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# Dams, moats, and cities: climate and societies in late-Holocene China

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*Abstract:* Whilst the late-Holocene climate was becoming drier with an increasing number of climatic anomalies, with notably more frequent fluctuations in summer rainfall on an annual or decadal scale, many walled sites or cities emerged and became regional centres that witnessed population agglomeration and technological flowering. To feed their growing populations and their increasing demands on land, water, food, and other resources, these 'cities' were drawn closer physically to riverine environments and wetlands. By diversifying and intensifying their subsistence strategies, and constructing infrastructure on a colossal scale, these late-Holocene walled towns or cities also fundamentally transformed their local landscapes. Examining key sites from the Huai river and the Yangtze Delta, this paper will compare the dynamic interactions between society, landscape, and the environment under different socio-economic conditions across different regions of late-Holocene China and investigate how these factors influenced and led to the emergence of complex societies or early states.

*Keywords:* Water management, moats, dams, late Holocene, Liangzhu, China.

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## Introduction

The middle to late Holocene (*c.* 6000–4000 BP) saw the rise of several early urban centres and their hinterlands across different regions of the Eurasian Continent. These centres included the Mesopotamian city of Uruk and its contemporaries, which began as early as the mid-4th millennium BC (Algaze 1993, 2009), the Harappa culture in the Indus Valley, consisting of several large-scale urban sites such as the Harappa, Mohenjo-Daro, and Dholavira sites (Coningham & Young 2015, Giosan *et al.* 2012, Petrie *et al.* 2017), and many Chinese late-Neolithic walled sites (Liu & Chen 2012). The development of these early urban centres coincided with pronounced population growth, technological innovation, and increasing regional interaction. These changes also coincided with a marked decrease in the rate of Holocene sea-level rise (Fleming *et al.* 1998). Local ecosystems around major rivers and their tributaries and coastal areas enjoyed high productivity and a rich biomass (Pennington *et al.* 2016, 2017). These early urban centres were drawn to such rich ecological habitats during their rapid socio-economic expansion when the late-Holocene climate was getting drier. Being drawn in this way, these centres were faced with a new kind of environmental–societal dynamic; that is, whilst they were able to harness favourable ecological conditions and transform them into economic benefits to support population growth and urban expansion, they had to deal with the unprecedented social and ecological consequences which resulted from their intensified exploitation of these new habitats. One of the consequences was the increasing need for better adaptations to the fluctuations of these alluvial systems. It was these new socio-ecological circumstances that pushed these early urban centres to respond to changing water situations in diverse and indeed dramatic ways.

This article draws on recent archaeological and environmental data from some late-Holocene urban centres in the Yangtze Delta and Huai river of China (Figure 1), and compares the dynamic interactions between society, landscape, and the environment under different socio-economic conditions between these two regions of late-Holocene China. I explore the trajectories through which these walled sites gradually rose to become urban centres or towns in their respective regions. Geoarchaeological and excavation evidence clearly illustrates the different choices for settlement locations within the wider spectrum of the environments of the respective regions and diverse considerations for water management strategies at these sites. Such detailed information also allows us to disentangle changing attitudes towards maintaining water management infrastructure in and around these early urban centres or towns and reconsider the heated debate surrounding the ‘collapse’ or ‘demise’ of these early urban centres.


**Figure 1.** Main sites mentioned in the text.

## Late-Holocene environment and climate in China

The pattern of middle to late-Holocene climate change in China roughly correlates with the observed changes in other regions of Asia, such as in South and Southwest Asia. As demonstrated by analyses of high-resolution speleothem geochemical data, after reaching its peak during the middle Holocene, the East Asia Summer Monsoon (EASM) gradually lost its strength from 6000 BP onwards, resulting in a slow but steady decrease in annual rainfall (Chen *et al.* 2015, Clift & Plumb 2008, Wang *et al.* 2005). More significantly, short-term temporal variations in precipitation became normal (Jiang *et al.* 2013). This increased climate seasonality, characterised by both decreased precipitation and more weather extremes such as droughts and floods, would have posed severe threats to established agrarian societies which were becoming increasingly reliant on predictable monsoon seasonality for food production. This trend of deteriorating climatic conditions continued, punctuated by a pronounced drop in summer rainfall around 4200 BP, marking the so-called 4.2 ka BP event, that is also recognised in other parts of the Eurasian Continent (Dixit *et al.* 2014, Staubwasser *et al.* 2003, Weiss 2017), even though the exact timing of this dramatic Holocene climate event in China remains to be further attested.

In addition to this temporal variation in summer rainfall, the EASM is also the decisive factor shaping the spatial patterning of annual precipitation across different regions of China. Southeast China and much of the Lower Yangtze river regions are situated at the forefront of the EASM and thus receive ample precipitation brought in by the EASM. Rainfall is concentrated during the summer months (May/June to August/September). The low-lying areas in these regions are particularly vulnerable to floods caused by concentrated summer rainfall. Floods and prolonged inundation under water are detrimental to rice farming, especially when rice is at the flowering and milking stages. Solutions to mitigate these risks include raising ground for the construction of residential space, digging canals for greater control and regulation of water, and building high dams for large-scale water management and control (see Mo & Zhuang 2018). The monsoon is gradually weakened as it moves further north to different parts of the Huai river in the central Plains and the middle–lower Yellow river regions, but it is still strong enough to produce sufficient precipitation for agriculture and other subsistence needs. The construction of water management infrastructure such as moats and canals further enhances a society's capacity to deal with an imbalance in seasonal or annual water distributions and the associated consequent challenges.

## From Yangshao to Longshan and Majiabang to Liangzhu: paths to social and economic intensification

Benefitting from the favourable climatic and environmental conditions during the Middle Holocene, the Yangshao culture (7000–5000 BP) along the Southern Loess Plateau, the Lower Yellow river, and neighbouring regions (Table 1) experienced a pronounced elaboration from the early to middle–late Yangshao period. Not only did the settlement numbers and settlement density increase to a much higher level than previously (Wagner *et al.* 2013), but very large-sized central settlements also occurred, forming a typical multiple-tier relationship between large and small sites in several key regions, such as the Guanzhong Basin of the Southern Loess Plateau and the Yiluo river valley of the Middle–Lower Yellow river. The size of large settlements reached

**Table 1.** Chronologies and geographical locations of the Neolithic cultures mentioned in the text.

| *Culture* | *Timespan* | *Geographical location* |
|---|---|---|
| Yangshao | 7000–5000 BP | Middle and Lower Yellow river valleys, including the southern and middle parts of the Loess Plateau, the Central Plains, and some intermediate regions such as the Nanyang Basin in Henan |
| Longshan | 4600–4000/3900 BP | Overlaps with the geographic extension of the Yangshao culture, but with a significant presence in Shandong |
| Majiabang | Early to middle Majiabang, 7000–6300 BP<br>Late Majiabang, 6300–6000 BP | Around the Taihu Lake region, especially its Middle and Northern parts |
| Songze | 6000–5300 BP | Almost the same geographical area as Majiabang, with some sites scattered in the southern part of Taihu |
| Liangzhu | 5300–4300 BP | Hangjiahu Plain and Ningshao Plain, with a strong tendency to territorial expansion |

around 80 ha (for example, the Yangguanzhai site, 5700–5300 BP (Wang *et al.* 2011)), within which large houses measuring as much as 240 $m^2$ (for example, at the Xipo site, 6000–5300 BP (Li *et al.* 2005)) appeared, probably for special functions. Evidence of social stratification also emerged at several cemeteries, where rich burials contained some elaborate objects such as jade that was obtained through long-distance exchange while poor burials contained only a few very simply made ceramic vessels (Zhang 2015). These new developments culminated in the appearance of walled sites, which paved the way for further socio-economic intensification and social stratification during the succeeding Longshan period. The continuous development of millet farming and other aspects of farming innovation, including the spread of rice farming in regions that had favourable environmental and hydrological conditions, greatly pushed up agricultural yields, feeding an ever-growing population at these Yangshao culture sites. At the Yuhuazhai site, for instance, millet farming had eventually gained a predominant position in this subsistence economy during the late Yangshao period (5500–5000 BP) (Z.J. Zhao 2017).

Although in some regions the quantity of settlement sites decreased from the Yangshao to Longshan periods (*c.* 4600–3900 BP) according to survey data, this does not necessarily suggest a decrease in regional population numbers. Rather, societies were experiencing fundamental social restructuring and reorganisation during the Longshan period (for example, in the Huai river catchments), leading to the emergence of mega urban centres within which populations were more concentrated. According to systematic regional surveys, the population density in regions such as the coastal areas of present-day Shandong Province during the Longshan period was higher even than during the early imperial period (for example, Han Dynasty, 202 BC–220 AD) (Underhill *et al.* 2002). The latter period is often considered to mark a demographic peak in ancient China. More and more of the population was being drawn into these late Neolithic mega urban centres or their surrounding areas (Stevens & Fuller 2017). The considerable increase in carrying capacity of these urban centres was materialised through (1) the expansion of settlements and/or reclamation of new farming lands around these large settlements; (2) the development of new farming strategies; and (3) the formation of new economic structures. The reconstructed economic pattern at the Taosi walled site (4300–3900 BP) and its contemporary sites are good examples of this third point. Zooarchaeological research has provided evidence of the exploitation of domesticated sheep for different purposes at Taosi, including the possibility of wool production (Brunson *et al.* 2015). The Taosi people might have monopolised stone tool production through controlling raw materials and other resources (Liu *et al.* 2013, Zhai 2015). This tendency towards economic specialisation would have created changes in economic structure, leading to increasing economic exchange within the region and further stimulating economic production. The Longshan period between the Yellow river and the Huai river saw the coming and going of new cultivars. Apart from the arrival of domesticated sheep just mentioned, many other new crops also contributed to the intensification and diversification of agricultural systems during the Longshan period in different areas of the region. At many sites, a multi-cropping system was established, in which rice, soybean, azuki bean, and other crops and plants became important additions to the existing millet farming system (Fuller & Stevens 2019 and references therein; Fuller & Zhang 2007). The cultivation of these new crops not only greatly contributed to the increased agricultural yields, but also came with fundamentally transformed water management practices in the regions, which we will explore below.

In the Taihu Lake region around the Yangtze Delta, a clear process of economic intensification and social reorganisation can be seen in the transition from the early–middle Majiabang culture (7000–6300 BP) to the late Majiabang culture (6300–6000 BP)—the Songze culture (6000–5300 BP). After the relatively quick spread of rice farming in the early Majiabang period, as evidenced by the discovery of rice remains at many early Majiabang sites such as Luojiajiao (7300–6900 BP) (Zheng *et al.* 2007, Zhu 2004) and Longqiuzhuang (7000–5500 BP (Longqiuzhuang Archaeological Team 1999)), continuous rice farming saw a dramatic increase in production during the late Majiabang period thanks to farming innovations and intensified water management (Zhuang 2018). The number of late Majiabang sites increased significantly from the early to middle Majiabang period (Zhuang 2018: 96). Rice fields were constructed and used at many Majiabang culture sites and the scale of these fields continued to increase. Forty-six paddy fields were unearthed at the Chuodun site (*c.* 6000 BP). The fields were small, averaging approximately 1–10 $m^2$. Associated water management features such as ditches and ponds were also found. By the Songze period, the size of paddy fields had increased to up to 100 $m^2$ at the Chenghu site (Ding 2004), indicative of large-scale rice farming. The establishment of a mature rice farming system during the late Majiabang period (Ma 2016) further stimulated settlement growth in the region. More than seventy late Majibang sites have been identified (Chen 2018). Social stratification began to emerge. At the Dongshancun site (6000–5300 BP), rich graves probably belonging to military elite (for example, burial no. M101) who were buried with abundant jade items as well as other elaborate objects, whilst other graves contained far fewer elaborate objects, indicative of the emergence of social and military power.

The economic developments and social changes during the Majiabang period and the succeeding Songze period laid solid foundations for the rapid urbanisation and social stratification that occurred during the Liangzhu period (5300–4300 BP); although the direct relationship between the Majiabang–Songze cultures and the Liangzhu culture remains to be further elucidated. The enormous scale of the Liangzhu centre, the elaborate material culture centred on the production and usage of jade as a prominent marker of social stratification, and the radical influence of the Liangzhu centre on the region as demonstrated by the well-structured regional settlement patterns, has been intensively studied by scholars over the past decade (Liu *et al.* 2020, Qin 2013). A fine division in different economic sectors of Liangzhu society was taking shape by the Liangzhu period. It is believed that the Liangzhu elites living in the Liangzhu city not only controlled the circulation of jade raw material but also monopolised the production of the most elaborate Liangzhu jade types (for example, *cong* tubes and three-pronged objects) and their motifs. There were also other jade workshops within or outside the Liangzhu city that were specialising in the production of other less elaborate jade types (Fang 2020, Qin 2020).

Liangzhu society was heavily reliant on rice as the staple food. Carbonised rice remains have been found at many Liangzhu culture sites through systematic archaeobotanical research (Zheng 2018: Table 1). Of particular importance are the discoveries of rice storage spaces at the Liangzhu city and the well-preserved rice paddy fields at the Maoshan site. The former consists of several locations (six) where abundant carbonised rice remains have been recovered from recent excavations. At the Chizhongsi location of the Liangzhu city, for instance, carbonised rice remains up to one metre in thickness are preserved in an area of approximately tens of thousands of square metres. The estimated volume of rice storage at this location alone reaches around 100,000 kg. Zheng (2018) estimates that the average yield of rice per *mou* (a Chinese measuring unit, *c.* 666 $m^2$) during Liangzhu was *c.* 141 kg, close to the level of production per *mou* during the historical Han period (150–180 kg). Though this is higher than Zhao's estimation (100 kg per *mou* (H. Zhao 2017)), it nonetheless suggests that the productivity of Liangzhu rice farming had already reached a high level and that the Liangzhu city was able to extract a large amount of rice yield from small production units. Indeed, the concentration of rice at the Liangzhu city also convincingly demonstrates that an exploitative economic structure was already in place during the Liangzhu period. It is believed that through this system the Liangzhu city was able to exploit, acquire, and attract growing economic resources, such as rice and other economic resources, through various ways from its neighbouring sites. The Maoshan site (4700–4200 BP) might be one of the farming villages that supplied rice to the elites at the Liangzhu city. The excavation at the Maoshan site reveals the structure of a typical village during the Liangzhu period that was composed of a residential area (small houses and graves) and its economic agricultural production zone (paddy fields). The Maoshan village was occupied for a long period of time. Two phases of paddy fields located in the low-lying area to the south of the village were constructed and used. The transition from the early to late phase saw a dramatic increase in the scale of rice farming. The size of a single paddy field increased from a maximum of 30–40 m$^2$ in the early phase to between 1000–2000 m$^2$ in the late phase. This increased scale of rice cultivation was accompanied by intensified water management. Many natural creeks, artificial canals and ditches, and other water management features were used during the late phase (Zhuang *et al.* 2014). As scholars have pointed out, this intensification process of rice farming represents the growth of the Maoshan village from a small village with a sparse population to a larger village with a correspondingly larger population and more economic investment and production (Zheng 2018). The reclamation of the paddy fields and the construction and maintenance of water management facilities suggests that the organisation of production at Maoshan during the late phase did not operate on a single household level but rather on a collective, village level, which was possibly under the direct management of a higher level organisation.

## The Liangzhu hydraulic system and water management practice

The Liangzhu city was constructed through several large-scale earthworks and infrastructural projects. An enormous mound, Mojiaoshan, 9–15 m high, was built in the middle of the city, measuring *c.* 30 ha, atop which palatial buildings and several rows of houses (35 in total) were built on three smaller mounds, Damojiaoshan, Xiaomojiaoshan, and Wuguishan. Between these buildings was a plaza covered with sand, reaching *c.* 7 ha in size. Surrounding the Mojiaoshan mound were other smaller mounds and other earthen works that were built and used for residences, cemeteries, and other purposes. The Liangzhu city walls were composed of two circles. The contiguous inner circle formed a round-cornered square shape, whilst the outer circle formed an irregular shape in plan-view to the east and south of the inner circle. The third large infrastructural project was the hydraulic system located to the north and northeast of the Liangzhu city. An equally enormous amount of labour and economic resources was invested into building the eleven dams (high and low dams) and the double levees (Tangshan) (Table 2).

The construction and operation of this enormous hydraulic enterprise represents the greatest achievement in altering the hydrological environment and harnessing hydrological-related resources in prehistoric China (cf. Scarborough 2017). The dams formed three reservoirs. Their capacity volumes were 0.34, 13.09, and 32.92 $m^3$, respectively, according to an estimation by hydraulic engineers from Hohai University, Nanjing. This estimate was conducted by adopting the simple principal that water naturally flows from higher places to lower places by gravity. From different water levels of the dams, vast areas would have been submerged. For instance, the low dam would have inundated an area of at least 1500 ha if the water level of the dam was 11 m above sea level (Figure 2).

The double levees at Tangshan, situated right in front of the Tianmu Mountains, have a more complicated structure than other parts of the hydraulic system. The eastern part of the Tangshan is composed of the double levees with several ditches located by the corner of the levees where they extend eastward. Two water outlets have been found in the middle part of the levees. In the western part, the double levees merge into a single one. To the south of the levees were several small mounds. The entire structure at Tangshan was likely to have been designed for sophisticated water

**Table 2.** Dimension of the dams and levees, and calculation of the amount of earth removed, after Liu *et al.* (2017).

| *Dam* | *Shape and dimension (m)* | *Amount of earth removed ($m^3$)* |
|---|---|---|
| Tangshan levee | 6,700 long, foot 50 wide, top 24 wide, and 8 high | (50+24)×8÷2×6700=1,983,200 |
| Low dams (Shizishan, Liyushan, Guanshan, and Wutongnong) | 1,000 long, foot 50 wide, top 24 wide, and 8 high | (50+24)×8÷2×1000=296,000 |
| High dam (Ganggongling) | Foot 80 long, top 200 long, bottom 140 wide, top 80 wide and 80 high | (140+80)×21÷2×140=323,400 |
| High dam (five in total) | 470 long, foot 100 wide, top 20 wide and 10 high | (100+20)×10÷2×470=282,000 |
| Total | | 2,884,600 |

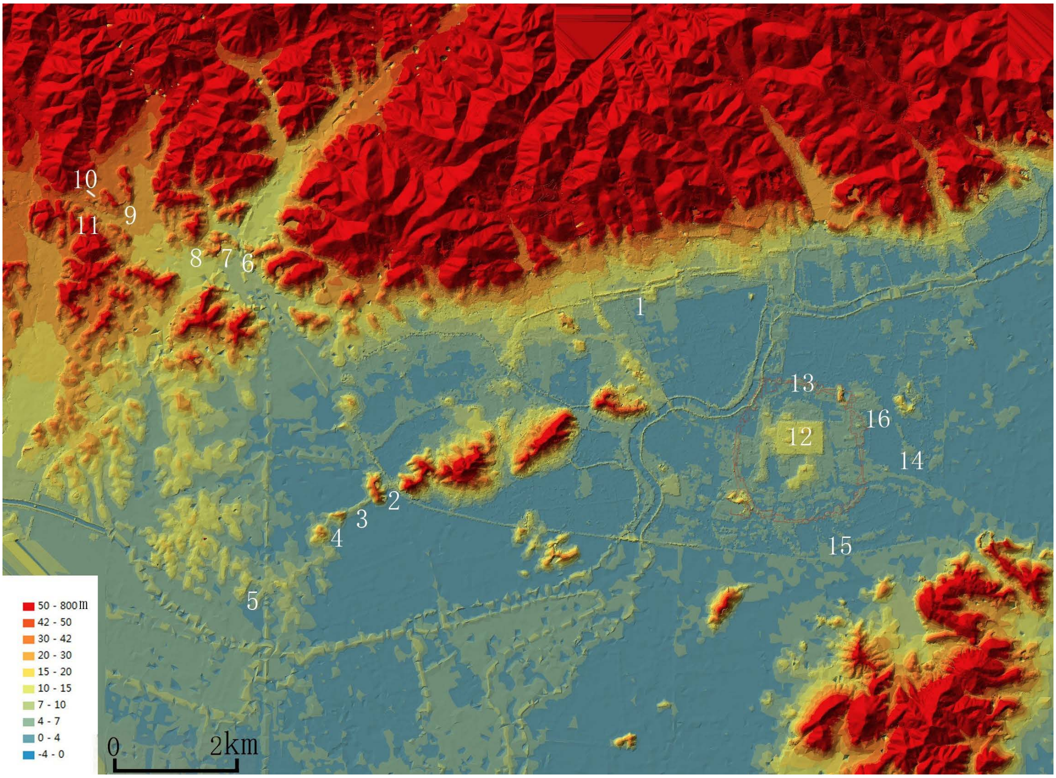


**Figure 2.** Digital Elevation Model map of the Liangzhu site complex, with locations of important discoveries mentioned in the text. 1, Tangshan Levee; 2, Shizishan dam; 3, Liyushan dam; 4, Guanshan dam; 5, Wutongnong dam; 6, Ganggongling dam; 7, Laohuling dam; 8, Zhoujiafan dam; 9, Qiuwu dam; 10, Shiwu dam; 11, Mifengnong dam; 12, Mojiaoshan mound; 13, northern section of the inner city walls; 14, eastern limit of outer city walls; 15, Meirendi; 16, Bianjiashan. The inner city walls form a near circle (note the 'water gates' as indicated by the gaps), while the outer city walls are distributed discontinuously. Meirendi (no. 15) and Bianjiashan (no. 16) were parts of the outer city walls.

management purposes, although the exact functions remain to be studied in further detail. Recently, several locations where spillways were possibly fitted have been identified. Preliminary excavations show that these locations were built directly on top of the geological bedrock, often 1–2m lower than the top of the dam; these conditions made them ideal locations to release overflow during a high water table inside the reservoirs, and also reduced water erosion and flood damage (personal communication with Professor Ningyuan Wang).

The above suggests that Liangzhu society was able to build and manage the hydraulic system based on their understanding of a scientific knowledge of hydraulic engineering and their ability to organise the required logistic support for the construction and maintenance of this complex technology. Similarly, the control of the water by Liangzhu society was on an enormous scale which required unprecedented centralised organisation and coordination.

The hydraulic system must have been multifunctional. One of the functions would have been for water transportation. The large water bodies in the reservoirs, for instance, would have significantly improved the navigational conditions on the otherwise hilly landforms near the mountains and thus promoted the transportation of natural sources from the mountainous area to the north of the hydraulic system to the Liangzhu city. Our geological survey and petrological study of the stone bases of the Liangzhu city walls have confirmed that most stones used at the construction sites of the Liangzhu city came from the mountains to the north and west of the city and the hydraulic system (Wang *et al.* in press). The Liangzhu builders collected readily available stones from various source areas in the surrounding mountains and environments and transported them through the well-connected water system to the construction sites at the Liangzhu city. This reconstructed water network, based on a simulation by synthesising data from coring surveys, satellite imaginary information, and other sources, connects the water bodies in and around the hydraulic system with the canals and ditches inside and outside of the Liangzhu city (Wang *et al.* in press). The average transportation distance, according to our simulation mentioned above, is around 3–4 km on water, most likely using bamboo rafts as the means of transportation (Figure 3).

Another function of the Liangzhu hydraulic system would have been to modulate and regulate the uneven distribution of rainfall water in the region. As mentioned above, heavy summer rainfall bought about by the abnormal summer monsoons would have posed a devastating threat to society. The modern Dongtiao river, surrounding the Liangzhu city site, remains a great threat to Hangzhou city during the summer rainfall season. Very high levees have been built and are carefully monitored by the city government. Modern residents often speak of the horrors of these summer floods, which inundated their houses and caused severe damage to property and livelihoods, which they encountered every summer before the levees were built. There is to date no evidence of flooding deposits found inside the Liangzhu city. Does this mean that the Liangzhu city did not encounter severe floods during the length of its occupation due to the successful operation of its impressive hydraulic system? To answer this question would require more systematic investigation and scientific evidence. It is likely that the hydraulic system would have played a key role in redistributing water during the draught seasons for irrigation and other purposes, although there is similarly no firm evidence of this as yet.

However, there is no doubt that Liangzhu society dedicated considerable energy and resources to the construction and functioning of its enormous hydraulic system, which in turn had far-flung implications for the social development of Liangzhu. This

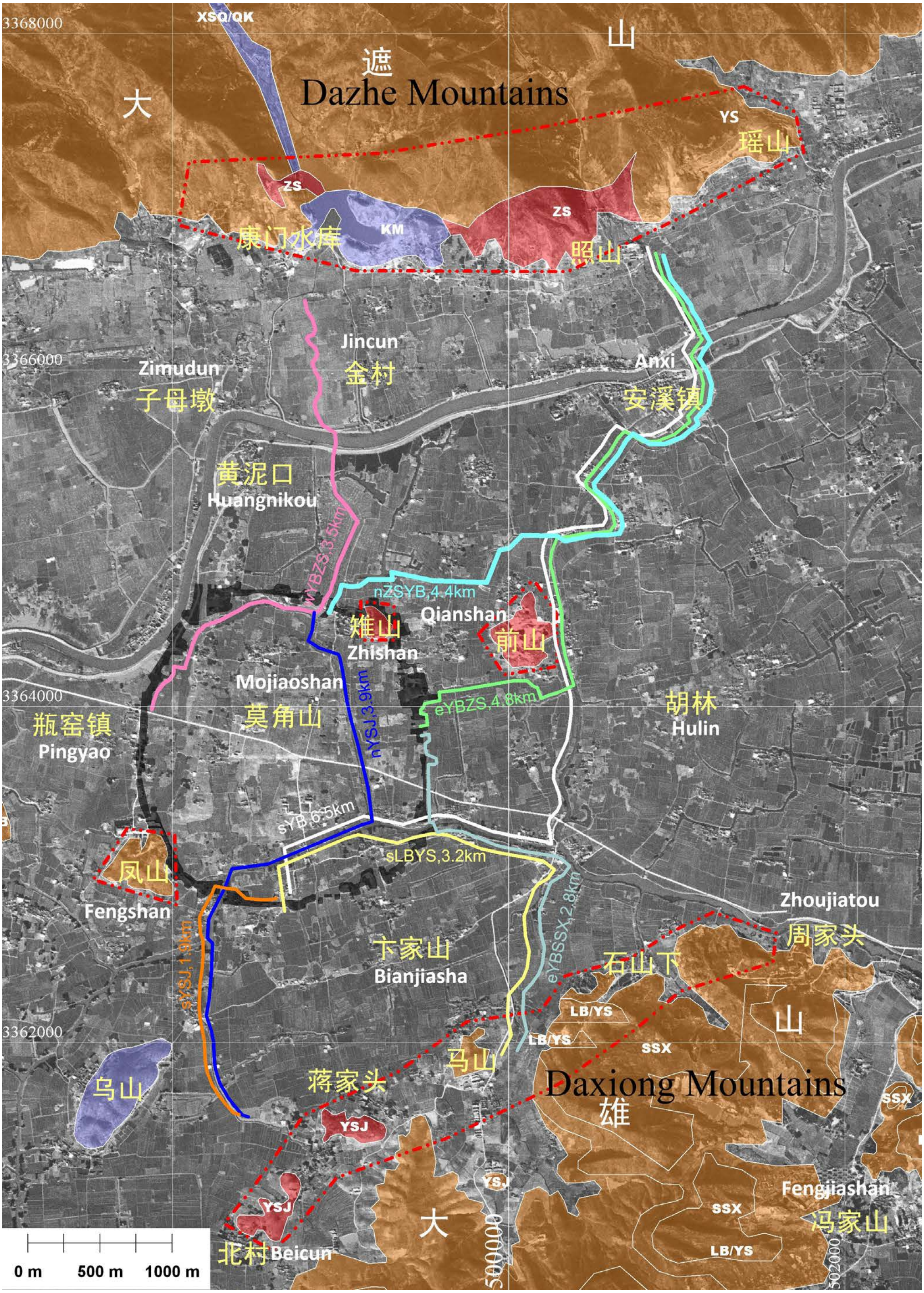


**Figure 3.** Reconstructed transportation routes and distances between the source areas and the Liangzhu city. Transportation routes are marked in pink, light blue, dark blue, green, yellow, and orange lines.

prompts the popular assertion that only a state-level society could have achieved such a sophisticated level of infrastructural investment and operation. Some of the elements of the relationship between state development and the hydraulic enterprise at Liangzhu, including its sheer scale of operation and state-level organisation behind this operation, might fit well into the classic theories developed by Wittfogel and other scholars on so-called ‘hydraulic societies’ (Wittfogel 1957). Nevertheless, it should also be noted that the Liangzhu hydraulic enterprise and other infrastructural projects were certainly built in multiple periods through a piecemeal process.

The 30-km-long water network inside the Liangzhu city consists of artificial canals, water gates, and other features such as piers, criss-crossing the entire city. However, evidence from a recent excavation at the Zhongjiagang canal shows that some of the features were not always well looked after during its ‘lifecycle’ of use. The Zhongjiagang canal was indeed used for a long time. It experienced three major episodes of changes throughout its ‘life cycle’. The width of the canal shrank significantly and its depth became gradually shallower, being filled up with domestic waste, mostly from the palatial area nearby. This would mean a significant reduction in the volume and carrying capacity of the water in this canal. The top of the canal was covered by a layer of sandy deposits, indicating there were localised flooding events, flushing sediments into the canal before it was completely filled up and finally abandoned. We do not know whether this was a common situation facing all the canals and artificial waterways in the city. Given the important location of the Zhongjiagang canal, next to the Mojiaoshan palatial mound, it is likely that it would normally have received careful maintenance. It may be possible that during the late Liangzhu period, Liangzhu society failed to properly maintain the water network immediately surrounding their living space. This lack of care might have made them less prepared for and become more vulnerable to floods.

## The Longshan period water management system: Guchengzhai and Pingliangtai

The Liangzhu city was the sole mega-centre in the Liangzhu culture region. Although there were other sub-centres in the region (for example, the Fuquanshan site), some also with a well-planned settlement structure and water-management infrastructure (for example, the Yujiashan site), none of them had earthen walls or came close to the Liangzhu city in terms of scale of construction and day-to-day operation. In contrast to this, the Longshan period walled sites between the Yellow and the Huai rivers of the Central Plains demonstrate a different regional settlement pattern. There is a clear lack of a sole mega-centre like that at the Liangzhu city in the region between the

**Table 3.** Longshan period walled settlements and their size.

| *Site* | *Size (ha)* |
|---|---|
| Wangchenggang | 1.2 |
| Puchengdian | 1.4–1.9 |
| Haojiatai | 3.3 |
| Pingliangtai | 3.4 |
| Qicheng | 14.4–17 |
| Mengzhuang | 13–16 |
| Guchengzhai | 17.6 |
| Xubao | 20 |
| Xijincheng | 30 |

Yellow and the Huai rivers. Many walled sites were constructed and occupied during the Longshan period. A roughly two-tier structure can be seen amongst these walled sites in terms of their scale (Table 3). The size difference between them is not massive, and both the small and large walled sites were constructed with very similar planning and structure. The Guchengzhai (17.6 ha) and Pingliangtai (3.4 ha) walled sites (*c.* 4600–3900 BP), for instance, fall into different tiers in terms of their sizes, but they both have rectangular or square-shaped walls made of pounded earth, moats or small ditches surrounding the earthen walls, and other features such as city gates. The above might indicate that the social structure and relationship inside and between these walled sites might not follow the typical centre–subcentre/periphery relationship seen in the Liangzhu region. Rather, the walled sites and the societies they represent might form a relatively more egalitarian relationship with regards to the construction and operation of their walled sites. Members of these societies might coordinate and collaborate with each other to build the walls and other engineering infrastructure. Together they might compete with their neighbouring walled sites for resources and social prestige (note that the Longshan period in the region saw increasing evidence of violence). The latter is considered an important factor driving regional economic intensification and social development in many regions of prehistoric China (cf. Liu 2003).

Despite these common characteristics, geoarchaeological investigations at several of these walled sites provide detailed information and allow us to understand the inter-site variations surrounding water management and its impact on society. The Piangliangtai site (4300 BP) is located on the floodplain of the Jialu river, a main tributary of the Huai river. Preliminary coring and a surface survey show that the palaeo-landform surrounding the site was quite different during the time of occupation. The site sits on top of a mound that was originally several metres higher than its surrounding flat floodplains. It is interesting to note that the site occupied only a small area of the large-sized mound. This perhaps suggests a ‘principle’ adopted by the Pingliangtai people that was very different from that of the Liangzhu city. The Pingliangtai people were careful in their selection of an ideal location for both occupation and development, ensuring that it was not too far from nor too close to the river. They were cautious also not to overly expand their settlement, perhaps deliberately reserving the other unoccupied area of the mound for other purposes such as farming.

On a relatively small size and scale, the well-planned Pingliangtai site was probably built within a relatively short timeframe. The almost square-shaped walled site encircled an area of around 3.4 ha (Figure 4). The pounded earthen walls form a trapezoidal shape (Cao 1990). Some sections still stand 3 m high today and would have been much higher when they were in use, as the current ground surface is deposited

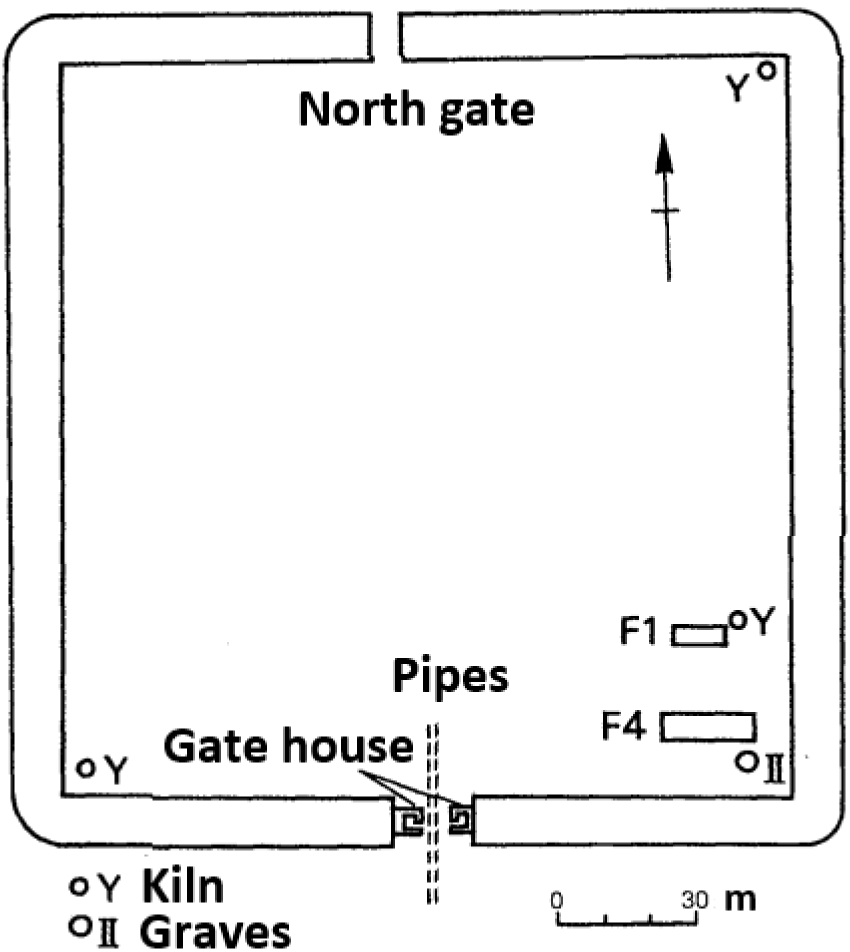


**Figure 4.** Plan of the Pingliangtai site, modified after Cao *et al.* (1983).

with thick late-Holocene alluvia. Two gates were opened in the middle of the northern and southern walls. Around the southern gate were gate houses. Several rows of houses were also found in the southern part of the enclosed area during past and recent excavations (Cao & Ma 1983, Cao *et al.* 2017). Features related to water management that were unearthed from the excavations included ditches, moats, and, most importantly, ceramic drainage pipes. These drainage facilities ran for several metres (up to 5 m) through different positions at the southern gate, each consisting of multiple sections of ceramic pipes (Cao & Ma 1983; and personal communications with Dr Hai Zhang and Yanpeng Cao). The tube-shaped pipes are 20–25 cm in diameter at one end and 22–30 cm at the other (Cao 1991). This special design was to make sure that they could be fitted into one another and aligned tightly in the ditch. The pipes were installed on different levels and at multiple times. Some of the pipes were obviously buried underneath the earthen walls before the walls were built, while others were installed relatively recently, possibly after the pre-buried ones were blocked and/or not in use anymore. For instance, the pipes underneath the eastern gate house at the southern gate must have been buried before the house was built. After their blockage, as it was not practical to reopen the ground under the house and earthen walls, the Pingliangtai occupants decided to move the location westward and install new pipes in the middle of the southern gateway. They might also have improved the design of the pipes to make them fit into each other more tightly to prevent leakages and further blockages (Figure 5).

The multiple installations of these ceramic drainage pipes vividly attest to the constant challenge facing the Pingliangtai occupants: that is, dealing with seasonal fluctuations of water. This incessant need for water management must have stimulated technological innovations at Pingliangtai. They invented the earliest ceramic drainage pipes to date, predating those commonly used in Bronze Age cities several thousand years later. However, these pipes did not always work. In the event of the pipes getting blocked and/or under extreme weather conditions that brought in excessive amounts of rainfall, the Pingliangtai occupants just dug drainage ditches around the gateway to discharge flood water.

Compared to Pingliangtai, the Guchengzhai site might have been faced with a higher magnitude of water-related challenges, a consequence of their deliberate choices. Our palaeo-environmental reconstruction shows that part of the Guchengzhai site was located in a low-relief area near a palaeo-lake of the Zhenshui river (Xu *et al.* 2013, Figure 6). Although by the time of construction the lake had already shrunk, the low-lying topography still made it an ideal spot where surface water gathered around the shrinking lake or wetlands. This created a rich ecosystem that was attractive to the Guchengzhai occupants who could exploit both water and other resources here.

**Figure 5.** Ceramic drainage pipe discovered at the Pingliangtai site. Online source: https://kknews.cc/zh-sg/culture/xq8pxnr.html

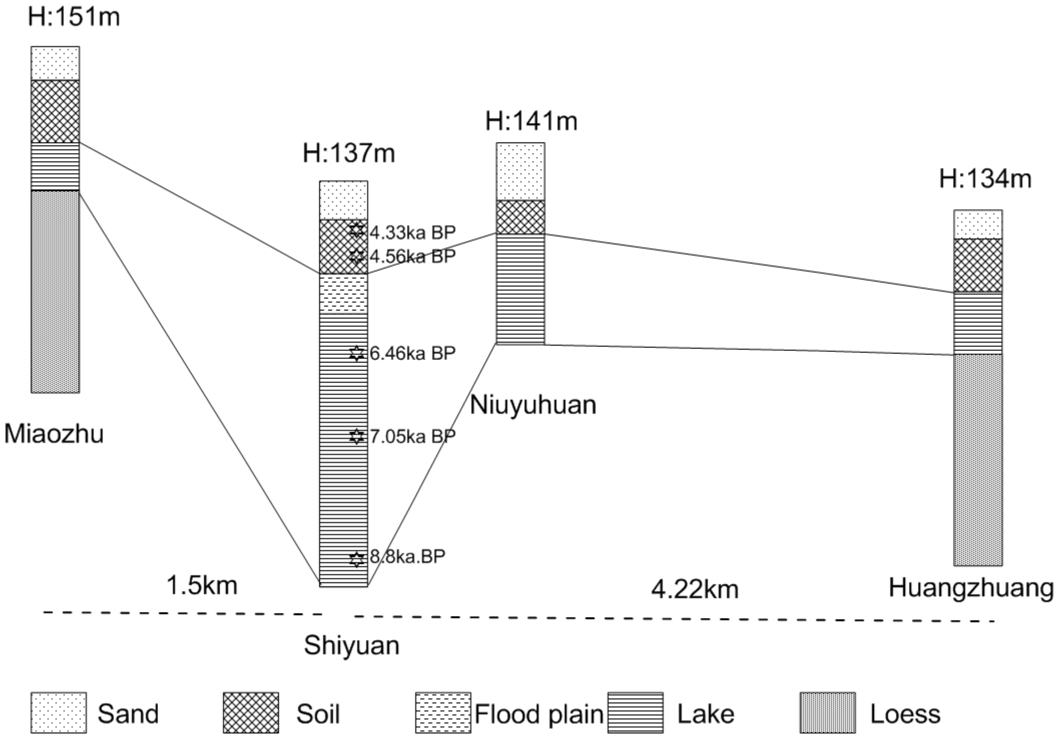


**Figure 6.** Elevations of key geological locations near the Guchengzhai site, Henan.

The construction of the Guchengzhai walled site was at a larger scale than at Pingliangtai. The area enclosed by the earthen walls reached around 18 ha (Figure 7). Parts of the earthen walls are relatively well preserved (but the western walls have already been destroyed by the modern river). Some sections of the walls still stand on the surface ground, up to 16.5 m higher than its surrounding surface. Excavations in the early 2000s revealed that the Guchengzhai builders applied typical earth pounding technology to build the walls, installing wooden planks and logs inside the earth before pounding it (Cai *et al.* 2002). Outside the walls was the moat. The moat was exceptionally wide, with the widest point being about 90 m (personal communication with Dr Xiaohu Zhang). The Guchengzhai occupants were primarily managing water through the construction and operation of the moat (but it cannot be ruled out that other facilities related to water management may be found in future excavations of the city). Given the volume of the moat, the water management at Guchengzhai was on a larger scale, compared to that at Pingliangtai. Considerable effort was also dedicated to multiple episodes of repairing the walls and moats. The recent excavation shows that the bank of the moat was repaired repeatedly after being damaged several times (personal communication with Dr Xiaohu Zhang). Heavy summer storms causing


**Figure 7.** Plan of the Guchengzhai site shown in Google Earth Maps.

instant floods, as surface runoff would have flowed to this low-relief spot, must have been one of the multiple causes responsible for the damage to the bank. From this perspective, it can be surmised that the floods were the inevitable consequence of the Guchengzhai occupants' choice in building their city on a low-relief area of the region. It can also be speculated that, during most of its occupation, the Guchengzhai occupants must have been vigilant in their response to flooding events. Thus, the floods provided both a challenge as well as an opportunity for the reorganisation of the social structure and reshuffling of social power in their society.

## Conclusion: climate, environment, and societies in late-Holocene china

The Holocene climate and environment broadly speaking followed temporal cycles. As sea level rises and falls, wetlands emerge and submerge, and rivers down cut or silt up. These environmental changes set the foundation for social and economic developments within prehistoric societies. By the late Holocene when the climate was getting drier and monsoonal precipitation was becoming more unpredictable, late Neolithic societies appeared able to break with convention and expand their economic activities when climatic and ecological conditions were not at their optimum. In so doing they grasped this opportunity of relatively stable sea-level change and alluvial settings and transformed them into highly productive landscapes. But they did so differently and hence the social and environmental outcomes also vary. The Liangzhu culture captured the monsoonal wet setting and invested a great deal in their permanent settlements. This served as a 'gravitational pull', through which many resources were consumed and an agricultural surplus was accumulated (cf. Scarborough 2017). But through this high-gain, high-risk strategy, the Liangzhu society suffered a very abrupt decline. The Guchengzhai and Pingliangtai societies seemed to be more careful in their investment in landscape transformation and settlement expansion. Whilst it was common for the occupants of the late-Neolithic walled site in the Huai river region to diversify their crop choices in response to deteriorating climate conditions, the Liangzhu people in the Yangtze Delta chose to intensify rice farming to an unprecedented level. This difference perhaps also fundamentally impacted upon the pathways towards settlement organisation and growth and expansion as the land and requirements of other resources for farming in these different societies (Table 4).

Thus, our geoarchaeological investigations at and around these late Neolithic sites under different environmental and socio-economic settings and the comparison between their water management strategies contribute to our understanding of two important aspects regarding water management and social evolution in late prehistoric China. First, whilst it is possible that some of the smaller scale bits of water management infrastructure were built in a relatively short timeframe (for example, Pingliangtai), the construction of larger scale hydraulic enterprises is undoubtedly a piecemeal and long process. It is also clear that their operation and maintenance (both large and small) also involved multiple periods of repair and reconstruction. Second, even though it is true that natural processes such as sea-level rise and/or increased summer rainfall had a devastating impact on the water management infrastructure, intensified economic activities and other cultural factors also played a key role in the

**Table 4.** Summary and comparison of environmental settings, economic models, and water management technologies at the three sites discussed in the text.

| *Site* | *Environmental settings* | *Economic models* | *Technologies* |
|---|---|---|---|
| Liangzhu | Deltaic wetlands | Rice farming | Dams, canals, and levees; other micro-management of local hydrological systems |
| Guchengzhai | Lake and riverine landscape | Millet farming and rice farming (?) | Moats and earthen walls |
| Pingliangtai | Riverine landscape | Mixed or multiple cropping of millet and rice | Moats, earthen walls, and ceramic drainage pipes |

eventual malfunction and abandonment of the water management infrastructure. It is also too simplistic to suggest that the abandonment of this infrastructure meant the total demise of these prehistoric societies. Detailed excavation and geoarchaeological data has clearly illustrated that many societies were concerned with the proper functioning of the moats, canals, and dams and dedicated multiple efforts for their maintenance. However, this active response to repairing and reconstruction of water management infrastructure gradually shifted to a more casual attitude towards regular maintenance. The reasons for such a shift in attitude might be complicated, possibly including a deliberate calculation between the economic costs of repairing and abandonment of the infrastructure, political acts that viewed and responded to massive labour organisation differently, and other possible socio-economic reasons.

It was such interactions between climate, environment, economic choices. and social responses that gave rise to complex societies or early states. By the end of the Neolithic or transitional period to the early Bronze Age, there is more evidence of floods and their devastating impact on the societies in the Huai river and surrounding regions. This provides an opportunity for the reorganisation of social structure and the reshuffling of social power in North China. The experience and knowledge they acquired from Pingliangtai and Guchengzhai was certainly crucial in this new process of power acquisition and reorganisation.

## References


Algaze, G. (1993), *The Uruk World System: The Dynamics of Expansion of Early Mesopotamian Civilization* (Chicago, IL, University of Chicago Press Chicago).

Algaze, G. (2009), *Ancient Mesopotamia at the Dawn of Civilization: The Evolution of an Urban Landscape* (Chicago, IL, University of Chicago Press). https://doi.org/10.7208/chicago/9780226013787.001.0001

Brunson, K., He, N. & Dai, X. (2016), 'Sheep, Cattle, and Specialization: New Zooarchaeological Perspectives on the Taosi Longshan', *International Journal of Osteoarchaeology*, 26: 460–75. https://doi.org/10.1002/oa.2436

Cai, Q.F. *et al.* (2002), 'Henan Xinmi Shi Guchengzhai Longshan Wenhua Chengzhi Fajue Jianbao [Preliminary Excavation Report of the Longshan Culture City at Guchengzhai, Xinmi, Henan]', *Huaxia Kaogu [Huaxia Archaeology]*, (2): 53–82.

Cao, G.C. (1990), 'Huaiyang Pingliangtai Chengzhi Shehui Xingzhi Tanxi [An Investigation of the Social Structure of the Pingliangtai City, Huaiyang]', *Zhongyuan Wenwu [Central Plain Cultural Relics]*, (2): 89–92.

Cao, G.C. (1991), 'Huaiyang Pingliangtai Longshan Wenhua Chengzhi Chutu de Taoyan he Taoshuiguan [Pottery Jars and Ceramic Drainage Pipes Discovered from the Longshan Culture City of Pingliangtai, Huaiyang]', *Huaxia Kaogu [Huaxia Archaeology]*, (2): 111–12.

Cao, G.C. & Ma, Q. (1983), 'Henan Huaiyang Pingliangtai Longshan Wenhua Chengzhi Shijue Jianbao [Preliminary Report of the Excavation of the Longshan Culture City at Pingliangtai, Huaiyang, Henan]', *Wenwu [Cultural Relics]*, (3): 21–37.

Cao, Y.P., *et al.* (2017), 'Henan Huaiyang Pingliangtai Yizhi Longshan Shiqi Muzang Fajue Baogao [Excavation Report of the Longshan Period Buriais at the Pingliangtai Site, Huaiyang, Henan]', *Huaxia Kaogu [Huaxia Archaeology]*, (3): 3–15.

Chen, F. *et al.* (2015), 'East Asian Summer Monsoon Precipitation Variability since the Last Deglaciation', *Scientific Reports*, 5: 11186. https://doi.org/10.1038/srep11186

Chen, M.H. (2018), 'Sumer Diqu yu Huantaihu Diqu de Shehui Fuzahua zhi lu [Pathways to Social Complexity in the Sumer Region and the Tai Lake Region: A Preliminary Comparison Between the Sumer and Liangzhu Civilizations]', *Nanfang Wenhua [Southern Culture]*, (1): 77–88.

Clift, P.D. & Plumb, R.A. (eds) (2008), *The Asian Monsoon: Causes, History and Effects* (Cambridge, Cambridge University Press). https://doi.org/10.1017/CBO9780511535833

Coningham, R. & Young, R. (2015), *The Archaeology of South Asia: From the Indus to Asoka, c. 6500 BCE–200 CE* (Cambridge, Cambridge University Press). https://doi.org/10.1017/CBO9781139020633

Ding, J.L. (2004), 'Changjiang Zhongyou Xinshiqi Shidai Shuidaotian yu Daozuo Nongye de Qiyuan [Neolithic Paddy Fields and the Origins of Rice Farming in the Lower River Yangtze]', *Dongnan Wenwu [Southeast Culture]*, (2): 19–23.

Dixit, Y., Hodell, D.A. & Petrie, C.A. (2014), 'Abrupt Weakening of the Summer Monsoon in Northwest India ~4100 yr ago', *Geology*, 42: 339–42. https://doi.org/10.1130/G35236.1

Fang, X.M. (2020), 'A Controlled Fine Craft: Jade Production Techniques in the Liangzhu Culture', in B. Liu, L. Qin & Y. Zhuang (eds) *Liangzhu Culture: Society, Belief and Art in Neolithic China* (Oxford, Routledge), 116–66.

Fleming, K., Johnston, P., Zwartz, D., Yokoyama, Y., Lambeck, K. & Chappell, J. (1998), 'Refining the Eustatic Sea-level Curve Since the Last Glacial Maximum using Far- and Intermediate-field Sites', *Earth and Planetary Science Letters*, 163: 327–42. https://doi.org/10.1016/S0012-821X(98)00198-8

Fuller, D.Q. & Stevens, C. (2019), 'Between Domestication and Civilization: The Role of Agriculture and Arboriculture in the Emergence of the First Urban Societies', *Vegetation History and Archaeobotany*, 28: 263–82. https://doi.org/10.1007/s00334-019-00727-4

Fuller, D.Q. & Zhang, H. (2007), 'A Preliminary Report of the Survey Archaeobotany of the Upper Ying Valley (Henan Province) (in Chinese and English)', in University and Henan Provincial Institute of Archaeology *Dengfeng wangchenggang yizhi de faxian yu yanjiu (2002–2005) [Archaeological Discovery and Research at the Wangchenggang Site in Dengfeng (2002–2005)]* (Zhengzhou, Great Elephant Press), 916–58.

Giosan, L. *et al.* (2012), 'Fluvial Landscapes of the Harappan Civilization', *PNAS*, 109: E1688–E1694. https://doi.org/10.1073/pnas.1112743109

Jiang, X., He, Y., Shen, C.-C., Li, Z. & Lin, K. (2013), 'Replicated Stalagmite-inferred Centennial-to decadal-scale Monsoon Precipitation Variability in Southwest China since the Mid Holocene', *The Holocene*, 23: 841–9. https://doi.org/10.1177/0959683612471986

Li, X.W., Ma, X.L. & Yang, H.Q. (2005), 'Henan Lingbao Xipo Yizhi Faxian Yizuo Yangshao Wenhua Zhongqi Teda Fangzhi [The Discovery of a Middle-Yangshao Large-sized House at the Xipo Site, Lingbao City, Henan]', *Kaogu [Archaeology]*, (3): 195–8.

Liu, B., Wang, N.Y., Chen, M.H., Wu, X.H., Mo, D.W., Liu, J.G., Xu, S.J. & Zhuang, Y. (2017), 'Earliest Hydraulic Enterprise in China, 5,100 Years Ago', *PNAS*, 114: 13637–42. https://doi.org/10.1073/pnas.1710516114

Liu, B., Wang, N.Y. & Chen, M.Y. (2020), 'The Liangzhu City: New Discoveries and Research', in B. Liu, L. Qin & Y. Zhuang (eds) *Liangzhu Culture: Society, Belief and Art in Neolithic China* (Oxford, Routledge).

Liu, L. (2003), 'The Products of Minds as Well as of Hands': Production of Prestige Goods in the Neolithic and Early State Periods of China', *Asian Perspectives*, 42: 1–40. https://doi.org/10.1353/asi.2003.0025

Liu, L. & Chen, X. (2012), *The Archaeology of China: From the Late Paleolithic to the Early Bronze Age* (Cambridge, Cambridge University Press). https://doi.org/10.1017/CBO9781139015301

Liu, L., Zhai, S. & Chen, X. (2013), 'Production of Ground Stone Tools at Taosi and Huizui: A Comparison', in A.P. Underhill (ed.) *A Companion to Chinese Archaeology* (Hoboken, NJ, Wiley), 278–99. https://doi.org/10.1002/9781118325698.ch14

Longqiuzhuang Archaeological Team (1999), *Longqiuzhuang: Report of the Excavation at the Neolithic Site in Eastern Jianghuai Region* (Beijing, Science Press).

Ma, Y.C. (2016), 'Changjiang Xiayou Diqu de Shuidao Xunhua Guocheng [Domestication Process of Rice in the Lower Yangtze River Region]', PhD dissertation, Shandong University.

Mo, D.W. & Zhuang, Y. (2018), 'Geoarchaeology of Prehistoric Moated Sites and Water Management in the Middle Yangtze River, China', in Y. Zhuang & M. Altaweel (eds) *Water Societies and Technologies from the Past and Present* (London, UCL Press), 62–86. https://doi.org/10.2307/j.ctv550c6p.10

Pennington, B.T., Bunbury, J. & Hovius, N. (2016), 'Emergence of Civilization, Changes in Fluvio-deltaic Style, and Nutrient Redistribution Forced by Holocene Sea-level Rise', *Geoarchaeology*, 31: 194–210. https://doi.org/10.1002/gea.21539

Pennington, B.T., Sturt, F., Wilson, P., Rowland, J. & Brown, A.G. (2017), 'The Fluvial Evolution of the Holocene Nile Delta', *Quaternary Science Reviews*, 170: 212–31. https://doi.org/10.1016/j.quascirev.2017.06.017

Petrie, C.A. *et al.* (2017), 'Adaptation to Variable Environments, Resilience to Climate Change: Investigating Land, Water and Settlement in Indus Northwest India', *Current Anthropology*, 58: 1–30. https://doi.org/10.1086/690112

Qin, L. (2013), 'The Liangzhu Culture', in A.P. Underhill (ed.) *A Companion to Chinese Archaeology* (Hoboken, NJ, Wiley), 574–96. https://doi.org/10.1002/9781118325698.ch28

Qin, L. (2020), 'Power and Belief: Reading the Liangzhu Jade and Society', in B. Liu, L. Qin & Y. Zhuang (eds) *Liangzhu Culture: Society, Belief and Art in Neolithic China* (Oxford, Routledge), 49–115. https://doi.org/10.4324/9781315151014-3

Scarborough, V. (2017), 'The Hydraulic Lift of Early States Societies', *PNAS*, 114: 13600–1. https://doi.org/10.1073/pnas.1719536115

Staubwasser, M., Sirocko, F., Grootes, P.M. & Segl, M. (2003), 'Climate Change at the 4.2 ka BP Termination of the Indus Valley Civilization and Holocene South Asian Monsoon Variability', *Geophysical Research Letters*, 30(8). https://doi.org/10.1029/2002GL016822

Stevens, C. & Fuller, D.Q. (2017), 'The Spread of Agriculture in Eastern Asia: Archaeological Bases for Hypothetical Farmer/language Dispersals', *Language Dynamics and Change*, 7(2): 152–86. https://doi.org/10.1163/22105832-00702001

Underhill, A.P., Feinman, G.M., Nicholas, L.M., Bennett, G., Fang, H., Luan, F.S., Yu, H.G. & Cai, F.S. (2002), 'Regional Survey and the Development of Complex Societies in Southeastern Shandong, China', *Antiquity*, 76: 745–55. https://doi.org/10.1017/S0003598X00091195

Wang, N.Y., Dong, C.W. & Xu, H.G. (in press), *Liangzhu Gucheng Chengqiang Pudianshi Laiyuan ji Gongcheng Yanjiu Baogao [Provenance and Engineering of the Stone Bases of the Liangzhu Ancient City]*.

Wang, W.L., Zhang, W., Zhang, P.C., Guo, X.N., Yuan, M. & Ma, M.Z. (2011), 'Shaanxi Gaoling Yangguanzhai Yizhi Fajue Jianbao [Preliminary Excavation Report of the Yangguanzhai Site, Gaoling, Shaanxi]', *Kaoyu yu Wenwu [Archaeology and Cultural Relics]*, (6): 16–32.

Wang, Y.J. *et al.* (2005), 'The Holocene Asian Monsoon: Links to Solar Changes and North Atlantic Climate', *Science*, 308: 854–7. https://doi.org/10.1126/science.1106296

Weiss, H. (2017), '4.2 ka BP Megadrought and the Akkadian Collapse', in H. Weiss (ed.) *Megadrought and Collapse: From Early Agriculture to Angkor* (Oxford, Oxford University Press), 93–160. https://doi.org/10.1093/oso/9780199329199.003.0004
Wittfogel, K.A. (1957), *Oriental Despotism* (New Haven, CT, Yale University Press).
Xu, J.J., Mo, D.W., Wang, H. & Zhou, K.S. (2013), 'Henan Xinmi Zhenshui Liuyu Quanxinshi Renlei Wenhua Yanhua de Huanjing Beijing Yanjiu [Environmental Backgrounds of the Holocene Cultural Evolution in the Zhenshui River, Xinmi, Henan]', *Disiji Yanjiu [Quaternary Research]*, 33: 954–64.
Zhai, S. (2015), 'A Preliminary Study on the Lithic Resources Utilization Mode of the Mount Dagudui Site in Xiangfen County, Shanxi', *Chinese Archaeology*. https://doi.org/10.1515/char-2015-0009
Zhang, C. (2015), *Shehui Quanli de Qiyuan: Zhongguo Shiqian Zangyi zhong de Shehui yu Guannian [The Origins of Social Power: Society and Ideology in Prehistoric Mortuary Rites of China]* (Beijing, Cultural Relics Press).
Zhao, H. (2017), 'Liangzhu Guojia Xingtai [State Pattern of Liangzhu]', *Zhongguo Wenhua Yichan [Chinese Cultural Heritage]*, (3): 22–8.
Zhao, Z.J. (2017), 'Yangshao Wenhua Shiqi Nonggeng Shengchan de Fazhan he Nongye Shehui de Jianli: Yuhuazhai Yizhi Fuxuan Jieguo de Fenci [Agricultural Development and the Establishment of Agricultural Society during the Yangshao Period: A Study of the Flotation Result from the Yuhuazhai Site]', *Jianghan Kaogu [Jianghan Archaeology]*, (6): 98–108.
Zheng, Y.F. (2018), 'Liangzhu Wenhua Shiqi de Shehui Shengye Xingtai yu Daozuo Nongye [Social Economic Subsistence Patterns and the Rice Farming of the Liangzhu Culture Period], *Nanfang Wenhua [Southern China]*, (1): 93–101.
Zheng, Y.F., Sun, G.P. & Chen, X.G. (2007), '7000 Nianqian Kaogu Yizhi Chutu Daogu de Xiaosuizhou [Characteristics of Rice Spikelets Discovered at a 7000-year-old Archaeological Site]', *Chinese Science Bulletin*, 52: 1037–41. https://doi.org/10.1007/s11434-007-0258-1
Zhu, N.C. (2004), 'Taihu yu Hangzhouwan Diqu Yuanshi Daozuo Nongye Qiyuan Chutan [Origins of Rice Farming in the Lake Taihu and Hangzhou Bay Regions]', *Dongnan Wenhua [Southeast Culture]*, (2): 24–31.
Zhuang Y. (2018), 'Rice Fields, Water Management and Agricultural Development in the Prehistoric Lake Taihu Region and the Ningshao Plain', in Y. Zhuang & M. Altaweel (eds) *Water Societies and Technologies from the Past and Present* (London, UCL Press), 87–108. https://doi.org/10.2307/j.ctv550c6p.11
Zhuang, Y., Ding, P. & French, C. (2014), 'Water Management and Agricultural Intensification of Rice Farming at the Late-Neolithic site of Maoshan, Lower Yangtze River, China', *The Holocene*, 24(5): 531–45. https://doi.org/10.1177/0959683614522310

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