban places. As Cerulo (2009) points out, nonhuman actors, including new raw materials, new domesticates, and new forms of settlements, become agents of social interaction. Understanding these processes is at the heart of understanding the relationship between technological change and changes to the landscape that relate to human activities.

The interaction of environmental and social conditions has not traditionally been a focus of Chinese archaeology, because of its historiographic orientation (Falkenhausen, 1993), though historical geographers such as Hou Renzhi of Peking University have made great contributions in this area. Now, many researchers are studying broad trends in climate change and settlement distribution using China's *Atlas of Cultural Relics* series (*Wenwu Dituji* 文物地图集), a multi-volume compendium of archaeological data across China. The volumes are an ambitious and critical repository, but they have limitations for studies of human-environment interaction. The sites in the *Atlas* volumes are mostly not scientifically dated, and are known from unsystematic surveys, making it difficult or impossible to determine their temporal relationship with any particular climatic event, or with one another (Jaffe et al., 2020).

Systematic archaeological survey is a critical source of data, to build on those in the *Atlas* volumes. Surveys reveal how global-, regional-, and local-scale patterns in the settlement record reflect complementary and concomitant rhythms in ancient political organization and subsistence modes (Braudel, 1996; Liu et al., 2020c), especially over long time scales (Guilaine, 2000). In Northeast China, systematic surveys of over 200 km^2 have revealed differences in settlement patterns, over both time and space, in the Chifeng mountainous region (Chifeng International Collaborative Archeological Research Project, 2003; Linduff et al., 2004; Teng, 2009), the Upper Daling River Valley (Drennan et al., 2014; Liaoning, 2010; Peterson et al., 2014), the mixed grassland and hills of Zhangwu (Williams, 2014, 2017a, 2017b), and the flatlands around the Yueliangpao and Xinhuangpao lakes at the northern border of the Horqin Desert (Liu et al., 2017c; Wang et al., 2015; Sebillaud et al., 2021). The long-running Yiluo regional survey project, covering over 1000 km^2, has found a complex trajectory of fluctuating population size, shifting political centers, and ever-increasing site hierarchy after the beginnings of sedentism in that region (Liu et al., 2019a). A long-term survey of coastal southeastern Shandong Province, which has covered over 3000 km^2 so far, has also revealed complex changes in settlement pattern and population across millennia (Feinman et al., 2019). These projects explicitly document that while landscape and environment are key factors affecting settlement, human socioeconomic systems as well as extra-regional networks also have an enduring role.

Therefore, multiscalar analysis is needed to understand the dynamic processes that govern the constant reorganization of human settlements. Models of human-environment systems in human-scale landscapes, such as river valleys, reveal different patterns than data on a regional scale. For instance, in an analysis of the spatial organization of settlements in the middle and lower courses of the Yellow River Valley during the transition from the Late Neolithic to the Early Bronze Age (c. 2500–1050 BCE), spatial statistics derived from over 6000 sites revealed that before 2000–1900 BCE, during the Longshan period, occupation of arable land was relatively homogeneous. Afterwards, many sites were abandoned and most new settlements were located on higher ground. The Yiluo Basin held a high concentration of sites of various sizes, likely a single settlement system, and the Erlitou site, at the core of this system, fostered an ever-growing population and fulfilled more and more social and political functions. Finally, after around 1600 BCE, a settlement pattern that used most of the available land was gradually restored during the Shang period (c. 1600–1050 BCE), with political centers shifting roughly every 200 years and new architectural features protecting the large cities from floods and wars (Sebillaud, 2014). For a spatially small-scale *longue durée* study of a site in Shaanxi, see Ye and Hein (2020), and for a detailed spatial study of a Bronze Age city in Shandong, see Li and Liang (2018).

A key motivating factor in settlement distribution is risk management, which might have been at the heart of the formation of the earliest political organizations. A comparison of the Western Liao Valley and the Central Plains shows two very different risk management strategies in the Neolithic, likely due to household-level decision making: the first tended towards dispersed households with access to multiple types of land, while the latter tended towards aggregation and cooperation in larger settlements (Drennan et al., 2020). Meanwhile, in Southeast China, the massive fortifications and water control systems built by the Liangzhu polity (Liu et al., 2017a) show that a priority of the politically powerful was to respond to the rise of sea-level. Moreover, in Zhejiang, where Liangzhu is located, there is a close relationship between human activity and environmental change: spatial analysis shows that the distribution of settlements was closely related to Holocene sea-level fluctuations, especially on Hangzhou Bay (Wu et al., 2014).

Information on human-environment and human-landscape interaction is essential to a better understanding of spatial data such as ancient people's site location choices, access to resources, implementation of exchange networks, etc. For instance, there is no way to correctly interpret the settlement patterns of northwest Jilin Province's protohistoric period without understanding the changes in the Nen River (or Nonni in Manchu) (Sebillaud, 2022; Zhu et al., 2013), to interpret the Longshan to Erlitou periods changes without a focus on the Yellow River floods (Cai, 1998; Wang, 1993, 1999), or to interpret land use in Neolithic Zhejiang without a good grasp of sea-level change (He et al., 2018). Landscape and spatial studies will tremendously influence how we understand human adaptation to past environmental change in China.

3. Study of the biosphere

3.1. Paleoethnobotany

Paleoethnobotanical research in China has contributed to knowledge of resilient responses to climate change, risk management through landscape management, changing food customs, and the spread of crops. This work is furthered by stable isotope analysis, in part thanks to the isotopic contrast between key cultivars: broomcorn and foxtail millet are C_4 plants whose $\delta^{13}C$ values differ from the wild C_3 plants that dominate the natural vegetation in most parts of North China (Rao et al., 2010), while rice, the dominant crop of the south, is a C_3 plant (d'Alpoim Guedes, 2011). Other C_3 cultivars domesticated or adopted later in the region including wheat, barley, buckwheat, and soybeans, together with multiple fruits, tubers, and nuts (An et al., 2015; Barton and An, 2014; Crawford, 2018; Crawford, 2017; Dong et al., 2017a; Jiang et al., 2019; Lee et al., 2011; Liu et al., 2015; Liu et al., 2014b; Liu et al., 2016; Long et al., 2018; Zhou et al., 2016).

Recent studies document increasing social-ecological resilience in the midst of climate changes through broadening plant food resources in China since the Last Glacial Maximum (LGM) period. Wild annual grains, including Job's tears and tribes of wheat and millet, were already collected as a starchy food source by Upper Paleolithic populations along the Qingshui River, a tributary of the Yellow River, by 28,000–24,000 cal BP (Bestel et al., 2014; Liu et al., 2018a; Liu et al., 2019b). Broad-spectrum resource use is well documented worldwide (Zeder, 2012a) in the Pleistocene-Holocene transition, and the use of starch from underground organs, nuts, and wild annuals was maintained in China even after millet farming was well established (Liu et al., 2014a; Wang et al., 2019).

Archaeological research has painted a sophisticated picture of the agricultural transitions of East Asia during the Holocene (recent syntheses include Lander et al., 2020; Leipe et al., 2019; Liu, 2016; Liu et al., 2015; Silva et al., 2015; Stevens and Fuller, 2017; Weisskopf et al., 2015). The adoption of domesticated plant species across China occurred through multiple mechanisms, and settlement changes and agricultural intensifications interacted throughout the Holocene climate fluctuations; this farming transition has been reviewed comprehensively elsewhere (Crawford, 2018; Crawford, 1992, 2006; Crawford, 2017; Crawford et al., 2016; Liu et al., 2015; Wang et al., 2019; Zhao, 2011). With the return of the colder and drier regime after the Holocene Climate Optimum, increasing hierarchy in settlements and social systems was probably supported by agricultural intensification in the Yellow River region (Crawford et al., 2005; Lee et al., 2007; Liu, 2015; Liu et al., 2019a). Experimental study of carbonization indicates the interdependence of agricultural producers and consumers across the settlement hierarchy in the Yiluo Basin during the Neolithic and later (Walsh et al., 2016). Rice cultivation also deeply modified the vegetation cover during the Neolithic in the Yangzi River region, but broad-leaf forest was restored rapidly following the collapse of Liangzhu civilization (Li et al., 2010).

Between 5000 and 1500 cal. BCE, the Eurasian and African landmass underpinned a continental-scale process of "globalization" of food and foodways (e.g., Jones et al., 2011; Lee, 2016; Liu et al., 2019e; Liu and Jones, 2014). Some species domesticated within China spread into contiguous ecological zones beyond their natural habitat, for instance, rice (Bettinger et al., 2010; Gross and Zhao, 2014) and millet. Millet likely originated in several places (Bettinger et al., 2007; Bettinger et al., 2010), including a fertile arc around the Central Plains of North China (Liu et al., 2012). Even more dramatic was the transplantation of some plants and animals into regions distant from their natural habitats, such as West Asian animals and plants introduced into East Asia, including sheep, goat, cattle, horses, barley, and wheat, among other technologies (recent publications include Barton and An, 2014; d'Alpoim Guedes, 2015; d'Alpoim Guedes et al., 2015; Dong et al., 2017a; Jaang et al., 2018; Jaffe and Flad, 2018; Jones et al., 2011; Lister et al., 2018; Liu et al., 2019e; Liu et al., 2014b; Long et al., 2018; Spengler et al., 2014; Stevens et al., 2016).

Both broomcorn and foxtail millet were first cultivated by ca. 7000–5000 BCE in the foothills running northeast-to-southwest along the eastern and southern parts of the Loess Plateau (Barton et al., 2009; Crawford, 2018; Lee et al., 2007; Liu et al., 2009; Tang et al., 2020; Zhao, 2011). Then, during the third millennium BCE, millet appeared in regions far west of where it first originated, e.g. southeast Kazakhstan (Frachetti et al., 2010; Hermes et al., 2019). It then expanded further westwards along a narrow foothill ecological zone (800–2000 m.a.s.l.) (Miller et al., 2016), in conditions similar to the landscape where millets were first cultivated (Frachetti, 2012; Liu et al., 2009; Ren et al., 2016). In the second millennium BCE, broomcorn millet appeared in

Kazakhstan, Kyrgyzstan, Afghanistan, Turkmenistan, and Turkey (Miller et al., 2016; Motuzaite Matuzeviciute et al., 2017; Spengler et al., 2014), as well as Yemen and Sudan (Boivin and Fuller, 2009; Fuller et al., 2011a). Millets are known from Europe (see Liu et al., 2018b for a review), the oldest uncontested direct date for which is c. 1600 cal. BCE in Hungary, during the Bronze Age (Motuzaite Matuzeviciute et al., 2013), and supported by both archaeobotanical and isotopic evidence (Lightfoot et al., 2013; Varalli et al., 2016). A series of much older, indirect dates of Neolithic millet remains (Jones, 2004) have been called into question (Hunt et al., 2008; Motuzaite Matuzeviciute et al., 2013). To the east, broomcorn millet is reported from Korea in the late fifth millennium BCE, and the Russian Far East in the fourth millennium BCE; foxtail millet in Taiwan and Thailand in the late third millennium BCE; and both millets at late Harappan sites in India from at least c. 2000 BCE (Kuzmin, 2013; Kwak and Lee, 2020; Li et al., 2020a; Pokharia et al., 2014; Stevens et al., 2016; Tsang, 2012).

By 2500 BCE, the southwest Asian cereals, specifically wheat and barley taxa, were also present along the Inner Asian Mountain Corridor, including the Altai (Frachetti, 2012; Spengler et al., 2014; Zhou et al., 2020), the Indus, and the upper Ganges (Liu et al., 2016; Liu et al., 2017b; Stevens et al., 2016). The chronology and routes of the subsequent introduction of wheat and barley into ancient China and broader East Asia have been much debated (Barton and An, 2014; Betts et al., 2014; Chen et al., 2020; Flad et al., 2010; Lee, 2016; Long et al., 2018; Zhao, 2009). However, substantial movements of wheat and barley took place during the third and second millennia BCE, spreading along the Inner Asian Mountain Corridor, then to northwest China (e.g., Liu et al., 2016; Ren et al., 2020; Spengler 2015). Some have argued the initial expansions of wheat and barley into China might be distinct in time and space, including a possible maritime route (Zhao, 2009) and a route over the southern Tibetan Plateau (Lister et al., 2018; Liu et al., 2017b).

Recent discussion has moved beyond routes and chronologies to consider the context in which agricultural innovation occurred. The timing of the eastern dispersal of wheat and barley reflects a range of choices that different communities made, sometimes driven by ecological expediency in novel environments. For example, when wheat and barley arrived in central China, they brought with them a degree of genetic diversity in flowering time responses, allowing farmers to exploit previously untenable farming seasons (Liu et al., 2017b). Such adaptive traits may have been developed first in the Tibetan Plateau in response to high-altitude environments, a possibility which has received much insightful discussion recently (d'Alpoim Guedes, 2015; d'Alpoim Guedes et al., 2014).

Culinary systems also influenced the adoption of novel crops. Early communities in East and West Asia were characterized by different food processing technologies: boiling and steaming of grain in the East, and grinding grain and baking flour in the West (Fuller and Rowlands, 2011). These culinary preferences had consequences for the selection of grain type and gluten/starch quality. Broomcorn millet, for example, underwent selection for waxy or glutinous starch in central-eastern China (Hunt et al., 2013), and wheat may have undergone selection for traits adapted to the boiling-and-steaming tradition (Liu et al., 2016). Contra to the rapid reception of wheat and barley in human diets in the continental interior, the very gradual adoption of these staples in central-eastern China (Li et al., 2020b; Liu et al., 2014b) was perhaps connected with their incompatibility with local culinary practices, which prioritized compact grains and starch quality (Liu and Reid, 2020).

Fermentation, another culinary tradition, is evidenced in rice remains at the Jiahu site in Henan Province as early as 9000 cal. BP (McGovern et al., 2004). Fermentation analysis has revealed the use of rice in beverages in the Neolithic (Liu et al., 2019b), and the northwestward expansion of rice to the Wei River region may have been related to its importance in alcohol production as early as 8000 years ago (Liu et al., 2019a). However, fermentation started long before fully domesticated rice was available. Various wild and domesticated plants, including broomcorn millet, wheat tribe wild grasses, Job's tears, rice, beans, snake gourd root, ginger, yam, lily and more, were fermented with various regional techniques, as documented in starch granules, phytoliths, and fungi residues extracted from early Neolithic vessels found in the Yellow and Yangzi River basins (Liu et al., 2020a; Liu et al., 2020b). The same taxa of wild grains, tubers, and nuts, as well as crops, were found further northwest in China (Wang et al., 2019), indicating a wide spread of these plant resources as food and possibly fermented drinks.

Recent developments in the understanding of Eastern farming systems have expanded notions of the origin of agricultural civilization. The dispersal of millets, for example, provides a clear case, possibly the oldest, of how East Asian agriculture had an influence on global systems. This encourages us to reflect on the assumptions we have held in a Western context, including those concerning what agriculture is and can be (Liu et al., 2018b).

3.2. *Zooarchaeology*

China's zooarchaeological record contributes to archaeological research on climate change and human-environment interaction in Holocene China in two main areas: by documenting human impacts on East Asia's native wild fauna, and by clarifying animal domestication processes. The continued development and application of scientific techniques in zooarchaeology is also a critical part of environmental archaeology in China (Lin, 2014).

Zooarchaeological research in China has revealed regional differences in the availability and use of wild and domestic fauna during the Neolithic and Bronze Age. For example, although domesticated taxa made up increasingly large proportions of faunal assemblages in the Yellow River Valley region, hunting and fishing of wild animals remained important in the Yangzi River Valley region (Jing et al., 2008; Yuan, 2015). On the Tibetan Plateau, foragers hunted a wide variety of animals including deer, gazelle, marmots, and large cats (either leopards or tigers), but supplemented their diet with domestic plant resources such as millet acquired through exchange with farmers living at lower elevations (Ren et al., 2019; Zhang et al., 2019). Shell midden sites are common in Shandong Province and along the coast where locally available marine resources made up a significant part of the diet (Zhongguo, 2007). In regions such as Yunnan that have a high degree of ecological diversity, animal exploitation also shows a high degree of variability as people adapted their subsistence strategies to local environmental conditions (Ren et al., 2017).

Deer were particularly important to people in early China both for meat and for their bones and antlers, which were used to make various artifacts. Their remains have been identified at over 90% of Neolithic and Bronze Age archaeological sites in the Yellow River Valley (Lander and Brunson, 2018b). Sika deer (*Cervus nippon*) have been identified at over 60% of all archaeological sites in the Yellow River Valley, often in considerable quantities. This suggests they were well adapted to living in anthropogenic environments around villages, and people may even have modified local ecosystems to create deer habitat. A similar scenario is also likely for certain kinds of birds (e.g. pheasants) typically considered "wild" but whose abundance, diversity, and diet may be strongly influenced by human action and landscape modification (Barton et al., 2020).

Much foundational work has been done on the adaptive responses of late Pleistocene/early Holocene hunter gatherers (Barton et al., 2007; Bettinger et al., 2010; Elston et al., 1997; Madsen et al., 1996; Yue et al., 2019; Zhao, 2020), but agriculture eventually became the dominant ecological system across much of Asia. A major consequence of this success over the last 5000 years, and the accompanying anthropogenic landscape alteration, was a dramatic reduction in biodiversity in China (Lander, 2020). Clearing of fields, lumbering, irrigation, population growth, and increased hunting led to the eradication of scores of previously common taxa, including charismatic megafauna, such as elephants, rhinoceroses, and alligators (Cao, 2018; Elvin, 2004; Lander and Brunson, 2018a; Lander and Brunson, 2018b). Domesticated animals often replaced their wild relatives, since they shared the same diets and habitats, and as niches were improved for domesticated species, niches conducive to reproduction of other taxa were lost. Various animals such as rats, cats, bats, and sparrows moved into human settlements and became inseparable parts of those ecosystems (Vigne et al., 2016).

Zooarchaeological assemblages are the only way to document the distributions of wild taxa in periods before textual records, and remain the most reliable one for most of the historical period. Many questions remain, though, about how people responded to declining numbers of once-common animals. In other parts of the world, researchers have documented zooarchaeological evidence for resource depression caused by human over-hunting or habitat modification, such as size reduction of prey species, shifting from high rank prey to low rank prey, and hunting a wider array of species (Broughton, 1994; Erlandson and Rick, 2009; Grayson, 2001; Nagaoka, 2002). There is great potential to look for similar evidence in China's zooarchaeological record—such as by looking at deer body size reduction through time—in order to clarify the nature and environmental impacts of human hunting strategies.

Another important area for development in zooarchaeological research in China is in the field of applied zooarchaeology (Rick and Lockwood, 2013; Wolverton and Lyman, 2012; Wolverton et al., 2016). Modern conservation biologists are often limited to observations about changing animal distributions over the last few decades. Zooarchaeologists can use animal bones to track changes in animal distributions over thousands of years. There is great potential to bring zooarchaeological data from China into discussions about the long-term ecological impacts of human activities (Cao, 2018; Turvey et al., 2017; Turvey et al., 2013).

However, it is important to remember that the zooarchaeological record does not reflect the entire suite of wild species that were ever present in a region. Fauna identified at archaeological sites have passed through a cultural filter (Daly, 1969; Reed, 1963), and are subject to taphonomic changes that may lead to underrepresentation of small animals, especially non-mammals. Traditionally, methods like fine mesh screening or floatation have been comparatively uncommon in archaeological excavations in China, so most zooarchaeological assemblages consist predominantly of larger animal bones collected by hand.

One promising technique that could supplement traditional zooarchaeological methods for documenting changes in faunal distributions through time is metagenomic analyses of ancient environmental DNA extracted from soils and sediment cores. Environmental DNA techniques identify the range of plant and animal species that were present, making it possible to reconstruct local ecosystems at various points in time (Bálint et al., 2018; Thomsen and Willerslev, 2015). This could also be useful for refining the chronology and routes of introduction for key domesticated species, even when macroscopic remains are not preserved.

A second way that zooarchaeology contributes to research on human-environment interaction is by documenting domestication and the introduction of foreign domesticates. Several animals were domesticated in China, including dogs, pigs, chickens, ducks, yaks, carp, and silk worms. Pigs are the best-studied of these animals, and provide a good example of the ways that animal domestication in ancient East Asia involved a combination of ecological and social factors. The wild progenitors of pigs, wild boar, are well adapted to anthropogenic niches, and likely followed a commensal pathway toward domestication (Zeder, 2012b, c). Pigs were domesticated in China gradually, perhaps initially as pets (Luo, 2012; Yuan, 2020). Pigs held a variety of roles in Neolithic and Bronze Age societies for subsistence as well as ritual practice (Luo, 2012), and pig manure was an important source of fertilizer in agricultural fields (Lander et al., 2020).

Pig domestication has also been studied isotopically in order to reveal when pigs began eating human agricultural waste (Barton et al., 2009; Cucchi et al., 2016). However, continued refinement of isotopic methods is still needed, e.g., to identify the isotopic signatures of native plants found in various regions of China. In particular, we cannot assume that millets were the only C_4 plants that animals ate. Paleogenomic research on pigs and other Chinese domesticates is also ongoing and has great potential to clarify the locations and timing of animal domestication, the relationships between wild and domesticated populations, and genes that were subject to selection during domestication.

Numerous domesticated animals including sheep, goats, cattle, horses, donkeys, water buffalo, and camels were introduced to China during the middle to late Holocene. The onset of the Meghalayan may have been a catalyst for promoting the adoption of new species, especially cattle, sheep, goats, and horses, as the climate of North China became more arid and people turned to pastoral activities to take advantage of new environmental niches (Brunson et al., 2016a; Brunson et al., 2020), though horseback riding was not introduced to China until the late first millennium BCE (Li et al., 2020c). The arrival of these new taxa and the expansion of agricultural and pastoral activities coincides with the decline of native species (Lander and Brunson, 2018b).

Research on the timing and routes of introduction for non-indigenous domesticated animals depends on further refining zooarchaeological methods for accurate species identification. There is already work being done to determine reliable morphological criteria for distinguishing between the bones of similar-looking species such as sheep, goats, and various wild bovids present in North China (Wang, 2017). Morphometric techniques for caprine identification (e.g., Salvagno and Albarella, 2017) may prove useful as well. Biomolecular methods such as collagen fingerprinting and ancient DNA also have great potential to clarify the introduction of West Asian domesticates (e.g., Cai et al., 2020; Dodson et al., 2014).

A final challenge to research on the introduction of domesticated animals into China is the lack of direct radiocarbon dates from the animal bones themselves (Brunson et al., 2020). Whenever possible, direct radiocarbon dates from animal bones should be used to document the emergence of new domesticates rather than dating by association. We also need better methods for data sharing and publication of raw data, which can facilitate synthetic, regional zooarchaeological analyses (Atici et al., 2013).

3.3. *Bioarchaeology/human osteoarchaeology*

All the processes outlined above impact not only the social-ecological systems of which humans are a part, but also the physical bodies of individual humans. Where we see the evidence of ancient environments on human bodies, those environments should be understood as both social and biophysical. For instance, nutritional inadequacy can result from causes as diverse as drought (the biophysical environment) or unequal distribution of food (social environment). Bioarchaeology is therefore well positioned to identify biocultural processes of adaptation and interaction with the environment.

Within bioarchaeology, subsistence activity and diet are perhaps the most well-studied mechanisms of adaptation. Subsistence activities are best reconstructed using material culture and faunal and floral remains, though degenerative changes to the body that result from daily activities are also detectable in the skeleton (Eng, 2016; Zhang et al., 2016). While dietary reconstruction can be approximated with oral health, as with animal remains, more specific insights can be gained from stable isotope analysis. Chinese bioarchaeology has a long history of stable isotope applications (Berger and Pechenkina, 2018; Hu, 2018) that offer information on diet and mobility over the life course, and this area of research is witnessing a great deal of recent growth. By 2018, there were over 90 articles published in English and Chinese reporting stable isotope compositions measured from human bone collagen, apatite, and/or tooth enamel from more than 120 sites across China (see Liu and Reid, 2020 for a review).

Human stable isotope signatures must be interpreted in the context of local plant and animal values and wider archaeological data on diet and subsistence, making the development of detailed local and regional databases an important goal (Makarewicz and Sealy, 2015). Human $\delta^{13}C$ values begin to indicate significant millet consumption at some sites in the Early Neolithic, suggesting initial domestication (Atahan et al., 2011b; Hu et al., 2008; Liu et al., 2012). This continued from the Yangshao period (5000 to 3000 BCE) onward for sites in the Yellow River drainage (e.g., Atahan et al., 2014; Barton et al., 2009; Chen et al., 2016b; Pechenkina et al., 2005; Zhang et al., 2011). The $\delta^{13}C$ values of some domesticated species—pigs, dogs, and later cattle—also frequently indicate millet consumption, showing that foddering or stubble grazing of selected animals was a key component of subsistence strategies (e.g, Atahan et al., 2011a; Barton et al., 2009; Chen et al., 2016c; Dai et al., 2016; Hou et al., 2013; Ma et al., 2016b; Pechenkina et al., 2005; Yang et al., 2019).

Even after the appearance of C_3 cultivars in the archaeological record, stable isotope analyses show that their early nutritional importance varied regionally. Human and animal bone $\delta^{13}C$ values indicating significant reliance on C_3 cultivars appear in the Hexi Corridor around 1900 BCE, and the upper Yellow River around 1600 BCE (Liu et al., 2014b; Long et al., 2018; Ma et al., 2016a; Ma et al., 2014; Yang et al., 2019). By contrast, on the Central Plains this shift does not start until the Eastern Zhou (771–221 BCE) and Han (206 BCE-220 CE) eras, and is characterized by high within- and between-site $\delta^{13}C$ variability (e.g., Atahan et al., 2014; Dong et al., 2017b; Hou et al., 2012; Pechenkina, 2018; Zhou and Garvie-Lok, 2015; Zhou et al., 2017). The $\delta^{13}C$ patterning at some sites suggests more C_3 consumption by the poor than by the rich, and more by women than by men (Dong et al., 2017b; Pechenkina, 2018; Zhou et al., 2017; Zhou et al., 2019), suggesting, for instance, a "bottom-up" pattern for the shift to dietary reliance on C_3 crops in the Hexi Corridor (Liu and Jones, 2014). However, the cultural, economic, and environmental reasons behind the shift are still debated (e.g., Barton and An, 2014; Cheung et al., 2019; Hou et al., 2012; Lister et al., 2018; Long et al., 2018; Pechenkina, 2018). This is a key area where fine-grained stable isotope studies of human and faunal remains will continue to yield important insights into changing subsistence adaptations.

Beyond these large-scale ancient subsistence transitions, climate change events are generally assumed to have a major impact on human health through a variety of mechanisms, including warfare and resource shortages (Wang et al., 2016; Zhang et al., 2006). The introduction of new animal species may also have introduced novel zoonotic diseases, whose transmission and evolution could be reconstructed through human paleopathology, zooarchaeology, and phylogenetic analysis of pathogen DNA (Berger and Pechenkina, 2018; Puckett et al., 2020), though this work has only just begun (for a review of aDNA research in China, see Sheng et al., 2016). However, as with cases discussed above, combining different scales of analysis presents the risk of oversimplifying complex interactions within systems (Coombes and Barber, 2005; Harrod and Martin, 2014; Jaffe et al., 2020; Martin and Osterholtz, 2016). For instance, bioarchaeological research comparing the health of populations who lived in the second and first millennia BCE in the Hexi Corridor (Berger and Wang, 2017) found improvement in community health, despite climatic fluctuation. This is likely due to the diverse and flexible subsistence system reconstructed for this time (e.g., Jaffe and Hein, 2020; Yang et al., 2019). Meanwhile, contemporaneous populations on the edge of the Qinghai Plateau give more ambiguous results (Berger and Wang, 2017; Han, 1990; Wang and Zhu, 2004). For instance, long bone measurements suggest males had better growth outcomes after 2000 BCE, but the opposite trend is seen among females (Eng and Zhang, 2021). Finally, the site of Mogou (1750–1100 BCE) in eastern Gansu Province has produced skeletons that show a much higher burden of infectious and metabolic diseases, as well as a high incidence of fatal violence among males (Dittmar et al., 2019; Dittmar et al., 2021). Therefore, multiple contradictory trends in growth, trauma, and nutrition can be observed within the same time period just within one part of Northwest China, indicating the gap between local and regional trends.

Beyond diet, indicators of general physiological stress can be used to assess mechanisms of risk aversion, resilience, and adaptation through careful integration of bioarchaeological evidence with archaeological and environmental context. For example, analysis of non-elites from Shang society has shown high levels of multiple indicators of both childhood and adult stress, likely caused by the correlates of urbanization and exacerbated by social and sex-based inequity (Zhang et al., 2016). By contrast, all occupants of Bronze Age Houtaomuga in northeast China older than 4 years of age exhibited enamel defects in the teeth, indicating disruptions in growth. However, the lesions can only form if an individual *survives* physiological stress, so despite encountering high stress levels, the population must also have had mechanisms of risk management. For instance, the addition of millet to the diet may have mitigated extreme stress in the face of deteriorating environmental conditions (Merrett et al., 2016).

Moving beyond North China, the Inner Asian steppe zone, which stretches across a broad geographic band with tremendous environmental and ecological diversity, provides more bioarchaeological evidence for risk management strategies. Pastoralism developed in the steppe during the Bronze Age and was further refined into mobile herding strategies in the early Iron Age. Mixed economic strategies further exploited the diverse available resources, from hunting and fishing near water sources, to agriculture in the northern areas of China and within the oases of the Tarim Basin. It may be expected that human remains from these different regions of the steppe reflect differences in diet and stressors, due to this diversity of lifeways. Indeed, recent stable isotope studies of human and animal remains (Hrivnyak and Eng, 2020; Machicek and Eng, 2017) have shown that in Northern Mongolia, human diets from the Bronze to the Iron Ages shifted from being consistent within each site but varying across sites, to being more diverse within each site but consistently so across the region. The occupation of the same locales but with more varied diets in the later period suggests behavioral changes, such as diversified subsistence strategies, or increased trade and exchange of resources likely accompanied by increased mobility. Meanwhile, in Xinjiang in far Northwest China, the diet shifted from primarily C_4-based to primarily C_3-based. This work has revealed significant diversity in ecological landscapes and biocultural adaptation within and between communities of the steppe zone.

Bioarchaeology can reconstruct both population-level changes and the impact of environmental and social change on individual lives, something that is hard to do in other areas of archaeology except perhaps mortuary analysis or household archaeology. Bioarchaeological datasets in China are rapidly growing, and have much to contribute in the areas of paleopathology, paleoepidemiology, paleogenetics, and paleodemography, in addition to dietary reconstruction and population history, which have been the field's main foci to date (Berger and Pechenkina, 2018, 2020; Pechenkina, 2012). Bioarchaeology in China is also well-integrated with archaeology, with bioarchaeologists taking part in field excavations, and their analyses are increasingly featured as integral parts of site reports rather than appearing as appendices (e.g., Ningxia and Pengyang, 2016; Shaanxi et al., 2018).

4. Conclusions and future goals

Three overarching conclusions emerge from the preceding synthesis. The contributors agree that datasets and research questions relating to ancient human-environment interaction should ideally be specific, multiscalar, and cross-disciplinary:

> *Specificity* First, datasets must be as local and specific as possible in both chronological and spatial terms, since both environmental changes and human responses are highly local and contingent. Examples given above include the need for detailed spatial knowledge about changes to specific landscape features over time (e.g. river

courses), the reconstruction of food systems at individual sites in order to detect trade vs. food production, and differing diet and health transitions during the Bronze Age across Northwest China and the Inner Asian steppe zone.

Multiscalarity Second, the field needs a robust theoretical framework for integrating data on multiple scales of complex social-natural systems, because the relationships between processes at different spatial and temporal scales must be shown rather than taken for granted. Examples discussed above include human-scale anthropogenic landforms interacting with regional-scale geomorphic processes, food production in individual villages interacting with dynastic governance and land management policies, regional vs. local forces driving technological innovation, and the adoption of new food crops at specific sites vs. the pan-continental process of their transmission.

Cross-disciplinarity Third, for our work to meaningfully contribute to urgent contemporary climate change research, effective communication of research findings to the public and to scientists in other disciplines should be routinely incorporated into research and publication plans. Archaeology can provide policy-related data, such as the composition of faunal communities over time, the origins of modern diseases, and the resilience of past communities. In addition, as is made clear by the same research topics arising in multiple sections of this paper, the work of various archaeological subdisciplines must be interpreted in light of each other.

Related to this last point, archaeology everywhere in the world has long had an omnivorous appetite for scientific methods borrowed from the natural and physical sciences. Archaeological science is well-funded and developing at a rapid pace in China, augmenting traditional archaeological field research, and archaeologists and other interested scientists are working to develop research projects that not only contribute to the task of reinforcing national identity, but also meaningfully contributing to policy by providing a longer and more objective perspective on environmental and social issues.

Finally, an important goal for a future-oriented archaeology in China, as everywhere, is breaking down institutional divisions. Projects must be able to incorporate data from across provinces administered by separate cultural heritage bureaus. Field work and archaeological science must work together at every stage, from designing a research question and conducting an excavation, to sampling artifacts, performing scientific analyses, and studying previously excavated legacy collections. International collaborations can also be very productive for developing scientifically robust, multidisciplinary approaches, and often have a large body of output. It would also be helpful to focus on improving the cross-linguistic accessibility of publications in both Chinese and other languages, by translating published papers, publishing bilingual reports, and at the least including bilingual abstracts. Finally, perhaps the most monumental task is to move towards open data standards (Jaffe et al., 2020). There are vast quantities of raw geological, archaeological, and historical data in China that could be published for potential collaborators, thereby ensuring that they will be reused and incorporated into future work (current efforts include Brunson et al., 2016b; Niu and Li, 2018; Womack and Hein, 2018).

China's high population density and interconnected physical geography present unique opportunities for insight into the human past and future. Historical sources in China are exceedingly rich and abundant, allowing the possibility of greater collaboration between historians and archaeologists. Moreover, China is one of the only large nations in the world that has developed a fairly standardized archaeological practice, uniform publishing language, and robust infrastructure supporting archaeological and geological surveys and excavations, producing datasets that span the Holocene and Pleistocene history of a vast landmass. The challenges should therefore not deter recognition of this work, as China is an essential piece of the anthropological puzzle of human behavior and environmental interactions.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

Allard, F., 1997. Growth and Stability Among Complex Societies in Prehistoric Lingnan, Southeast China. Papers from the Institute of Archaeology 8.

An, C.-B., Dong, W., Li, H., Zhang, P., Zhao, Y., Zhao, X., Yu, S.-Y., 2015. Variability of the stable carbon isotope ratio in modern and archaeological millets: evidence from northern China. J. Archaeol. Sci. 53, 316–322.

Anderson, D.G., Maasch, K.A., Sandweiss, D.H., Maasch, K., 2011. Climate Change and Cultural Dynamics: A Global Perspective on Mid-Holocene Transitions. Elsevier Science & Technology, San Diego.

Atahan, P., Dodson, J., Li, X., Zhou, X., Chen, L., Barry, L., Bertuch, F., 2014. Temporal trends in millet consumption in northern China. J. Archaeol. Sci. 50, 171–177.

Atahan, P., Dodson, J., Li, X., Zhou, X., Hu, S., Bertuch, F., Sun, N., 2011a. Subsistence and the isotopic signature of herding in the Bronze Age Hexi Corridor, NW Gansu, China. J. Archaeol. Sci. 38, 1747–1753.

Atahan, P., Dodson, J., Li, X., Zhou, X., Hu, S., Chen, L., Bertuch, F., Grice, K., 2011b. Early Neolithic diets at Baijia, Wei River valley, China: Stable carbon and nitrogen isotope analysis of human and faunal remains. J. Archaeol. Sci. 38, 2811–2817.

Atici, L., Kansa, S.W., Lev-Tov, J., Kansa, E.C., 2013. Other people's data: a demonstration of the imperative of publishing primary data. J. Archaeo. Method Theory 20, 663–681.

Bálint, M., Pfenninger, M., Grossart, H.-P., Taberlet, P., Vellend, M., Leibold, M.A., Englund, G., Bowler, D., 2018. Environmental DNA Time Series in Ecology. Trends Ecol. Evol. 33, 945–957.

Barton, L., An, C., 2014. An evaluation of competing hypotheses for the early adoption of wheat in East Asia. World Archaeology 46, 775–798.

Barton, L., Bingham, B., Sankaranarayanan, K., Monroe, C., Thomas, A., Kemp, B.M., 2020. The earliest farmers of northwest China exploited grain-fed pheasants not chickens. Sci. Rep. 10, 2556.

Barton, L., Brantingham, P.J., Du, X.J., 2007. Late Pleistocene climate change and Paleolithic cultural evolution in northern China: implications from the Last Glacial Maximum. In: Madsen, D.B., Gao, X., Chen, F. (Eds.), Late Quaternary Climate Change and Human Adaptation in Arid China. Elsevier, pp. 105–128.

Barton, L., Newsome, S.D., Chen, F.-H., Wang, H., Guilderson, T.P., Bettinger, R.L., 2009. Agricultural origins and the isotopic identity of domestication in northern China. Proc. Natl. Acad. Sci. United States of America 106, 5523–5528.

Bauer, A.M., Bhan, M., 2018. Climate without Nature: A Critical Anthropology of the Anthropocene. Cambridge University Press, Cambridge.

Bauer, A.M., Ellis, E.C., 2018. The Anthropocene divide: Obscuring understanding of social-environmental change. Current Anthropology 59, 209–227.

Beijing Daxue Zhongguo Kaoguxue Yanjiu Zhongxin (Center for the Study of Chinese Archaeology, P.U.), Juluo yanbian yu zaoqi wenming (Settlement change and formation of early civilization), 2015. Wenwu Chubanshe, Beijing.

Berger, E., 2018. Bioarchaeology of China: Bridging biological and archaeological inquiries. Archaeological Human Remains 25–43.

Berger, E., Pechenkina, K., 2020. Paleopathological research in continental China: Introduction to the Special Issue. International Journal of Paleopathology 28, 92-98.

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[2] The conference program can be viewed here: https://ii.umich.edu/lrccs/news-events/events/conferences/environments-and-adaptation-in-ancient-china–recent-advances-an.html.

Berger, E., Wang, H., 2017. Bioarchaeology of adaptation to a marginal environment in bronze age Western China. American J. Human Biol. 29.

Bestel, S., Crawford, G.W., Liu, L., Shi, J., Song, Y., Chen, X., 2014. The evolution of millet domestication, Middle Yellow River Region, North China: Evidence from charred seeds at the late Upper Paleolithic Shizitan Locality 9 site. The Holocene 24, 261–265.

Bettinger, R., Barton, L., Richerson, P., Boyd, R., Wang, H., Choi, W., 2007. The transition to agriculture in northwestern China. Develop. Quaternary Sci. 9, 83–101.

Bettinger, R.L., Barton, L., Morgan, C., Chen, F., Wang, H., Guilderson, T.P., Ji, D., Zhang, D., 2010. The transition to agriculture at Dadiwan, People's Republic of China. Curr. Anthropol. 51, 703–714.

Betts, A., Jia, P.W., Dodson, J., 2014. The origins of wheat in China and potential pathways for its introduction: a review. Quat. Int. 348, 158–168.

Boivin, N., Fuller, D.Q., 2009. Shell middens, ships and seeds: exploring soastal subsistence, maritime trade and the dispersal of domesticates in and around the ancient Arabian Peninsula. . World Prehistory 22, 113–118.

Boivin, N.L., Zeder, M.A., Fuller, D.Q., Crowther, A., Larson, G., Erlandson, J.M., Denham, T., Petraglia, M.D., 2016. Ecological consequences of human niche construction: examining long-term anthropogenic shaping of global species distributions. Proc. Natl. Acad. Sci. 113, 6388–6396.

Braudel, F., 1996. The Mediterranean and the Mediterranean World in the Age of Philip II. University of California Press, Berkeley.

Broughton, J.M., 1994. Declines in mammalian foraging efficiency during the Late Holocene, San Francisco Bay, California. J. Anthropol. Archaeol. 13, 371–401.

Brunson, K., He, N., Dai, X., 2016a. Sheep, cattle, and specialization: New zooarchaeological perspectives on the Taosi Longshan. Int. J. Osteoarchaeol. 26, 460–475.

Brunson, K., Li, Z., Flad, R., 2016b. Oracle Bones in East Asia, Released: 2016-04-04 ed. Open Context.

Brunson, K., Ren, L., Zhao, X., Dong, X., Wang, H., Zhou, J., Flad, R., 2020. Zooarchaeology, ancient mtDNA, and radiocarbon dating provide new evidence for the emergence of domestic cattle and caprines in the Tao River Valley of Gansu Province, northwest China. J. Archaeolog. Sci.: Rep. 31.

Cai, C., 1998. The formation and environmental evolution of the Xuan River and the Lower Yellow River (Huanghe xiayou Xuanhe xingcheng yu huangjing yanbian), Loess, Yellow River and Yellow River cultures (Huangtu, Huanghe, Huanghe wenhua). Huanghe shuili chubanshe, Zhengzhou, pp. 110–117.

Cai, Yudong, Fu, Weiwei, Cai, Dawei, Heller, Rasmus, Zheng, Zhuqing, Wen, Jia, Li, Hui, Wang, Xiaolong, Alshawi, Akil, Sun, Zhouyong, Zhu, Siqi, Wang, Juan, Yang, Miaomiao, Hu, Songmei, Li, Yan, Yang, Zhirui, Gong, Mian, Hou, Yunan, Lan, Tianming, Wu, Kui, Chen, Yulin, Jiang, Yu, Wang, Xihong, 2020. Ancient genomes reveal the evolutionary history and origin of cashmere-producing goats in China., Molecular Biology and Evolution 37 (7), 2099–2109. doi:10.1093/molbev/msaa103.

Cao, J., 2018. The extirpation of the Chinese alligator in North China, Anthropology. University of Pittsburgh, Pittsburgh.

Cao, Z.-H., Ding, J., Hu, Z.Y., Knicker, H., Kögel-Knabner, I., Yang, L., Yin, R., Lin, X., Dong, Y.H., 2006. Ancient paddy soils from the Neolithic age in China's Yangtze River Delta. Die Naturwissenschaften 93, 232–236.

Cerulo, K.A., 2009. Nonhumans in social interaction. Annual Rev. Sociol. 35, 531–552.

Chastain, M.L., 2019. The ceramic technology of bronze-casting molds in ancient China: Production practices at three western Zhou foundry sites in the Zhouyuan area, Materials Science and Engineering. Massachusetts Institute of Technology, Cambridge, MA.

Chen, K., Mei, J., Rehren, T., Liu, S., Yang, W., Martinón-Torres, M., Zhao, C., Hirao, Y., Chen, J., Liu, Y., 2019. Hanzhong bronzes and highly radiogenic lead in Shang period China. J. Archaeol. Sci. 101, 131–139.

Chen, K., Mei, J., Rehren, T., Zhao, C., 2016a. Indigenous production and interregional exchange: late second-millennium BC bronzes from the Hanzhong basin, China. Antiquity 90, 665–678.

Chen, K., Rehren, T., Mei, J., Zhao, C., 2009. Special alloys from remote frontiers of the Shang Kingdom: scientific study of the Hanzhong bronzes from southwest Shaanxi, China. J. Archaeol. Sci. 36, 2108–2118.

Chen, T., Qiu, M., Liu, R., Li, H., Hou, H., Howarth, P., Bowring, S., Zhou, A., 2020. Human Responses to Climate Change in the Late Prehistoric Western Loess Plateau, Northwest China. Radiocarbon 1–15.

Chen, X., Guo, X., Wang, W., Hu, S., Yang, M., Wu, Y., Hu, Y., 2016b. The subsistence patterns of the Shengedaliang site (∼4,000 yr BP) revealed by stable carbon and nitrogen isotopes in northern Shaanxi, China. Science China Earth Sciences 60.

Chen, X.L., Hu, S.M., Hu, Y.W., Wang, W.L., Ma, Y.Y., Lü, P., Wang, C.S., 2016c. Raising practices of Neolithic livestock evidenced by stable isotope analysis in the Wei River Valley, North China. Int. J. Osteoarchaeol. 26, 42–52.

Chen, Y., Syvitski, J.P., Gao, S., Overeem, I., Kettner, A.J., 2012. Socio-economic impacts on flooding: a 4000-year history of the Yellow River, China. Ambio 41, 682–698.

Cheung, C., Zhang, H., Hepburn, J.C., Yang, D.Y., Richards, M.P., 2019. Stable isotope and dental caries data reveal abrupt changes in subsistence economy in ancient China in response to global climate change. PLoS ONE 14, e0218943.

Chi, Z., Hung, Z., 2008. The Neolithic of Southern China: Origin, Development, and Dispersal. Asian Perspect. 47, 299–329.

Chifeng International Collaborative Archeological Research Project, 2003. Regional Archeology in Eastern Inner Mongolia: A Methodological Exploration. Science Press, Beijing.

China Ministry of Environmental Protection, 2013. Soil Polution and Physical Health. Science Publishing House, Beijing.

Cohen, K.M., Harper, D.A.T., Gibbard, P.L., Fan, J., 2018. The ICS International Chronostratigraphic Chart, Revised 15 July, 2018. ed. International Commission on Stratigraphy.

Coombes, P., Barber, K., 2005. Environmental determinism in Holocene research: causality or coincidence? Area 37, 303–311.

Crawford, G., 2018. Domestication and the origins of agriculture in China. In: Feinman, G., Bekke, D., Niziolek, L. (Eds.), Visions Through the Ages. University of Chicago Press, Chicago, pp. 45–63.

Crawford, G., Underhill, A., Zhao, Z., Lee, G.-A., Feinman, G., Nicholas, L., Luan, F., Yu, H., Fang, H., Cai, F., 2005. Late Neolithic Plant Remains from Northern China: Preliminary Results from Liangchengzhen, Shandong. Curr. Anthropol. 46, 309–317.

Crawford, G.W., 1992. Prehistoric plant domestication in East Asia. In: Cowan, C.W., Watson, P.J. (Eds.), The Origins of Agriculture: an International Perspective. Smithsonian Institution Press, Washington, pp. 7–38.

Crawford, G.W., 2006. East Asian plant domestication. In: Stark, M.T. (Ed.), Archaeology of Asia. Blackwell Publishing, Malden, pp. 77–95.

Crawford, G.W., 2017. Plant Domestication in East Asia. In: Habu, J., Lape, P.V., Olsen, J. W. (Eds.), Handbook of East and Southeast Asian Archaeology, 2 ed. Springer, New York, pp. 421–435.

Crawford, G.W., Chen, X., Luan, F., Wang, J., 2016. People and plant interaction at the Houli Culture Yuezhuang site in Shandong Province, China. The Holocene 26, 1594–1604.

Crutzen, P.J., Stoermer, E.F., 2000. The "Anthropocene". Global Change Newsletter, 17–18.

Cucchi, T., Dai, L., Balasse, M., Zhao, C., Gao, J., Hu, Y., Yuan, J., Vigne, J.-D., 2016. Social complexification and pig (*Sus scrofa*) husbandry in ancient China: a combined geometric morphometric and isotopic approach. PLoS ONE 11, e0158523.

d'Alpoim Guedes, J., 2015. Rethinking the spread of agriculture to the Tibetan Plateau. The Holocene 25.

d'Alpoim Guedes, J., Lu, H., Li, Y., Spengler, R.N., Wu, X., Aldenderfer, M.S., 2014. Moving agriculture onto the Tibetan Plateau: The archaeobotanical evidence. Archaeol. Anthropol. Sci. 6, 255–269.

d'Alpoim Guedes, J.A., Crabtree, S.A., Bocinsky, R.K., Kohler, T.A., 2016. Twenty-first century approaches to ancient problems: Climate and society. Proc .Natl. Acad. Sci. U S A 113, 14483–14491.

d'Alpoim Guedes, J.A., Lu, H., Hein, A.M., Schmidt, A.H., 2015. Early evidence for the use of wheat and barley as staple crops on the margins of the Tibetan Plateau. Proceedings of National Academy of Science of the United States of America 112, 5625–5630.

d'Alpoim Guedes, J., 2011. Millets, Rice, Social Complexity, and the Spread of Agriculture to the Chengdu Plain and Southwest China. Rice 4, 104–113.

Dai, L.L., Li, Z.P., Zhao, C.Q., Yuan, J., Hou, L.L., Wang, C.S., Fuller, B.T., Hu, Y.W., 2016. An isotopic perspective on animal husbandry at the Xinzhai site during the initial stage of the legendary Xia Dynasty (2070–1600 BC). Int. J. Osteoarchaeol. 26, 885–896.

Daly, P., 1969. Approaches to faunal analysis in archaeology. Am. Antiq. 34, 146–153.

Davis, H., Todd, Z., 2017. On the Importance of a Date, or, Decolonizing the Anthropocene. ACME: Int. J. Crit. Geographies 16, 761–780.

Devi, K., Alakanandana, A., Vijaya, V., 2017. Impacts of Cement Industry on Environment - An Overview.

Di Cosmo, N., 1994. Ancient Inner Asian nomads: their economic basis and its significance in Chinese history. J. Asian Stud. 53, 1092–1126.

Dittmar, J.M., Berger, E., Zhan, X., Mao, R., Wang, H., Yeh, H.-Y., 2019. Skeletal evidence for violent trauma from the bronze age Qijia culture (2,300–1,500 BCE), Gansu Province, China. Int. J. Paleopathol. 27, 66–79.

Dittmar, J.M., Berger, E.S., Mao, R., Wang, H., Yeh, H.-Y., 2021. The Mogou Bioarchaeology Project: exploring health in the Chinese Bronze Age. Antiquity 1–7.

Dodson, J., Dodson, E., Banati, R., Li, X., Atahan, P., Hu, S., Middleton, R.J., Zhou, X., Nan, S., 2014. Oldest Directly Dated Remains of Sheep in China. Sci. Rep. 4, 7170.

Dong, G., Jia, X., Elston, R., Chen, F., Li, S., Wang, L., Cai, L., An, C., 2013. Spatial and temporal variety of prehistoric human settlement and its influencing factors in the upper Yellow River valley, Qinghai Province, China. J. Archaeol. Sci. 40, 2538–2546.

Dong, G., Yang, Y., Liu, X., Li, H., Yifu, C., Wang, H., Chen, G., Dodson, J., Chen, F., 2017a. Prehistoric trans-continental cultural exchange in the Hexi Corridor, northwest China. The Holocene 28.

Dong, Y., Morgan, C., Chinenov, Y., Zhou, L., Fan, W., Ma, X., Pechenkina, K., 2017b. Shifting diets and the rise of male-biased inequality on the Central Plains of China during Eastern Zhou. Proc. Natl. Acad. Sci. 114, 932–937.

Drennan, R.D., Peterson, C.E., Berrey, C.A., 2020. Environmental risk buffering in Chinese Neolithic villages: Impacts on community structure in the Central Plains and the Western Liao Valley. Archaeological Research in Asia 21, 100165.

Drennan, R.D., Peterson, C.E., Lü, X., Zhu, D., Hou, S., 2014. Settlement and social dynamics in the Upper Daling and Chifeng regions of Northeast China. Asian Archaeology 50–76.

Elston, R., Cheng, X., Madsen, D., Kan, Z., Bettinger, R., Jingzen, L., Brantingham, P., Huiming, W., Jun, Y., 1997. New dates for the north China Mesolithic. Antiquity 71, 985–993.

Elvin, M., 2004. The Retreat of the Elephants: An Environmental History of China. Yale University Press.

Eng, J.T., 2016. A bioarchaeological study of osteoarthritis among populations of northern China and Mongolia during the Bronze Age to Iron Age transition to nomadic pastoralism. Quat. Int. 405, 172–185.

Eng, J.T., Zhang, Q., 2021. Investigating the potential impact of climate change on community health: bioarchaeological analysis of Neolithic and Bronze Age samples from Qinghai Province, China, 48th Annual Meeting of the North American Paleopathology Association, Online.

Erlandson, J.M., Rick, T.C., 2009. Archaeology meets marine ecology: The antiquity of maritime cultures and human impacts on marine fisheries and ecosystems. Ann.Rev. Marine Sci. 2, 231–251.

Falkenhausen, L.v., 1993. On the historiographical orientation of Chinese archaeology. Antiquity, 839-849.

Falkenhausen, L. von., 2018. The economic role of cities in Eastern Zhou China. Archaeological Research in Asia 14, 161–169.

Fang, X., Su, Y., Wei, Z., Yin, J., 2019. Social Impacts of Climate Change in Historical China. In: Yang, L.E., Bork, H.-.R., Fang, X., Mischke, S. (Eds.), Socio-Environmental Dynamics along the Historical Silk Road. Springer International Publishing, Cham, pp. 231–245.

Feinman, G.M., Fang, H., Nicholas, L.M., 2019. Coastal Shandong, China: the longue durée. J. Anthropol. Archaeol. 55, 101076.

Fisher, C.T., Feinman, G.M., 2005. Introduction to "Landscapes over Time". American Anthropologist 107, 62–69.

Flad, R., Li, S., Wu, X., Zhao, Z., 2010. Early wheat in China: Results from new studies at Donghuishan in the Hexi Corridor. The Holocene 20, 955–965.

Frachetti, M.D., 2012. Multiregional emergence of mobile pastoralism and nonuniform institutional complexity across Eurasia. Current Anthropology 53, 2–38.

Frachetti, M.D., Spengler, R.N., Fritz, G.J., Mar'yashev, A.N., 2010. Earliest direct evidence for broomcorn millet and wheat in the central Eurasian steppe region. Antiquity 84, 993–1010.

Fuller, D., Rowlands, M., 2011. Ingestion and food technologies: Maintaining differences over the long-term in West, South and East Asia. In: Wilkinson, T.C., Sherratt, S., Bennet, J. (Eds.), Interveaving Worlds: systemic interactions in Eurasia, 7th to 1st millennia BC. Oxbow Books, Oxford.

Fuller, D.Q., Boivin, N., Hoogervorst, T., Allaby, R., 2011a. Across the Indian Ocean: the prehistoric movement of plants and animals. Antiquity 85, 544–558.

Fuller, D.Q., Qin, L., 2010. Declining oaks, increasing artistry, and cultivating rice: the environmental and social context of the emergence of farming in the Lower Yangtze Region. Environ. Archaeol. 15, 139–159.

Fuller, D.Q., van Etten, J., Manning, K., Castillo, C., Kingwell-Banham, E., Weisskopf, A., Qin, L., Sato, Y.-I., Hijmans, R.J., 2011b. The contribution of rice agriculture and livestock pastoralism to prehistoric methane levels: an archaeological assessment. The Holocene 21, 743–759.

Gong, Z.T., Zhang, G.L., Luo, G.B., 1999. Diversity of anthrosols in China. Pedosphere 9, 193–204.

Gou, A., Wang, J., 2010. The development of roof color in ancient China. Color Res. Appl. 35, 246–266.

Grayson, D.K., 2001. The archaeological record of human impacts on animal populations. J. World Prehistory 15, 1–68.

Gross, B.L., Zhao, Z., 2014. Archaeological and genetic insights into the origins of domesticated rice. Proc. Natl. Acad. Sci. 111, 6190.

Guilaine, J., 2000. Changeons d'échelles : pour la très longue durée, pour de larges espaces. Études rurales 9–21.

Guo, Q., 2016. Interpreting roof tiles from the Qin state (c. 400–300 BC) at Yongcheng in a comparative context. Construction History 31, 1–24.

Guojia Wenwuju, 2007. Implementation Plan and Criteria of the National Third Cultural Relics Survey (Disanci quanguo wenwu pucha shishi fang'an ji xiangguan biaozhun).

Guojia Wenwuju, 2018. Guidelines for Identification of Immovable cultural relics (Buke yidong wenwu rending zhunze).

Han, K., 1990. Qinghai Minhe Yangshan mudi rengu (Human remains from the Yangshan Cemetery, Minhe, Qinghai), in: yanjiusuo, Q.s.w.k. (Ed.), Minhe Yangshan (Excavation of Cemetery at Yangshan Minhe Qinghai). Wenwu chubanshe, Beijing, pp. 160-173.

Han, R., Chen, J.C., 2013. Casting iron in ancient China, in: World of Iron, C., Humphris, J., Rehren, T. (Eds.), The World of Iron. Archetype Publications, London.

Harrod, R.P., Martin, D.L., 2014. Bioarchaeology of Climate Change and Violence. Springer, New York.

He, K., Lu, H., Zheng, Y., Zhang, J., Xu, D., Huan, X., Wang, J., Lei, S., 2018. Middle-Holocene sea-level fluctuations interrupted the developing Hemudu Culture in the Lower Yangtze River, China. Quaternary Science Reviews 90–103.

He, N., 2018. Taosi: An archaeological example of urbanization as a political center in prehistoric China. Archaeol. Res. Asia 14, 20–32.

Hein, A., 2018. Tibetan Plateau. Archaeology of. 1–14.

Henan sheng wenwu kaogu yanjiusuo, 2002. Preliminary report on the 2001 spring season excavation of Xipo site (Henan Lingbaoshi Xipo yizhi 2001nian chun fajue jianbao). Huaxia Kaogu 31–52, 92.

Henan sheng wenwukaogu yanjiuyuan, Zhongguo kexue jishu daxue kejishi yu kejikaogu xi, 2015. Wuyang Jiahu (Wuyang Site in Jiahu). Kexue Chubanshe, Beijing!

Hermes, T.R., Frachetti, M.D., Dupuy, P.N.D., Mar'yashev, A., Nebel, A., Makarewicz, C. A., 2019. Early integratio of pastoralism and millet cultivation in Bronze Age Eurasia. Proc. R. Soc. B 286, doi.org/10.1098/rspb.2019.1273.

Hillman, A.L., Abbott, M.B., Yu, J., Bain, D.J., Chiou-Peng, T., 2015. Environmental legacy of copper metallurgy and Mongol silver smelting recorded in Yunnan lake sediments. Environmental Science & Technology 49, 3349-3357.

Holling, C.S., Gunderson, L.H., 2002. Resilience and adaptive cycles. In: Gunderson, L.H., Holling, C.S. (Eds.), Panarchy: Understanding Transformations in Human and Natural Systems. Island Press, Washington, DC, pp. 25–62.

Hong, S., Candelone, J.-P., Patterson, C.C., Boutron, C.F., 1994. Greenland ice evidence of hemispheric lead pollution two millennia ago by Greek and Roman civilizations. Science 265, 1841–1843.

Hong, S., Candelone, J.-P., Patterson, C.C., Boutron, C.Fl., 1996. History of ancient copper smelting pollution during Roman and Medieval times recorded in Greenland ice. Science 272, 246–249.

Hornborg, A., 2017. Dithering while the planet burns: Anthropologists' approaches to the Anthropocene. Rev. Anthropol. 46, 1–17.

Horsley, T.J., Flad, R.K., Bennett, G.P., Li, S., Jiang, Z., Chen, P., 2009. Investigating ancient landscapes and settlement patterns in the Chengdu Plain, Sichuan, China. ArcheoSciences 33 (suppl.), 187-190.

Hou, L., Hu, Y., Zhao, X., Li, S., Wei, D., Hou, Y., Hu, B., Lv, P., Li, T., Song, G., Wang, C., 2013. Human subsistence strategy at Liuzhuang site, Henan, China during the proto-Shang culture (~2000–1600 BC) by stable isotopic analysis. J. Archaeol. Sci. 40, 2344–2351.

Hou, L., Wang, N., Lü, P., Hu, Y., Song, G., Wang, C., 2012. Transition of human diets and agricultural economy in Shenmingpu Site, Henan, from the Warring States to Han Dynasties. Science China Earth Sciences 55, 975 <last_page> 982.

Hrivnyak, M., Eng, J.T., 2020. Environmental dynamics and stable isotopic signatures in early Inner Asian Steppe communities. In: Schug, G.R. (Ed.), The Routledge Handbook of the Bioarchaeology of Environmental Change. Routledge, London, UK.

Hu, L., Chao, Z., Gu, M., Li, F., Chen, L., Liu, B., Li, X., Huang, Z., Li, Y., Xing, B., Dai, J., 2013. Evidence for a Neolithic Age fire-irrigation paddy cultivation system in the lower Yangtze River Delta, China. J. Archaeol. Sci. 40, 72–78.

Hu, Y., 2018. Thirty-four years of stable isotopic analyses of ancient skeletons in China: An overview, progress and prospects. Archaeometry 60, 144–156.

Hu, Y., Wang, S., Luan, F., Wang, C., Richards, M.P., 2008. Stable isotope analysis of humans from Xiaojingshan site: implications for understanding the origin of millet agriculture in China. J. Archaeol. Sci. 35, 2960–2965.

Hung, H.-C., Zhang, C., 2019. The Origins, Expansion and Decline of Early Hunter-Gatherers Along the South China Coast, pp. 53-79.

Hunt, H.V., Linden, M.V., Liu, X., Motuzaite-Matuzeviciute, G., Colledge, S., Jones, M.K., 2008. Millets across Eurasia: chronology and context of early records of the genera *Panicum* and *Setaria* from archaeological sites in the Old World. Vegetation History and Archaeobotany 17, 5–18.

Hunt, H.V., Moots, H.M., Graybosch, R.A., Jones, H., Parker, M., Romanova, O., Jones, M.K., Howe, C.J., Trafford, K., 2013. Waxy phenotype evolution in the allotetraploid cereal broomcorn millet: mutations at the GBSSI locus in their functional and phylogenetic context. Mol Biol Evol 30, 109–122.

Jaang, L., Sun, Z., Shao, J., Li, M., 2018. When peripheries were centres: a preliminary study of the Shimao-centred polity in the loess highland, China. Antiquity 92, 1008–1022.

Jaffe, Y., Flad, R., 2018. Prehistoric globalizing processes in the Tao River Valley, Gansu, China? In: Boivin, N., Frachetti, M. (Eds.), Globalization in Prehistory Contact, Exchange, and the 'People Without History'. Cambridge University Press, Cambridge, pp. 131–161.

Jaffe, Y.Y., Castellano, L., Shelach-Lavi, G., Campbell, R.B., 2020. Mismatches of scale in the application of paleoclimatic research to Chinese archaeology. Quat. Res. 1–20.

Jaffe, Y.Y., Hein, A., 2020. Considering change with archaeological data: Reevaluating local variation in the role of the ~4.2k BP event in Northwest China. The Holocene.

Jia, P., 2008. The transition to farming in northeast China: a model and application. Before Farming 4, 1–21.

Jiang, W., Wu, H., Li, Q., Lin, Y., Yu, Y., 2019. Spatiotemporal changes in C4 plant abundance in China since the Last Glacial Maximum and their driving factors. Palaeogeogr. Palaeoclimatol. Palaeoecol. 518, 10–21.

Jiao, T., 2013. The Neolithic Archaeology of Southeast China. In: Underhill, A.P. (Ed.), A Companion to Chinese Archaeology. Wiley-Blackwell, Chichester, UK, pp. 597–611.

Jin, Z., Li, X., Zhang, B., Han, Y., Zheng, G., 2013. Geochemical records in Holocene lake sediments of northern China: Implication for natural and anthropogenic inputs. Quat. Int. 304, 200–208.

Jing, Y., Flad, R., Yunbing, L., 2008. Meat-acquisition patterns in the Neolithic Yangzi river valley, China. Antiquity 82, 351–366.

Johnson, A.W., Earle, T., 2000. The Evolution of Human Societies: From Foraging Group to Agrarian State, Second Edition. Stanford University Press, Stanford.

Jones, M., Hunt, H., Lightfoot, E., Lister, D., Liu, X., Motuzaite-Matuzeviciute, G., 2011. Food globalization in prehistory. World Archaeology 43, 665–675.

Jones, M.K., 2004. Between fertile crescents: minor grain crops and agricultural origins. In: Jones, M.K. (Ed.), Traces of Ancestry - Studies in Honour of Colin Renfrew. McDonald Institute Monographs, Cambridge, pp. 127–135.

Kaufman, Brett, Bernard, Hans, Drine, Ali, Khedher, Rayed, Farahani, Alan, Ben Tahar, Sami, Jerray, Elyssa, Damiata, Brian N., Daniels, Megan, Fenn, Thomas, Moses, Victoria, 2021. Quantifying surplus and sustainability in the archaeological record at the Carthaginian to Roman urban mound of Zita, Tripolitania. Current Anthropology 62 (4).

Kidder, T.R., Liu, H., Storozum, M.J., Qin, Z., 2015. New perspectives on the collapse and regeneration of the Han Dynasty. In: Faulseit, R.K. (Ed.), Beyond Collapse: Archaeological Perspectives on Resilience, Revitalization, and Transformation in Complex Societies. Southern Illinois University Press, Carbondale, IL, pp. 70–98.

Kidder, T.R., Liu, H.W., Li, M.L., 2012. Sanyangzhuang: early farming and a Han settlement preserved beneath Yellow River flood deposits. Antiquity 86, 30–47.

Kidder, T.R., Zhuang, Y., 2015. Anthropocene archaeology of the Yellow River, China, 5000–2000 BP. The Holocene 25, 1627–1639.

Knappett, C., 2013. Network Analysis in Archaeology: New Approaches to Regional Interaction.

Kölbl, A., Schad, P., Jahn, R., Amelung, W., Bannert, A., Cao, Z.H., Fiedler, S., Kalbitz, K., Lehndorff, E., Müller-Niggemann, C., Schloter, M., Schwark, L., Vogelsang, V., Wissing, L., Kögel-Knabner, I., 2014. Accelerated soil formation due to paddy management on marshlands (Zhejiang Province, China). Geoderma 228-229, 67-89.

Kosiba, S., 2019. New digs: Networks, assemblages, and the dissolution of binary categories in anthropological archaeology. American Anthropologist 121, 447–463.

Kuzmin, Y.V., 2013. The beginnings of prehistoric agriculture in the Russian Far East: Current evidence and concepts. Documenta Praehistorica XL 1–12.

Kwak, S., Lee, G.-A., 2020. Broad-spectrum foodways in southern coastal Korea in the Holocene: Isotopic and archaeobotanical signatures in Neolithic shell middens. The Journal of Island and Coastal Archaeology 1–29.

Laland, K.N., O'Brien, M.J., 2010. Niche construction theory and archaeology. J. Archaeol. Method Theory 17, 303–322.

Lander, B., 2020. Birds and Beasts Were Many: the ecology and climate of the Guanzhong Basin in the pre-imperial period. Early China 43, 207–245.

Lander, B., Brunson, K., 2018a. The Sumatran rhinoceros was extirpated from mainland East Asia by hunting and habitat loss. Curr Biol 28, R252–R253.

Lander, B., Brunson, K., 2018b. Wild mammals of ancient North China. J. Chinese History 2, 1–22.

Lander, B., Schneider, M., Brunson, K., 2020. A history of pigs in China: From curious omnivores to industrial pork. J. Asian Studies 1–25.

Lane, P.J., 2015. Archaeology in the age of the Anthropocene: a critical assessment of its scope and societal contributions. J. Field Archaeol. 40, 485–498.

Lee, G.-A., Crawford, G.W., Liu, L., Chen, X., 2007. Plants and people from the Early Neolithic to Shang periods in North China. PNAS 104, 1087–1092.

Lee, G.A., Crawford, G.W., Liu, L., Sasaki, Y., Chen, X., 2011. Archaeological soybean (Glycine max) in East Asia: does size matter? PLoS ONE 6, e26720.

Lee, H., 2016. Study on Plant Resource Use in Prehistoric Northeast China: Focusing on the Houtaomuga Site. University of Oregon, Jilin.

Lee, H.F., Zhang, D.D., Pei, Q., Jia, X., Yue, R.P., 2017. Quantitative analysis of the impact of droughts and floods on internal wars in China over the last 500 years. Sci. China Earth Sci. 1–11.

Leipe, C., Long, T., Sergusheva, E.A., Wagner, M., Tarasov, P.E., 2019. Discontinuous spread of millet agriculture in eastern Asia and prehistoric population dynamics. Sci. Adv. 5, eaax6225.

Lewis, S.L., Maslin, M.A., 2015. Defining the Anthropocene. Nature 519, 171–180.

Li, F., Liang, Z., 2018. Guicheng: A Study of the Formation of States on the Jiaodong Peninsula in Late Bronze-Age China, 1000–500 BCE. Beijing Kexue Chubanshe, Beijing.

Li, J., Mackay, A.W., Zhang, Y., Li, J., 2013a. A 1000-year record of vegetation change and wildfire from maar lake Erlongwan in northeast China. Quat. Int. 290–291, 313–321.

Li, K., Liu, E., Zhang, E., Li, Y., Shen, J., Liu, X., 2017a. Historical variations of atmospheric trace metal pollution in Southwest China: Reconstruction from a 150-year lacustrine sediment record in the Erhai Lake. J. Geochem. Explor. 172, 62–70.

Li, N., He, N., Mao, Z.W., Wang, C., 2007. Taosi yizhi chutu de banwa fenxi (Analysis of the flat tiles unearthed from Taosi site). Kaogu.

Li, T., Ning, C., Zhushchikhovskaya, I.S., Hudson, M.J., Robbeets, M., 2020a. Millet agriculture dispersed from Northeast China to the Russian Far East: Integrating archaeology, genetics, and linguistics. Archaeol. Res. Asia 22, 100177.

Li, X., Sun, N., Dodson, J., Ji, M., Zhao, K., Zhou, X., 2011. The impact of early smelting on the environment of Huoshiliang in Hexi Corridor, NW China, as recorded by fossil charcoal and chemical elements. Palaeogeogr. Palaeoclimatol. Palaeoecol. 305, 329–336.

Li, X., Zhang, S., Lu, M., Qiu, M., Wen, S., Ma, M., 2020b. Dietary shift and social hierarchy from the Proto-Shang to Zhou Dynasty in the Central Plains of China. Environ. Res. Lett. 15.

Li, Y., Storozum, M., Tian, D., Frachetti, M., Su, K., Wang, X., 2019. Farming strategies of 1st millennium CE agro-pastoralists on the southern foothills of the Tianshan Mountains: a geoarchaeological and macrobotanical investigation of the Mohuchahangoukou (MGK) site, Xinjiang. China. PLoS One 14, e0217171.

Li, Y., Storozum, M.J., Wang, X., Guo, W., 2017b. Early irrigation and agropastoralism at Mohuchahangoukou (MGK), Xinjiang, China. Archaeol. Res. Asia 12, 23–32.

Li, Y., Wang, R., Wei, Q., Chen, J., 2018. Handan Xuhushang zhi tie yizhi chubu kaocha yanjiu (Primary investigation of Xihushang iron smelting site in Handan of Hebei Province). Youse Jinshu (Yelian Bufen) 79–86.

Li, Y., Wu, J., Hou, S., Shi, C., Mo, D., Liu, B., Zhou, L., 2010. Palaeoecological records of environmental change and cultural development from the Liangzhu and Qujialing archaeological sites in the middle and lower reaches of the Yangtze River. Quat. Int. 227, 29–37.

Li, Y., Zhang, C., Taylor, W.T.T., Chen, L., Flad, R.K., Boivin, N., Liu, H., You, Y., Wang, J., Ren, M., Xi, T., Han, Y., Wen, R., Ma, J., 2020c. Early evidence for mounted horseback riding in northwest China. Proc. Natl. Acad. Sci. U S A.

Li, Z., Zhao, L., Li, L., Wang, J., 2013b. Research on the modification of two traditional building materials in ancient China. Heritage Science 1, 27.

Liaoning sheng wenwu kaogu yanjiusuo, Pittsburgh University Department of Anthropology, University of Hawaii, 2010. Preliminary report on the archaeology survey on the upper Daling river valley in Liaoning (Liaoning Dalinghe shangyou liuyu kaogu diaocha jianbao). Kaogu, 24–35.

Lightfoot, E., Liu, X., Jones, M.K., 2013. Why move starchy cereals? a review of the isotopic evidence for prehistoric millet consumption across Eurasia. World Archaeol. 45, 574–623.

Lin, M., 2014. A statistical view for Chinese zooarchaeology: from the Neolithic to Pre-Han periods. Archaeological and Anthropological Sciences 8.

Lin, Q., Liu, E., Zhang, E., Li, K., Shen, J., 2016. Spatial distribution, contamination and ecological risk assessment of heavy metals in surface sediments of Erhai Lake, a large eutrophic plateau lake in southwest China. CATENA 145, 193–203.

Linduff, K.M., Drennan, R.D., Shelach, G., 2004. Early complex societies in NE China: The Chifeng International Collaborative Archaeological Research Project. J. Field Archaeol. 29, 45–73.

Linduff, K.M., Mei, J., 2009. Metallurgy in ancient Eastern Asia: Retrospect and prospects. J. World Prehistory 22, 265–281.

Lister, D.L., Jones, H., Oliveira, H.R., Petrie, C.A., Liu, X., Cockram, J., Kneale, C.J., Kovaleva, O., Jones, M.K., 2018. Barley heads east: Genetic analyses reveal routes of spread through diverse Eurasian landscapes. PLOS one 13, e0196652-e0196652.

Liu, B., Wang, N., Chen, M., Wu, X., Mo, D., Liu, J., Xu, S., Zhuang, Y., 2017a. Earliest hydraulic enterprise in China, 5,100 years ago. Proc. Natl. Acad. Sci. 114, 13637.

Liu, F., Feng, Z., 2012. A dramatic climatic transition at ~4000 cal. yr BP and its cultural responses in Chinese cultural domains. The Holocene 22, 1181–1197.

Liu, L., 1996. Settlement patterns, chiefdom variability, and the development of early states in North China. J. Anthropol. Archaeol. 15, 237–288.

Liu, L., 2015. A long process towards agriculture in the middle Yellow River Valley, China: Evidence from macro-and micro-botanical remains. Journal of Indo-Pacific. Archaeology 35.

Liu, L., Chen, X., 2012. The Archaeology of China, from the Late Paleolithic to the Early Bronze Age. Cambridge University Press, Cambridge.

Liu, L., Chen, X., Wright, H., Xu, H., Li, Y., Chen, G., Zhao, H., Kim, H., Lee, G.-A., 2019a. Rise and fall of complex societies in the Yiluo region, North China: The spatial and temporal changes. Quat. Int. 521, 4–15.

Liu, L., Kealhofer, L., Chen, X., Ji, P., 2014a. A broad-spectrum subsistence economy in Neolithic Inner Mongolia, China: Evidence from grinding stones. The Holocene.

Liu, L., Levin, M.J., Bonomo, M.F., Wang, J., Shi, J., Chen, X., Han, J., Song, Y., 2018a. Harvesting and processing wild cereals in the Upper Palaeolithic Yellow River Valley, China. Antiquity 92, 603–619.

Liu, L., Li, Y., Hou, J., 2020a. Making beer with malted cereals and qu starter in the Neolithic Yangshao culture, China. J. Archaeol. Sci.: Rep. 29, 102134.

Liu, L., Wang, J., Levin, M.J., Sinnott-Armstrong, N., Zhao, H., Zhao, Y., Shao, J., Di, N., Zhang, T.e., 2019b. The origins of specialized pottery and diverse alcohol fermentation techniques in Early Neolithic China. Proceedings of the National Academy of Sciences 116, 12767.

Liu, L., Wang, J., Liu, H., 2020b. The brewing function of the first amphorae in the Neolithic Yangshao culture, North China. Archaeol. Anthropological Sci. 12, 118.

Liu, L., Chen, Xingcan, Lee, Yun Kuen, Wright, Henry, Rosen, Arlene, 2004. Settlement patterns and development of social complexity in the Yiluo Region, North Region. J. Field Archaeol. 29, 75–100.

Liu, R., Dong, G., Ma, M., Pollard, A.M., 2020c. Introduction to the Special Issue: Correlating changes for environmental, technological and societal transformation in prehistoric eastern Asia. The Holocene.

Liu, R., Pollard, A.M., Rawson, J., Tang, X., Bray, P., Zhang, C., 2019c. Panlongcheng, Zhengzhou and the movement of metal in early Bronze Age China. J. World Prehistory 32, 393–428.

Liu, S., Rehren, T., Qin, D., Chen, J., Zhou, W., Martinón-Torres, M., Huang, X., Qian, W., 2019d. Coal-fuelled crucible lead-silver smelting in 12th-13th century China:a technological innovation in the age of deforestation. J. Archaeol. Sci. 104, 75–84.

Liu, S., Wang, K., Cai, Q., Chen, J., 2013. Microscopic study of Chinese bronze casting moulds from the Eastern Zhou period. J. Archaeol. Sci. 40, 2402–2414.

Liu, X., 2016. Archaeological study of the distribution and assemblages of crops during the Pre-Qin period and the Han Dynasty (Xian Qin liang Han nongwu fenbu zuhe de kaoguxue yanjiu). Kaogu xuebao (Acta archaeologica sinica) 465–494.

Liu, X., Fuller, D.Q., Jones, M., 2015. Early agriculture in China, in: Goucher, C., Barker, G. (Eds.), The Cambridge World History: Volume 2: A World with Agriculture, 12,000 BCE–500 CE. Cambridge University Press, Cambridge, pp. 310-334.

Liu, X., Hunt, H.V., Jones, M.K., 2009. River valleys and foothills: changing archaeological perceptions of north China's earliest farms. Antiquity 83, 82-95.

Liu, X., Jones, M.K., 2014. Food globalisation in prehistory: top down or bottom up? Antiquity 88, 956–963.

Liu, X., Jones, M.K., Zhao, Z., Liu, G., O'Connell, T.C., 2012. The earliest evidence of millet as a staple crop: new light on neolithic foodways in North China. Am. J. Phys. Anthropol. 149, 283–290.

Liu, X., Jones, P.J., Motuzaite Matuzeviviute, G., Hunt, H.V., Lister, D.L., An, T., Przelomska, N., Kneale, C.J., Zhao, Z., Jones, M.K., 2019e. From ecological opportunism to multi-cropping: mapping food globalisation in prehistory. Quat. Sci. Rev. 206, 21–28.

Liu, X., Lightfoot, E., O'Connell, T.C., Wang, H., Li, S., Zhou, L., Hu, Y., Motuzaite-Matuzeviciute, G., Jones, M.K., 2014b. From necessity to choice: Dietary revolutions in west China in the second millennium BC. World Archaeol. 46, 661–680.

Liu, X., Lister, D.L., Zhao, Z.-Z., Staff, R.A., Jones, P.J., Zhou, L.-P., Pokharia, A.K., Petrie, C.A., Pathak, A., Lu, H.-L., Motuzaite Matuzeviciute, G., Bates, J., Pilgram, T. K., Jones, M.J., 2016. The virtues of small grain size: Potential pathways to a distinguishing feature of Asian wheats. Quat. Int. 426, 107–109.

Liu, X., Lister, D.L., Zhao, Z., Petrie, C.A., Zeng, X., Jones, P.J., Staff, R., Pokharia, A.K., Bates, J., Singh, R.N., Weber, S.A., Motuzaite Matuzeviviute, G., Dong, G., Li, H., Lü, H., Jiang, H., Wang, J., Ma, J., Tian, D., Jin, G., Zhou, L., Wu, X., Jones, M.K., 2017b. Journey to the East: diverse routes and variable flowering times for wheat and barley *en route* to prehistoric China. PLoS ONE 12, e0209518.

Liu, X., Motuzaite Matuzeviciute, G., Hunt, H.V., 2018b. From a fertile idea to a fertile arc: The origins of broomcorn millet 15 years on, in: Lightfoot, E., Liu, X., Fuller, D. Q. (Eds.), Far from the Hearth: Essays in Honour of Martin K. Jones. McDonald Institute Conversations, Cambridge, pp. 155-164.

Liu, X., Reid, R.E.B., 2020. The prehistoric roots of Chinese cuisines: mapping staple food systems of China, 6000 BC–220 AD. PLoS ONE 15, e0240930.

Liu, X., Sebillaud, P., Li, Y., Wang, L., 2017c. Intra-site analysis using a systematic regional survey method: a case-study on the Hanshu site (Quyuxing xitong diaocha fangfa zai dianxing yizhi zhong de yingyong - yi Hanshu yizhi wei li). Bianjiang kaogu yanjiu 297–312.

Long, T., Leipe, C., Jin, G., Wagner, M., Guo, R., Schröder, O., Tarasov, P., 2018. The early history of wheat in China from 14C dating and Bayesian chronological modelling. Nat. Plants 4.

Luan, F., Wagner, M., 2009. The chronology and basic development sequence of archaeological cultures in the Haidai Region. In: Wagner, M., Luan, F., Tarasov, P. (Eds.), Chinese Archaeology and Palaeoenvironment I: Prehistory at the Lower Reaches of the Yellow River: The Haidai Region. Verlag Philipp von Zabern, Mainz, Germany, pp. 1–15.

Luo, Y., 2012. Zhongguo Gudai Zhu Lei Xunhua, Siyang yu Yishixing Shiyong (The Domestication, Raising and Ritual Use of Pig in Ancient China). Kexue Chubanshe, Beijing.

Luoyang kaogu fajuedui, 1959. Luoyang Shaogou Hanmu (The Han Tombs at Shaogou in Luoyang). Kexue Chubanshe, Beijing.

Ma, M., Dong, G., Jia, X., Wang, H., Cui, Y., Chen, F., 2016a. Dietary shift after 3600 cal yr BP and its influencing factors in northwestern China: Evidence from stable isotopes. Quat. Sci. Rev. 145, 57–70.

Ma, M., Dong, G., Lightfoot, E., Wang, H., Liu, X., Jia, X., Zhang, K., Chen, F., 2014. Stable isotope analysis of human and faunal remains in the western Loess Plateau, approximately 2000 calbc. Archaeometry 56, 237–255.

Ma, Y., Fuller, B.T., Wei, D., Shi, L., Zhang, X., Hu, Y., Richards, M.P., 2016b. Isotopic perspectives (δ13C, δ15N, δ34S) of diet, social complexity, and animal husbandry during the proto-Shang period (ca. 2000–1600 BC) of China. Am. J. Phys. Anthropol. 160, 433–445.

Machicek, M., Eng, J.T., 2017. Identifying the effects of diverse ecological and biological variability in Bronze-Iron Age Inner Asian steppe populations, 86th Annual Meeting of the American Association of Physical Anthropologists, New Orleans, LA.

Madsen, D., Elston, R., Bettinger, R., Cheng, X., Kan, Z., 1996. Settlement Patterns Reflected in Assemblages from the Pleistocene /Holocene Transition of North Central China. Journal of Archaeological Science 23, 217-231.

Makarewicz, C.A., Sealy, J., 2015. Dietary reconstruction, mobility, and the analysis of ancient skeletal tissues: Expanding the prospects of stable isotope research in archaeology. J. Archaeol. Sci. 56, 146–158.

Marston, J.M., 2011. Archaeological markers of agricultural risk management. J. Anthropol. Archaeol. 30, 190–205.

Martin, D., Osterholtz, A., 2016. Broken bodies and broken bones: Biocultural approaches to ancient slavery and torture. In: Zuckerman, M.K., Martin, D.L. (Eds.), New Directions in Biocultural Anthropology. Wiley, Hoboken, NJ, pp. 471–490.

McGovern, P.E., Zhang, J., Tang, J., Zhang, Z., Hall, G.R., Moreau, R.A., Nuñez, A., Butrym, E.D., Richards, M.P., Wang, C.-S., Cheng, G., Zhao, Z., Wang, C., 2004. Fermented beverages of pre- and proto-historic China. PNAS 101, 17593.

Mei, J., Wang, P., Chen, K., Wang, L., Wang, Y., Liu, Y., 2015. Archaeometallurgical studies in China: some recent developments and challenging issues. J. Archaeol. Sci. 56, 221–232.

Merrett, D., Zhang, H., Xiao, X., Zhang, Q., Wei, D., Wang, L., Zhu, H., Yang, D., 2016. Enamel hypoplasia in Northeast China: Evidence from Houtaomuga. Quat. Int. 405, 11–21.

Middleton, G.D., 2018. Bang or whimper? Science 361, 1204.

Miller, N., Spengler, R., Frachetti, M.D., 2016. Millet cultivation across Eurasia: Origins, spread, and the influence of seasonal climate. The Holocene 26, 1566–1575.

Milliman, J.D., Yun-Shan, Q., Mei-E, R., Saito, Y., 1987. Man's Influence on the Erosion and Transport of Sediment by Asian Rivers: The Yellow River (Huanghe) Example. J. Geol. 95, 751–762.

Morrison, K.D., 2018. Empires as ecosystem engineers: Toward a nonbinary political ecology. J. Anthropol. Archaeol. 52, 196–203.

Motuzaite Matuzeviciute, G., Preece, G., Wang, C., Solominas, S., Ohnuma, L., Kume, K., Abdykanova, A., James, M.K., 2017. Ecology and subsistence at the Mesolithic and Bronze Age site of Aigyrzhal-2, Naryn valley, Kyrgyzstan. Quat. Int. 437, 35–49.

Motuzaite Matuzeviciute, G., Staff, R.A., Hunt, H.V., Liu, X., Jones, M.K., 2013. The early chronology of broomcorn millet (Panicum miliaceum) in Europe. Antiquity 87, 1073–1085.

Nagaoka, L., 2002. The effects of resource depression on foraging efficiency, diet breadth, and patch use in southern New Zealand. J. Anthropol. Archaeol. 21, 419–442.

Nakajima, T., Hudson, M.J., Uchiyama, J., Makibayashi, K., Zhang, J., 2019. Common carp aquaculture in Neolithic China dates back 8,000 years. Nat. Ecol. Evol. 3, 1415–1418.

Needham, J., Lu, G.-D., 1971. Science and Civilisation in China: Volume 4, Physics and Physical Technology, Part 3. Civil Engineering and Nautics. Cambridge University Press, Cambridge, UK.

Nelson, S.M., 2002. Performing power in early China: examples from the Shang dynasty and the Hongshan culture. Dynamics of power 30, 151–167.

Nickel, L., 2015. Bricks in ancient China and the question of early cross-Asian interaction. Arts Asiatiques 70, 49–62.

Ningxia wenwu kaogu yanjiusuo, guanlisuo, P.x.w., 2016. Wangdahu yu Jiulongshan: Beifang Qingtong Wenhua Mudi (Wangdahu and Jiulongshan: A Cemetery of Northern Bronze Culture). Wenwu chubanshe, Beijing.

Niu, W., Li, Y., 2018. Guonei Xiyu lishi wenhua lei shujuku jianshe diaochao–Jianlun Talimu Daxue Shuzi Xiyu Pingtai jianshe (Investigating the construction of the history and culture databases of the Western Regions in China——As well as discussing the construction of the digital Western Regions Platform of Tarim University). Journal of Tarim University 30, 135–143.

Nriagu, J.O., 1996. A history of global metal pollution. Science 272, 223-223.

Nylan, M., Loewe, M., 2015. Supplying the capital with water and food. In: Nylan, M., Vankeerberghen, G. (Eds.), Chang'an 26 BCE. University of Washington Press, pp. 99–130.

Odling-Smee, F., Laland, K., Feldman, M., 2003. Niche Construction: The Neglected Process in Evolution.

Omran, A.R., 1971. The Epidemiologic Transition: A Theory of the Epidemiology of Population Change. The Milbank Quarterly 83, 731–757.

Omran, A.R., 1983. The epidemiologic transition theory. A preliminary update. J Trop Pediatr 29, 305–316.

Pechenkina, K., 2012. From morphometrics to holistics: The emergence of paleopathology in China. In: Buikstra, J.E., Roberts, C. (Eds.), The global history of paleopathology: Pioneers and prospects. Oxford University Press, Oxford, pp. 345–360.

Pechenkina, K., 2018. Of millet and wheat: Diet and health on the Central Plain of China during the Neolithic and Bronze Age. In: Goldin, P.R. (Ed.), Routledge Handbook of Early Chinese History. Routledge, New York, pp. 39–60.

Pechenkina, K., Ambrose, S.H., Xiaolin, M., Benfer, R.A., 2005. Reconstructing northern Chinese Neolithic subsistence practices by isotopic analysis. J. Archaeol. Sci. 32, 1176–1189.

Peterson, C.E., Lü, X., Drennan, R.D., Zhu, D., 2014. Hongshan Regional Organization in the Upper Daling Valley Center for Comparative Archaeology Department of Anthropology. University of Pittsburgh.

Pokharia, A.K., Kharakwal, J.S., Srivastava, A., 2014. Archaebotanical evidence of millets in the Indian subcontinent with some observations on their role in the Indus civilization. J. Archaeol. Sci. 42, 442–455.

Puckett, E.E., Orton, D., Munshi-South, J., 2020. Commensal rats and humans: Integrating rodent phylogeography and zooarchaeology to highlight connections between human societies. BioEssays 42, e1900160.

Qian, Y., Wang, Z., Chen, X., Chen, X., Shao, J., Zhu, Z., Hu, W., 2009. Preliminary report on the 2007-2008 season excavation of the Longshan remains in Anban (2007-2008 niandu Anban yizhi Longshan shidai yicun fajue jianbao). Xibu kaogu.

Qin, L., Fuller, D.Q., Harvey, E., 2006. Subsistence patterns at the Hemudu site: Discussing some issues with the use of rice remains in the investigation of agriculture (Hemudu yizhi de shengji moshi - Jiantan daozuo nongye yanjiu zhong de ruogan wenti). Dongfang Kaogu 307–350.

Qindu Xianyang kaogu gongzuozhan, 1976. Preliminary report on the No. 1 palatial building at Xianyang, the capital of the Qin State (Qindu Xianyang diyihao gongdian jainzhu yizhi jianbao). Wenwu 12–24, 43.

Rao, Z., Zhu, Z., Jia, G., Chen, F., Barton, L., Zhang, J., Qiang, M., 2010. Relationship between climatic conditions and the relative abundance of modern C3 and C4 plants in three regions around the North Pacific. Chin. Sci. Bull. 55, 1931–1936.

Reed, C.A., 1963. Osteo-archaeology. In: Higgs, E.S., Brothwell, D. (Eds.), Science in Archaeology. Thames and Hudson, New York, pp. 204–216.

Ren, L., Dong, G., Liu, F., d'Alpoim Guedes, J., Flad, R., Ma, M., Li, H., Yang, Y., Liu, Y., Zhang, D., Li, G., Li, J., Chen, F., 2019. Archaeobotanical and zooarchaeological evidence of trade and exchange between foragers and farmers on the Tibetan Plateau. Antiquity.

Ren, L., Li, X., Kang, L., Brunson, K., Liu, H., Dong, W., Li, H., Min, R., Liu, X., Dong, G., 2017. Human paleodiet and animal utilization strategies during the Bronze Age in northwest Yunnan Province, southwest China. PLoS ONE 12.

Ren, L., Yang, Y., Wang, Q., Zhang, S., Chen, T., Cui, Y., Wang, Z., Liang, G., Dong, G., 2020. The transformation of cropping patterns from Late Neolithic to Early Iron Age (5900–2100 BP) in the Gansu-Qinghai region of northwest China. The Holocene.

Ren, M.e., 2015. Sediment discharge of the Yellow River, China: Past, present and future—A synthesis. Acta Oceanologica Sinica 34, 1-8.

Ren, M.e., Zhu, X., 1994. Anthropogenic influences on changes in the sediment load of the Yellow River, China, during the Holocene. The Holocene 4, 314-320.

Ren, X., Lemoine, X., Mo, D., Kidder, T.R., Guo, Y., Qin, Z., Liu, X., 2016. Foothills and intermountain basins: Does China's Fertile Arc have 'Hilly Flanks'? Quat. Int. 426, 86–96.

Rick, T.C., Lockwood, R., 2013. Integrating paleobiology, archeology, and history to inform biological conservation. Conserv. Biol. 27, 45–54.

Rick, T.C., Sandweiss, D.H., 2020. Archaeology, climate, and global change in the Age of Humans. Proc. Natl. Acad. Sci. U S A 117, 8250–8253.

Robbins Schug, G., Parnell, E.K., Harrod, R.P., 2019. Changing the climate: bioarchaeology responds to deterministic thinking about human-environmental interactions in the past. Bioarchaeol. Speak Out 133–159.

Rockman, M., Hritz, C., 2020. Expanding use of archaeology in climate change response by changing its social environment. Proc. Natl. Acad. Sci. USA 117, 8295–8302.

Rosen, A., Macphail, R., Liu, L., Chen, X., Weisskopf, A., 2017. Rising social complexity, agricultural intensification, and the earliest rice paddies on the Loess Plateau of northern China. Quat. Int. 437, 50–59.

Rosen, A.M., Lee, J., Li, M., Wright, J., Wright, H.T., Fang, H., 2015. The Anthropocene and the landscape of Confucius: a historical ecology of landscape changes in northern and eastern China during the middle to late-Holocene. The Holocene 25, 1640–1650.

Rowley-Conwy, P., Layton, R., 2011. Foraging and farming as niche construction: stable and unstable adaptations. Philos. Trans. R Soc. Lond. B Biol. Sci 366., 849–862.

Salvagno, L., Albarella, U., 2017. A morphometric system to distinguish sheep and goat postcranial bones. PLoS ONE 12, e0178543.

Sebillaud, P., 2014. La distribution spatiale de l'habitat en Chine dans la plaine Centrale à la transition entre le Néolithique et l'âge du Bronze [env.2500-1050 av. n. è.], Ph. D. dissertation. Ecole Pratique des Hautes Etudes, Paris.

Sebillaud, Pauline, 2016. Gongyuanqian liangqianji qianhou Zhongyuan diqu de shuidao sheshi (Waterway facilities in the Central Plains around the 2000s BC). Wenwu chunqiu 1, 3–12.

Sebillaud, P., 2022. Huan Yueliangpao diqu quyuxing kaogu diaocha baogao (Report on the systematic regional survey around the Yueliang Lake). Kexue Chubanshe, Beijing.

Sebillaud, P., Berger, E.B., Liu, X., Hou, K., 2019. A glimpse into burial practices of medieval (10th to 13th c. A.D.) elites in the Horqin region, Northeast China. Bulletin de l'Ecole Française d'Extrême-Orient 105, 255–319.

Sebillaud, Pauline, Williams, James, Liu, Xiaoxi, Wang, Lixin, 2021. Changing settlement patterns and subsistence strategies in Northeast China: Results of the Yueliang regional survey. Archaeological Research in Asia 25, 1-19-19.

Shaanxi kaogu yanjiuyuan, Baojishi kaogu yanjiusuo, Fengxiang xian bowuguan, 2013. Qin Yongcheng Doufucun Zhanguo Zhitao Zuofang (Pottery Workshops in the Yong City of the Qin State during the Warring States Period). Kexue Chubanshe, Beijing.

Shaanxi sheng kao gu yan jiu yuan, Yan'an shi wenwu yanjiusuo, Huangling xian lüyou wenwuju, 2018. Zhaitouhe: The Excavation of the Warring-States-Period Rong-Barbarian Cemetery at Huangling, Shaanxi (Zhaitouhe: Shanxi Huangling Zhanguo Rong Ren Mudi Kaogu Fajue Baogao), Di 1 ban. ed. Shanghai guji chubanshe, Shanghai.

Shaanxi sheng kaogu yanjiusuo, Shihuangling qinyongkeng kaogu fajuedui, 1988. Soldiers and Horses Pit of the Qinshihuang Mausoleum: Excavation Report of Pit No.1, 1974-1984 (Qinshihuangling Bingmayong Keng: Yihaokeng Fajue Baogao 1974-1984). Wenwu Chubanshe, Beijing.

Shaanxi Zhouyuan kaogudui, 1979. Preliminary report on the excavation of the Western Zhou buildings' foundations in Fengchu village, Qishan, Shaanxi (Shaanxi Qishan Fengchucun Xizhou jianzhu jizhi fajue jianbao). Wenwu 27–34.

Shelach, G., 2009. Prehistoric Societies on the Northern Frontiers of China: Archaeological Perspectives on Identity Formation and Economic Change During the First Millennium BCE. Equinox Pub, London.

Shelach, G., Jaffe, Y., 2014. The Earliest States in China: A Long-term Trajectory Approach. J. Archaeol. Res. 22, 327–364.

Sheng, G., Lai, X., Yuan, J., Hou, X., Song, L., 2016. Review and outlook on 35 years of aDNA research (Gu DNA yanjiu 35 nian huigu yu zhanwang. Scientia Sinica Terrae 46, 1564–1578.

Shi, C., Zhang, L., Xu, J., Guo, L., 2010. Sediment load and storage in the lower yellow river during the late holocene. Geografiska Annaler: Series A, Physical Geography 92, 297–309.

Silva, F., Stevens, C.J., Weisskopf, A., Castillo, C., Qin, L., Bevan, A., Fuller, D.Q., 2015. Modelling the geographical origin of rice cultivation in Asia using the rice archaeological database. PLoS ONE 10, e0137024.

Sima, Q., 1997. Basic Annals 6, Shiji (Record of the Grand Historian). Zhonghua shuju, Beijing, p. 234.

Smith, B.D., 2011. General patterns of niche construction and the management of 'wild' plant and animal resources by small-scale pre-industrial societies. Philos. Trans. R Soc. Lond. B Biol. Sci. 366, 836–848.

Smith, B.D., Zeder, M.A., 2013. The onset of the Anthropocene. Anthropocene 4, 8–13.

Spengler, R., Frachetti, M., Doumani, P., Rouse, L., Cerasetti, B., Bullion, E., Mar'yashev, A., 2014. Early agriculture and crop transmission among Bronze Age mobile pastoralists of Central Eurasia. Proc. Biol. Sci. 281, 20133382.

Spengler, R.N., 2015. Agriculture in the Central Asian Bronze Age. J. World Prehistory 28, 215–253.

Stephens, D.W., 1990. Risk and incomplete information in behavioral ecology. In: Cashdam, E. (Ed.), Risk and Uncertainty in Tribal and Peasant Economies. Westview Press, London, pp. 19–46.

Stephens, L., Fuller, D., Boivin, N., Rick, T., Gauthier, N., Kay, A., Marwick, B., Armstrong, C.G., Barton, C.M., Denham, T., Douglass, K., Driver, J., Janz, L., Roberts, P., Rogers, J.D., Thakar, H., Altaweel, M., Johnson, A.L., Sampietro Vattuone, M.M., Aldenderfer, M., Archila, S., Artioli, G., Bale, M.T., Beach, T., Borrell, F., Braje, T., Buckland, P.I., Jiménez Cano, N.G., Capriles, J.M., Diez Castillo, A., Çilingiroğlu, Ç., Negus Cleary, M., Conolly, J., Coutros, P.R., Covey, R.A., Cremaschi, M., Crowther, A., Der, L., di Lernia, S., Doershuk, J.F., Doolittle, W.E., Edwards, K.J., Erlandson, J.M., Evans, D., Fairbairn, A., Faulkner, P., Feinman, G., Fernandes, R., Fitzpatrick, S.M., Fyfe, R., Garcea, E., Goldstein, S., Goodman, R.C., Dalpoim Guedes, J., Herrmann, J., Hiscock, P., Hommel, P., Horsburgh, K.A., Hritz, C., Ives, J.W., Junno, A., Kahn, J.G., Kaufman, B., Kearns, C., Kidder, T.R., Lanoë, F., Lawrence, D., Lee, G.-A., Levin, M.J., Lindskoug, H.B., López-Sáez, J.A., Macrae, S., Marchant, R., Marston, J.M., McClure, S., McCoy, M.D., Miller, A.V., Morrison, M., Motuzaite Matuzeviciute, G., Müller, J., Nayak, A., Noerwidi, S., Peres, T.M., Peterson, C.E., Proctor, L., Randall, A.R., Renette, S., Robbins Schug, G., Ryzewski, K., Saini, R., Scheinsohn, V., Schmidt, P., Sebillaud, P., Seitsonen, O., Simpson, I.A., Sołtysiak, A., Speakman, R.J., Spengler, R.N., Steffen, M.L., Storozum, M.J., Strickland, K.M., Thompson, J., Thurston, T.L., Ulm, S., Ustunkaya, M.C., Welker, M. H., West, C., Williams, P.R., Wright, D.K., Wright, N., Zahir, M., Zerboni, A., Beaudoin, E., Munevar Garcia, S., Powell, J., Thornton, A., Kaplan, J.O., Gaillard, M.-J., Klein Goldewijk, K., Ellis, E., 2019. Archaeological assessment reveals Earth's early transformation through land use. Science 365, 897-902.

Stevens, C., Fuller, D., 2017. The spread of agriculture in eastern Asia: archaeological bases for hypothetical farmer/language dispersals. Language Dynamics Change 7, 152–186.

Stevens, C.J., Murphy, C., Roberts, R., Lucas, L., Silva, F., Fuller, D.Q., 2016. Between China and South Asia: A Middle Asian corridor of crop dispersal and agricultural innovation in the Bronze Age. The Holocene 26, 1541–1555.

Storozum, M., Liu, H., Qin, Z., Ming, K., Fu, K., Wang, H., Kidder, T., 2018. Early evidence of irrigation technology in the North China Plain: Geoarchaeological investigations at the Anshang Site, Neihuang County, Henan Province, China. Geoarchaeology 33, 143–161.

Storozum, M., Lu, P., Wang, S., Chen, P., Yang, R., Ge, Q., Cao, J., Wan, J., Wang, H., Qin, Z., Liu, H., Park, E., 2020a. Geoarchaeological evidence of the AD 1642 Yellow River flood that destroyed Kaifeng, a former capital of dynastic China. Sci. Rep. 10, 3765.

Storozum, M.J., Qin, Z., Wang, Y.V., Liu, H., 2020b. Buried soils as archives of paleo-pollution in the North China Plain. Anthropocene 31, 100251.

Tang, X., Loewe, M., 2015. The evolution of imperial urban form in Western Han Chang'an. In: Nylan, M., Vankeerberghen, G. (Eds.), Chang'an 26 BCE. University of Washington Press, pp. 55–74.

Tang, Z.-W., Lee, H., Wang, L., Sebillaud, P., Fang, Q., Lee, G.-A., 2020. Plant remains recovered from the Houtaomuga site in Jilin Province, Northeast China: a focus on Phase I (12,900–11,000 cal. BP) and Phase II (8,000–7,000cal. BP). Archaeol. Res. Asia 22, 100192.

Teng, M., 2009. GIS Zhichi Xia de Chifeng Diqu Huanjing Kaogu Yanjiu (GIS-Based Environmental Archaeology Research on the Chifeng Region). Kexue chubanshe, Beijing.

Thomsen, P.F., Willerslev, E., 2015. Environmental DNA – an emerging tool in conservation for monitoring past and present biodiversity. Biol. Conserv. 183, 4–18.

Tsang, Z., 2012. Issues relating to the ancient rice and millet grains unearthed from the archaeological sites in Tainan Science Park. J. Chinese Dietary Culture 8, 1–24.

Turvey, S.T., Crees, J.J., Li, Z., Bielby, J., Yuan, J., 2017. Long-term archives reveal shifting extinction selectivity in China's postglacial mammal fauna. Proc. Royal Soc. B: Biol. Sci. 284, 20171979.

Turvey, S.T., Tong, H., Stuart, A.J., Lister, A.M., 2013. Holocene survival of Late Pleistocene megafauna in China: a critical review of the evidence. Quat. Sci. Rev. 76, 156–166.

Underhill, A.P., Feinman, G.M., Nicholas, L.M., Fang, H., Luan, F., Yu, H., Cai, F., 2008. Changes in regional settlement patterns and the development of complex societies in southeastern Shandong, China. J. Anthropol. Archaeol. 27, 1–29.

Varalli, A., Moggi-Cecchi, J., Moroni, A., Goude, G., 2016. Dietary variability during Bronze Age in central Italy: first results. Int. J. Osteoarchaeol. 26, 431–446.

Vigne, J.-D., Evin, A., Cucchi, T., Dai, L., Yu, C., Hu, S., Soulages, N., Wang, W., Sun, Z., Gao, J., Dobney, K., Yuan, J., 2016. Earliest "domestic" cats in China identified as leopard cat (Prionailurus bengalensis). PLOS One 11, e0147295-e0147295.

Walsh, R., Lee, G.-A., Liu, L., Chen, X., 2016. Millet grain morphometry as a tool for social inference: A case study from the Yiluo basin, China. The Holocene 26, 1778–1787.

Wang, J., Sun, L., Chen, L., Xu, L., Wang, Y., Wang, X., 2016. The abrupt climate change near 4,400 yr BP on the cultural transition in Yuchisi, China and its global linkage. Sci. Rep. 6, 27723.

Wang, J., Zhao, X., Wang, H., Liu, L., 2019. Plant exploitation of the first farmers in Northwest China: Microbotanical evidence from Dadiwan. Quaternary International.

Wang, L., Sebillaud, P., 2019. The emergence of early pottery in East Asia: New discoveries and perspectives. J. World Prehistory 32, 73–110.

Wang, M., Zhu, H., 2004. Minhe Hetaozhuang shiqian wenhua mudi rengu yanjiu (Research on the human bones from the prehistoric cemetary at Hetaozhuang, Minhe), Minhe Hetaozhuang (Hetaozhuang at Minhe County). Kexue chubanshe, Beijing, pp. 281–320.

Wang, Q., 1993. Discussion on the riverbed changes of the Lower Yellow River course and the development of ancient cultures (Shilun shiqian Huanghe xiayou de gaidao yu guwenhua de fazhan). Zhongyuan wenwu 63–72.

Wang, Q., 1999. The geographical context of the water control by the Great Yu (Da Yu zhi shui de dili beijing). Zhongyuan wenwu 34–42.

Wang, T., Yang, L., Wang, L., 2015. Survey results of the Houdiwopu site in Da'an city, Jilin province (Jilin Da'an shi Houdiwopu yizhi de diaocha yu renshi). Bianjiang kaogu yanjiu 9–28.

Wang, Y., 2017. Identifying the Beginnings of Sheep Husbandry in Western China. University of Cambridge.

Waters, C.N., Zalasiewicz, J., Summerhayes, C., Barnosky, A.D., Poirier, C., Gałuszka, A., Cearreta, A., Edgeworth, M., Ellis, E.C., Ellis, M., Jeandel, C., Leinfelder, R., McNeill, J.R., Richter, D.d., Steffen, W., Syvitski, J., Vidas, D., Wagreich, M., Williams, M., Zhisheng, A., Grinevald, J., Odada, E., Oreskes, N., Wolfe, A.P., 2016. The Anthropocene is functionally and stratigraphically distinct from the Holocene. Science 351, aad2622.

Wei, Z.D., Rosen, A.M., Fang, X.Q., Su, Y., Zhang, X.Z., 2015. Macro-economic cycles related to climate change in dynastic China. Quat. Res. 83, 13–23.

Weisskopf, A., Deng, Z., Qin, L., Fuller, D.Q., 2015. The interplay of millets and rice in Neolithic central China: integrating phytoliths into the archaeobotany of Baligang. Archaeol. Res. Asia 4, 36–45.

Williams, J.T., 2014. Staple Economies and Social Integration in North-East China: Regional Organization in Zhangwu, Liaoning, China, Anthropology. Pittsburgh University, Pittsburgh.

Williams, J.T., 2017a. Bronze Age subsistence change at regional and microscopic scales in Northeast China. Asian Perspect. 56, 166–190.

Williams, J.T., 2017b. Use-wear analysis and research on settlement patterns of Bronze Age sites in Zhangwu, Liaoning (Liaoning Zhangwu diqu Qingtong shidai shiqi fenxi yu juluo xingtai yanjiu). Bianjiang kaogu yanjiu 109–124.

Wolverton, S., Lyman, R.L., 2012. Conservation Biology and Applied Zooarchaeology. The University of Arizona Press, Tucson.

Wolverton, S., Nagaoka, L., Rick, T.C., 2016. Applied Zooarchaeology: Five Case Studies. Eliot Werner Publications Inc, New York.

Womack, A., Flad, R., Zhou, J., Brunson, K., Toro, F.H., Su, X., Hein, A., d'Alpoim Guedes, J., Jin, G., Wu, X., Wang, H., 2021. The Majiayao to Qijia transition: exploring the intersection of technological and social continuity and change. Asian Archaeol.

Womack, A., Hein, A., 2018. China Ceramic Petrography Database, Released: 2018-10-30 ed. Open Context.

Wong, E., 2014. One-Fifth of China's Farmland Is Polluted, State Study Finds, New York Times, New York, p. A7.

Wu, L., Zhu, C., Zheng, C., Ma, C., Wang, X., Li, F., Li, B., Li, K., 2014. Impact of Holocene climate change on the prehistoric cultures of Zhejiang region, East China. J. Geog. Sci. 24, 669–688.

Wu, W., Liu, T., 2004. Possible role of the ''Holocene Event 3'' on the collapse of Neolithic Cultures around the Central Plain of China. Quat. Int. 114, 153–166.

Wu, X., Zhang, C., Goldberg, P., Cohen, D., Pan, Y., Arpin, T., Bar-Yosef, O., 2012. Early pottery at 20,000 years ago in Xianrendong Cave, China. Science 336, 1696–1700.

Xibei daxue wenhua yichan yu kaoguxue yanjiu zhongxin, Shaanxi sheng kaogu yanjiusuo, 2005. Xunyi Xiaweiluo (Xiaweiluo of Xunyi). Kexue Chubanshe, Beijing.

Xie, L., 2018. Scapulae for shovels: Does raw material choice reflect technological ease and low cost in production? J. Archaeol. Sci. 97, 77–89.

Xie, L., Kuhn, S.L., Sun, G., Olsen, J.W., Zheng, Y., Ding, P., Zhao, Y., 2015. Labor costs for prehistoric earthwork construction: Experimental and archaeological insights from the Lower Yangzi Basin, China. Am. Antiq. 80, 67–88.

Xie, L., Lu, X., Sun, G., Huang, W., 2017. Functionality and morphology: Identifying *si* agricultural tools from among Hemudu scapular implements in Eastern China. J. Archaeol. Method Theory 24, 377–423.

Xu, T., 2006. Archaeological achievements and thoughts on the Zhougongmiao site (Zhougongmiao yizhi de kaogu shouhuo ji suosi). Wenwu 55–62.

Yan, H., Liguang, S., Wang, Y., Liu, X., Qiu, S., Cheng, W., 2010. A 2000-year record of copper pollution in South China Sea derived from seabird excrements: a potential indicator for copper production and civilization of China. J. Paleolimnol. 44, 431–442.

Yang, Y., Ren, L., Dong, G., Cui, Y., Liu, R., Chen, G., Wang, H., Wilkins, S., Chen, F., 2019. Economic change in the prehistoric Hexi Corridor (4800–2200 BP), North-west China. Archaeometry.

Yao, A., 2016. The Ancient Highlands of Southwest China: From the Bronze Age to the Han Empire. Oxford University Press, Oxford.

Yao, A., Jiang, Z., Chen, X., Liang, Y., 2015. Bronze Age wetland/scapes: Complex political formations in the humid subtropics of southwest China, 900–100 BC. Journal of Anthropological Archaeology 40, 213-229.

Yasuda, Y., Fujiki, T., Nasu, H., Kato, M., Morita, Y., Mori, Y., Kanehara, M., Toyama, S., Yano, A., Okuno, M., Jiejun, H., Ishihara, S., Kitagawa, H., Fukusawa, H., Naruse, T., 2004. Environmental archaeology at the Chengtoushan site, Hunan Province, China, and implications for environmental change and the rise and fall of the Yangtze River civilization. Quat. Int. 123–125, 149–158.

Ye, W., Hein, A., 2020. A buried past: five thousand years of (pre) history on the Jing-Wei floodplain. Asian Archaeol.

Yi, S., Lu, H., Zeng, L., Xu, Z., 2013. Paleoclimate changes and reconstruction of the border of the Horqin dunefield (Northeastern China) since the last glacial maximum (Moci chengbingqi yilai Ke'erqin shadi guqihou bianhua jiqi bianjie chongjian). Disiji yanjiu 206–217.

Yuan, G., 2021. Kaoguxue shiyexia de Huanghe gaidao yu wenming bianqian (Course changes of the Yellow River and changes in civilization from the perspective of archaeology). Zhongguo Shehui Kexue 123–143.

Yuan, J., 2015. Zhongguo Dongwu Kaogu Xue (Zooarchaeology of China). Wenwu Chubanshe, Beijing.

Yuan, J., 2020. Rethinking the origins of animal domestication in China. Chinese. Archaeology.

Yue, J.-P., Li, Y.-Q., Yang, S.-X., 2019. Neolithisation in the southern Lesser Khingan Mountains: lithic technologies and ecological adaptation. Antiquity 93, 1144–1160.

Zalasiewicz, J., Waters, C.N., Williams, M., Barnosky, A.D., Cearreta, A., Crutzen, P., Ellis, E., Ellis, M.A., Fairchild, I.J., Grinevald, J., Haff, P.K., Hajdas, I., Leinfelder, R., McNeill, J., Odada, E.O., Poirier, C., Richter, D., Steffen, W., Summerhayes, C., Syvitski, J.P.M., Vidas, D., Wagreich, M., Wing, S.L., Wolfe, A.P., An, Z., Oreskes, N., 2015. When did the Anthropocene begin? A mid-twentieth century boundary level is stratigraphically optimal. Quat. Int. 383, 196–203.

Zeder, M., 2012a. The broad spectrum revolution at 40: Resource diversity, intensification, and an alternative to optimal foraging explanations. J. Anthropol. Archaeol. 31, 241–264.

Zeder, M.A., 2012b. The domestication of animals. J. Anthropol. Res. 68, 161–190.

Zeder, M.A., 2012c. Pathways to animal domestication. In: Gepts, P., Famula, T.R., Bettinger, R.L., Brush, S.B., Damania, A.B., McGuire, P.E., Qualset, C.O. (Eds.), Biodiversity in Agriculture: Domestication, Evolution, and Sustainability. Cambridge University Press, Cambridge, pp. 227–259.

Zhang, D.D., Jim, C., Lin, G.C., He, Y.-Q., Wang, J.J., Lee, H.F., 2006. Climatic change, wars and dynastic cycles in China over the last millennium. Clim. Change 76, 459–477.

Zhang, D.D., Zhang, J., Lee, H.F., He, Y.-Q., 2007. Climate change and war frequency in Eastern China over the last millennium. Human Ecol. 35, 403–414.

Zhang, H., Merrett, D.C., Jing, Z., Tang, J., He, Y., Yue, H., Yue, Z., Yang, D.Y., 2016. Osteoarchaeological studies of human systemic stress of early urbanization in late Shang at Anyang. China. PLoS One 11.

Zhang, S., Yang, Y., Storozum, M.J., Li, H., Cui, Y., Dong, G., 2017. Copper smelting and sediment pollution in Bronze Age China: a case study in the Hexi corridor, Northwest China. CATENA 156, 92–101.

Zhang, X., Zhao, X., Cheng, L., 2011. Human diets of Yangshao Culture in the Central Plains. Chinese Archaeol. 11, 188–196.

Zhang, Z., Chen, Z., Marshall, F., Lü, H., Lemoine, X., Wangyal, T., Dorje, T., Liu, X., 2019. The importance of localized hunting of diverse animals to early inhabitants of the Eastern Tibetan Plateau at the Neolithic site of Xiaoenda. Quat. Int. 529, 38–46.

Zhao, C., 2020. The Climate Fluctuation of the 8.2 ka BP Cooling Event and the Transition into Neolithic Lifeways in North China. Quaternary 3.

Zhao, S., Xia, D., Jin, H., Wen, Y., Liu, J., Liu, B., Li, G., 2013. High-resolution climate evolution records of the Horqin sandy land since about 5000 cal aB.P. (Ke'erqin shadi guoqu jin 5000 nian gaofenbianlü qihou yanbian). Disiji yanjiu 283–292.

Zhao, Z., 2009. Eastward spread of wheat into China: New data and new issues, in: Liu, Q., Bai, Y. (Eds.), Chinese Archaeology - Volume Nine. China Social Press, Beijing, pp. 1-9.

Zhao, Z., 2011. New archaeobotanic data for the study of the origins of agriculture in China. Curr. Anthropol. 52, S295–S304.

Zheng, Y., Sun, G., Qin, L., Li, C., Wu, X., Chen, X., 2009. Rice fields and modes of rice cultivation between 5000 and 2500 BC in east China. J. Archaeol. Sci. 36, 2609–2616.

Zhongguo Shehui Kexue Yuan Kaogu Yanjiu Suo, 2007. Jiaodong Bandao Beiqiu Yizhi Huanjing Kaogu (Shell Midden Sites in the Jiaodong Peninsula Studies in Environmental Archaeology). Shehui kexue wenxian chuban she, Beijing.

Zhongguo Shehui Kexue Yuan; Shaanxi Sheng Xi'an Banpo Bowuguan, 1962. Xi'an Banpo—Yuanshi Shizu Gongshe Juluo Yizhi (The Neolithic Village at Banpo). Wenwu Chubanshe, Beijing.

Zhou, L., Garvie-Lok, S.J., 2015. Isotopic evidence for the expansion of wheat consumption in northern China. Archaeol. Res. Asia 4, 25–35.

Zhou, L., Garvie-Lok, S.J., Fan, W., Chu, X., 2017. Human diets during the social transition from territorial states to empire: Stable isotope analysis of human and animal remains from 770BCE to 220CE on the Central Plains of China. J. Archaeol. Sci.: Rep. 11, 211–223.

Zhou, L., Yang, S., Han, Z., Sun, L., Garvie-Lok, S.J., 2019. Social stratification and human diet in the Eastern Zhou China: an isotopic view from the Central Plains. Archaeol. Res. Asia 20, 100162.

Zhou, X., Li, X., Dodson, J., Zhao, K., 2016. Rapid agricultural transformation in the prehistoric Hexi corridor, China. Quat. Int. 426, 33–41.

Zhou, X., Yu, J., Spengler, R.N., Shen, H., Zhao, K., Ge, J., Bao, Y., Liu, J., Yang, Q., Chen, G., Jia, P.W., Li, X., 2020. 5,200-year-old cereal grains from the eastern Altai Mountains redate the trans-Eurasian crop exchange. Nat. Plants 6, 78–87.

Zhu, W., Tang, W., Dou, J., 2013. Formation and evolution of the ancient riverbed of the Nen River (Nenjiang liuyu gu hedao de xingcheng yu yanhua). Dixia shui, 85–86 and 115.

Zhuang, Y., Kidder, T.R., 2014. Archaeology of the Anthropocene in the Yellow River region, China, 8000–2000 cal. BP. The Holocene 24, 1602–1623.

Zhuang, Y., Lee, H., Kidder, T.R., 2016. The cradle of heaven-human induction idealism: agricultural intensification, environmental consequences and social responses in Han China and Three-Kingdoms Korea. World Archaeol. 48, 563–585.

Zong, Y., Chen, Z., Innes, J.B., Chen, C., Wang, Z., Wang, H., 2007. Fire and flood management of coastal swamp enabled first rice paddy cultivation in east China. Nature 449, 459–462.