



Agricultural Transformations and Their Influential Factors Revealed by Archaeobotanical Evidence in Holocene Jiangsu Province, Eastern China

Haiming Li^{1,2,3}, Zhen Liu^{4,5,6}, Nathaniel James⁷, Xinsheng Li^{1,2,3}, Zhujun Hu^{4,5,6}, Hongwei Shi^{4,5,6}, Liqiang Sun^{1,2,3}, Yong Lu^{1,2,3*} and Xin Jia^{4,5,6*}

OPEN ACCESS

Edited by:

Guanghai Dong,
Lanzhou University, China

Reviewed by:

Yijie Zhuang,
University College London,
United Kingdom
Yan Liu,
East China Normal University, China

*Correspondence:

Xin Jia
jiaxin@njnu.edu.cn
Yong Lu
luyong@njau.edu.cn

Specialty section:

This article was submitted to
Quaternary Science, Geomorphology
and Paleoenvironment,
a section of the journal
Frontiers in Earth Science

Received: 31 January 2021

Accepted: 04 May 2021

Published: 15 June 2021

Citation:

Li H, Liu Z, James N, Li X, Hu Z, Shi H,
Sun L, Lu Y and Jia X (2021)
Agricultural Transformations and Their
Influential Factors Revealed by
Archaeobotanical Evidence in
Holocene Jiangsu Province,
Eastern China.
Front. Earth Sci. 9:661684.
doi: 10.3389/feart.2021.661684

¹College of Humanities & Social Development, Nanjing Agricultural University, Nanjing, China, ²Institution of Chinese Agricultural Civilization, Nanjing Agricultural University, Nanjing, China, ³Agricultural Archaeology Research Center, Nanjing Agricultural University, Nanjing, China, ⁴Jiangsu Center for Collaborative Innovation in Geographical Information Resource Development and Application, Nanjing Normal University, Nanjing, China, ⁵Key Laboratory of Virtual Geographic Environment (Ministry of Education of PRC), Nanjing Normal University, Nanjing, China, ⁶School of Geography, Nanjing Normal University, Nanjing, China, ⁷Department of Anthropology, University of California San Diego, San Diego, CA, United States

The development and adoption of agriculture has been investigated for decades, and remains a central topic within archaeology. However, most previous studies focus on the crop's domestication centers, leading to gaps in knowledge, particularly in transitional zones between these centers. This paper reviews published archaeobotanical evidence and historical documents to reconstruct the trajectory of agricultural systems in Holocene Jiangsu Province. Comparing these new results to paleoclimate information, historical documents, and archaeological data enables us to better understand the underlying influences of past agricultural development. Our results indicate that a warm and wet climate may have promoted ancient peoples to first settle in Jiangsu between 8,500 and 6,000 BP and adopt rice farming. The continuous warm and wet climate may have facilitated the rapid development and expansion of rice agriculture, ultimately contributing to large-scale human settlement in 6,000–4,000 BP in Jiangsu Province. Between 4,000 and 2,300 BP during a cooler and drier climate millet agriculture diffused southward, facilitating a mixed rice and millet agricultural system. This mixed farming supported a continued widespread settlement and population growth in Jiangsu. After 2,300 BP, political instability in north China resulted in further southeastward migration, advanced planting technology was brought about to south China, facilitating highly developed agricultural systems and rapid population expansion in Jiangsu. Population growth led to the establishment of Jiangnan as the regional economic center, where people chose high-yielding rice and wheat rather than millet.

Keywords: archaeobotany, rice, millet, wheat, Yangtze River, Huai River, climate change

INTRODUCTION

The transition to entrenched agricultural systems is a critical topic relevant to modern economics, politics, international security, and climate change and adaptation. Environmental factors such as climate, landform, hydrology, and soil are critical variables impacting changing agricultural systems (Zhang et al., 2014; Chen et al., 2015; Ren et al., 2016; Wang et al., 2017; Liao et al., 2019). Climatic change is regarded as a key factor for prehistoric agriculture changes and cultural evolution (e.g., Dalfes et al., 1997; Bawden and Reycraft, 2002; Staubwasser et al., 2003; An et al., 2005; Jia et al., 2013, Jia et al., 2016; Dong et al., 2019, Dong et al., 2021). It is argued that a warm and humid climate was critical in promoting the large-scale development of millet farming on the Loess Plateau after 6,000 BP (An et al., 2004; Sheng et al., 2018; Dong et al., 2019). While a cold and dry climate supported the widespread cultivation of barley and wheat in the Hexi Corridor and northeast Tibetan Plateau around 4,000 BP (Chen et al., 2015; Zhou et al., 2016; Li and Dong, 2018). Other researchers have argued that geomorphic and hydrological conditions constrained agricultural systems (Wang et al., 2017). Wang et al. (2017) posit that two modes of farming existed along the middle reaches of the Yellow River Basin during the Peiligang period (8,500–7,000 BP): millet-based agriculture in hilly areas and mixed rice-millet farming on the plains. In addition to human innovation and adaptation, cultural and political factors played pivotal roles in subsistence systems (Kearns, 2010; Zhang et al., 2015; Pei et al., 2019), as did people's preference for certain crops change agricultural systems (Zhou et al., 2016; Xhaufclair et al., 2017; Overton and Barry, 2018). To anticipate potential future agricultural risks, it is necessary to understand the many complex variables impacting changing ancient agricultural systems, particularly in transitional areas between regions.

The widespread adoption of agriculture is regarded as one of the most significant events in human history (Zohary et al., 2012; Barker and Goucher, 2015). Around 10,000 BP, crops were almost simultaneously domesticated in six discrete centers across the world (Mannion, 1999; Lev-Yadun et al., 2000; Zohary and Hopf, 2000; Diamond and Bellwood, 2003; Nakamura, 2010; Price and Bar-Yosef, 2011). This strategy has improved the ability of human beings to adapt to their surrounding environment, increasing worldwide population dramatically (Gignoux et al., 2011). Newly domesticated crops spread from centers of domestication alongside Neolithic peoples, initiating agricultural production in new areas (Gignoux et al., 2011). Many scholars have conducted studies of agricultural exchanges between centers of domestication, including the spread of wheat and barley from Western Asia to China, and of millet from the Yellow River basin to Western Asia (Sherratt, 2006; Frachetti et al., 2010; d'Alpoim Guedes, 2011; Jones et al., 2011; Spengler et al., 2014; Jones et al., 2016; Stevens et al., 2016; Dong et al., 2017, Dong et al., 2018; Liu et al., 2019; Dai et al., 2021). However, the spread of agricultural systems is often ignored in the transitional areas between adjacent centers of domestication. This is likely due to the complexity and difficulty of understanding the relationships within these processes.

In East Asia, millets and rice were domesticated in the Yellow River Basin and the mid-lower reaches of the Yangtze river around 10,000 BP, changing human lifeways and subsistence in these two areas, then spreading (Fuller et al., 2009; Lu et al., 2009; Zhao Y., 2011, Qin, 2012; Zhao, 2014; Yang et al., 2012). Located in the center of Eastern China, Jiangsu Province lies between a center of dry-land agriculture, Shandong Province to the north and a center of rice agriculture, Zhejiang Province to the south (Fuller et al., 2009; Crawford et al., 2016; Jin et al., 2016; Zhao, 2020). Therefore, Jiangsu Province is a transitional area where the north dry-land agriculture spread southward and the southern wet rice agriculture spread northward. However, the changing impact of these agricultural systems on local people's subsistence strategies in Jiangsu remain unclear. Sporadic archaeobotanical data indicates that rice farming first appeared in Jiangsu Province around 8,500 BP (Lin et al., 2014; Yang et al., 2016; Qiu et al., 2018), with millet farming introduced around 6,000 BP (Cheng et al., 2020), and wheat and soybean identified after 4,000 BP (Wu et al., 2019). These studies indicate the timeline and potential routes of millet and rice agriculture into Jiangsu Province, but have not paid much attention to the transformations in agricultural systems after their introduction. Further complicating our understanding is that Jiangsu is densely covered with lakes and rivers, with a variety of landforms, with a complex and changeable ecology.

To address these complications, this paper reconstructs the trajectories of agricultural systems in Holocene Jiangsu through published prehistoric archaeobotanical data and historical agricultural records. In addition, paleoclimate information, historical documents, and other archaeological data influences on agricultural change in Jiangsu Province are also explored. This study contributes to our understanding of changes in areas of converging agricultural systems and human adaptation within those ecologically diverse regions.

Regional Settings and Data Sources

Jiangsu Province (30°45'–35°20' N, 116°18'–121°57' E) is located in the center of Eastern China between Shandong Province in the north and Zhejiang Province in the south (Figure 1). Its total land area is 10.72×10^4 km², accounting for 1.12% of China's total. The primary landforms include low hills, alluvial plains, and water areas. Easily traversable flat terrain spans most of the plains area of Jiangsu Province, providing convenient communication and access between the north and south of the province. The Yangtze River runs across the south of Jiangsu, while the Huai River runs through central Jiangsu. These two rivers divide Jiangsu into three areas, from north to south: the northern Jiangsu Plain, the Jianghuai area and the southern Jiangsu area (Zhou and Han, 2008; Zhao Z., 2011). There are significant environmental differences between the southern Jiangsu area and the northern Jiangsu Plain, with the Jianghuai region transitioning between them. The climate of Jiangsu province is impacted by a transitional monsoon climate, and is split between a subtropical humid monsoon climate in the south and warm temperate humid monsoon climate in the north (Jiang et al., 2006; Xia et al., 2015). The average annual precipitation in Jiangsu Province is 660–1,617 mm (Xu, 2016), and the average annual

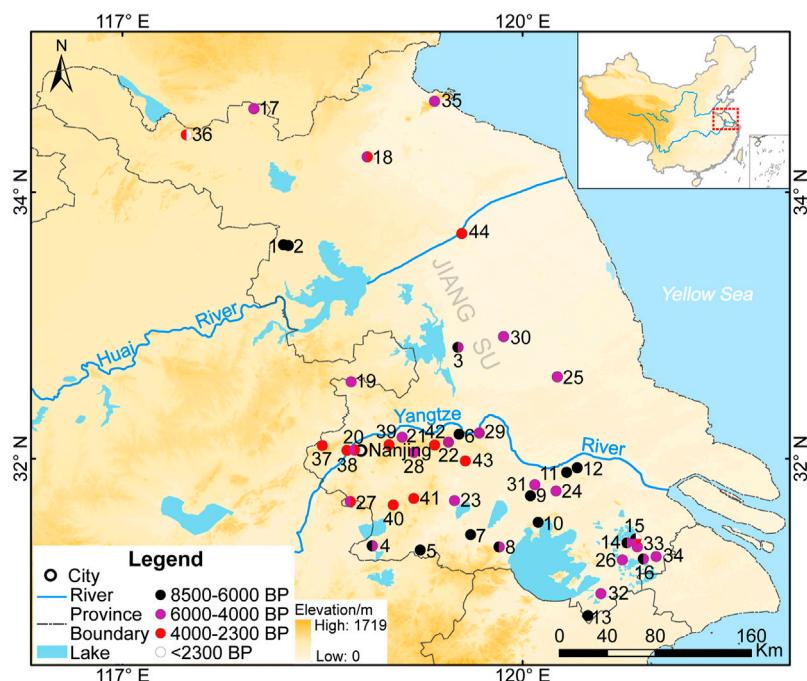


FIGURE 1 | Map of Jiangsu and sites mentioned in this study. 1) Shunshanji; 2) Hanjing; 3) Longqiuzhuang; 4) Xuecheng; 5) Shendun; 6) Zuohu; 7) Xixi; 8) Luotoudun; 9) Weidun; 10) Yangjia; 11) Qitoushan; 12) Dongshancun; 13) Guangfucun; 14) Caoxieshan; 15) Chuodun; 16) Jiangli; 17) Dadunzi; 18) Wanbei; 19) Miaoshan; 20) Beiyinyangying; 21) Dingshadi; 22) Sijiaodun; 23) Sanxingcun; 24) Nanlou; 25) Qingdun; 26) Chenghu; 27) Xiaodanyang; 28) Chengtoushan; 29) Mopanshan; 30) Jiangzhuang; 31) Sidun; 32) Longnan; 33) Zhumucun; 34) Shaoqingshan; 35) Tenghualuo; 36) Miaotaizi; 37) Niutougang; 38) Longshan; 39) Dianjiangtai; 40) Lishuixian; 41) Fushanguoyuan; 42) Dingjiacun; 43) Fenghuangshan; 44) Luzhuang.

temperature is 13–14°C in the north, 14–15°C in the Jianghuai, and 15–16°C in the south. The principle modern crops in the region are rice, wheat, corn, and potatoes, and the main livestock are pigs, cattle, and sheep.

Forty-five published archaeobotanical records from Jiangsu are presented here, including macrobotanical seeds, phytoliths, and starch grains samples. Information from twenty historical documents about crops in Jiangsu are summarized and presented. For the presented chronology, we used direct radiocarbon dating on macrobotanical crop remains when available, followed by carbonized charcoal from the related contexts. Four relative chronological intervals were selected based on artifact assemblage and are combined with prehistorical archaeological culture and historical periods: 8,500–6,000, 6,000–4,000, 4,000–2,300 BP, and <2,300 BP. The locations of these sites are shown in **Figure 1**, and detailed information can be obtained from published archives (**Table 1** and **Supplementary Table S1**).

RESULTS AND DISCUSSION

The History of Agricultural Processes in Holocene Jiangsu Province

Based on previous archaeobotanical studies, rice farming appeared around 8,500 BP in Jiangsu Province. Starch grains and phytoliths of rice were identified from the Shunshanji and Hanjing sites, respectively, from the Shunshanji Culture

(8,500–7,000 BP) in Suqian, northern Jiangsu Plain (Yang et al., 2016; Qiu et al., 2018). Charred rice was also recovered at the Shunshanji and Hanjing sites, and directly radiocarbon dated to $7,869 \pm 74$ and $8,284 \pm 88$ cal yr BP, respectively, (Lin et al., 2014; National Museum of China et al., 2018). While rice remains were identified from thirteen Majiabang cultural (7,000–6,000 BP) sites in southern Jiangsu (**Figure 1**; **Table 1**). Rice agriculture was clearly present in Jiangsu Province around 8,500–6,000, however, there are differences in the timing of appearance. Rice farming appeared earlier on the northern Jiangsu plains than in southern Jiangsu (**Table 1**; **Figure 1**). It must be emphasized that it is very possible that rice management was a supplement to a primarily hunting and gathering economy. For example, the ubiquity and proportion of wild plant remains such as *Coix lacryma-jobi* and *Trichosanthes kirilowii* dominate the microfossil assemblages (phytoliths and starch grains) at the Shunshanji and Hanjing sites (Yang et al., 2016; Wu et al., 2017a; Qiu et al., 2018). Further wild plant remains such as *Euryale ferox* and water chestnut account for more than 80% of the macrofossil remains (charred seeds) in the Longqiuzhuang site in Gaoyou (Tang and Zhang, 1996; Tang, 1999; Wang, 1999), 93.33% in the Jiangli site in Kunshan (Qiu et al., 2013), and 71.6% in the Yangjia site in Wuxi (Qiu et al., 2016). While rice was planted by people in Jiangsu Province between 8,500 and 6,000 BP, it was likely a supplementary component of hunting and gathering subsistence.

Rice agriculture was established and developed rapidly between 6,000 and 4,000 BP. The number of archaeological

TABLE 1 | Botanical evidence of major crops in Holocene in Jiangsu Province, Eastern China.

Sites/region	Rice	Millet	Wheat	Culture	References
Phase I (8,500–6,000 BP)					
Shunshanji	PSC	—	—	Shunshanji (8,500–7,500 BP)	Lin et al. (2014); Yang et al. (2016); Luo et al. (2016)
Hanjing	PCD	—	—	Shunshanji (8,500–7,500 BP)	National Museum of China et al. (2018); Qiu et al. (2018)
Longqiuzhuang	PC	—	—	Early Longqiuzhuang (7,000–6300 BP)	Tang and Zhang, (1996); Tang, (1999); Wang, (1982)
Zuohu	P	—	—	Majiabang (7,000–6,000 BP)	Lin and Wang, (2000)
Dongshancun	PC	—	—	Majiabang (7,000–6000 BP)	Wang and Ding, (1999); Qin, (2016)
Qitoushan	D	—	—	Majiabang (7,000–6,000 BP)	Zhu et al. (2003)
Weidun	D	—	—	Majiabang (7,000–6,000 BP)	You, (2001); Chen, (1995)
Xuecheng	P	—	—	Majiabang (7,000–6,000 BP)	Wang et al. (2013)
Shendun	PD	—	—	Majiabang (7,000–6,000 BP)	Wang, (2007); Tang, (2016)
Xixi	CD	—	—	Majiabang (7,000–6,000 BP)	Tian et al. (2009)
Yangjia	PC	—	—	Majiabang (7,000–6000 BP)	Qiu et al. (2016)
Luotodun	D	—	—	Majiabang (7,000–6,000 BP)	Lin et al. (2003); Lin and Tian, (2009); Zhang and Lin, (2008); Li et al. (2008)
Chuodun	PCD	—	—	Majiabang (7,000–6,000 BP)	Ding, (2004); Qin, (2011); Fuller, (2011) Cao et al. (2007)
Caoxieshan	PC	—	—	Majiabang (7,000–6,000 BP)	Gu et al. (1998); Udatsu et al. (1998); Tang et al. (1999)
Jiangli	PC	—	—	Majiabang (7,000–6,000 BP)	Qiu et al. (2013), Qiu et al. (2014a)
Guangfucun	P	—	—	Majiabang (7,000–6,000 BP)	Wang and Ding, (2001)
Phase II (6,000–4,000 BP)					
Longqiuzhuang	PC	—	—	Late Longqiuzhuang (6,300–5500 BP)	Tang and Zhang, (1996); Tang, (1999); Wang, (1982)
Wanbei	C	C	—	Early Dawenkou (6,200–5600 BP)	Cheng et al. (2020)
Dadunzi	D	D	—	Dawenkou (6,200–4600 BP)	Yin et al. (1964)
Qingdun	PD	—	—	Songze (6,000–5300 BP)	Guo, (2000)
Miaoshan	D	—	—	Beiyinyangying (6,000–5300 BP)	Chen, (2013)
Dingshadi	PD	—	—	Beiyinyangying (6,000–5,300 BP)	Chen, (2013)
Sijiaodun	P	—	—	Beiyinyangying (6,000–5,300 BP)	Chen, (2013)
Beiyinyangying	P	—	—	Beiyinyangying (6,000–5,300 BP)	Chen, (2013)
Nanlou	D	—	—	Songze (6,000–5,300 BP)	Fan, (2011); Wang, (2007)
Sanxingcun	D	—	—	Beiyinyangying (6,000–5,300 BP)	Wang and Zhang, (2004)
Chuodun	PC	—	—	Songze (6,000–5,300 BP)	Ding, (2004); Qin, (2011) Fuller, (2011)
Caoxieshan	PC	—	—	Songze (6,000–5,300 BP)	Gu et al. (1998); Udatsu et al. (1998); Tang et al. (1999)
Xuecheng	P	—	—	Songze (6,000–5,300 BP)	Wang et al. (2013)
Luotodun	CD	—	—	Songze (6,000–5,300 BP)	Lin et al. (2003); Lin and Tian, (2009); Zhang and Lin, (2009); Li et al. (2008)
Jiangli	PC	—	—	Songze (6,000–5,300 BP)	Qiu et al. (2013), Qiu et al., 2014a
Chenghu	PC	—	—	Songze (6,000–5,300 BP)	Qin, (2011) Fuller, (2011); Ding and Zhang, (2004)
Wanbei	C	C	—	Middle and late Dawenkou (5,600–4,600 BP)	Cheng et al. (2020)
Jiangzhuang	C	C	—	Liangzhu (5,300–4,000 BP)	Wu et al. (2019)
Mopandun	D	—	—	Liangzhu (5,300–4,000 BP)	Chen, (2013)
Chengtoushan	D	—	—	Liangzhu (5,300–4,000 BP)	Min, (1986)
Sidun	D	—	—	Liangzhu (5,300–4,000 BP)	Wang et al. (1984)
Xiaodanyang	D	—	—	Liangzhu (5,300–4,000 BP)	Yi, (1988); Chen, (2013)
Zhumucun	PC	—	—	Liangzhu (5,300–4,000 BP)	Qiu et al. (2014b)
Shaoqingshan	PD	—	—	Liangzhu (5,300–4,000 BP)	Xi, (2003); Wang and Ding, (2000)
Jiangli	PC	—	—	Liangzhu (5,300–4,000 BP)	Qiu et al., 2013, Qiu et al. (2014a)
Tenghualuo	PC	—	—	Longshan (4,500–4,000 BP)	Lin and Zhang, (2005); Nanjing Museum and Lianyungang Museum, (2015)
Longnan	PD	—	—	Liangzhu (5,300–4,000 BP)	Zheng and Chen, (2006); Qian et al. (2006); Zheng et al. (1994); Tang et al. (1992)
Phase III (4,000–2300 BP)					
Chuodun	P	—	—	Maqiao (4,000–3,400 BP)	Ding, (2004); Qin, (2011) Fuller, (2011) Cao et al. (2007)
Miaotaizi	C	C	C	Shang and Zhou (3,600–2,256 BP)	Wu et al. (2021), in press
Wanbei	C	C	C	Shang and Zhou (3,600–2,256 BP)	Cheng et al. (2020)
Beiyinyangying	P	—	—	Shang and Zhou (3,600–2,256 BP)	Chen, (2013)
Luzhuang	D	—	—	Hushu (3,600–2,400 BP)	Shen, (2009)
Dianjiangtai	D	—	—	Hushu (3,600–2,400 BP)	Zhong, (1987)
Dingjiacun	C	C	C	Hushu (3,600–2,400 BP)	Wu et al. (2017a)
Niutougang	D	—	—	Hushu (3,600–2,400 BP)	Han, (1997)
Longshan	D	—	—	Hushu (3,600–2,400 BP)	Chen, (2013)
Fenghuangshan	D	—	—	Hushu (3,600–2,400 BP)	Wang et al. (2002)

(Continued on following page)

TABLE 1 | (Continued) Botanical evidence of major crops in Holocene in Jiangsu Province, Eastern China.

Sites/region	Rice	Millets	Wheat	Culture	References
Fushanguoyuan	D	—	—	Hushu (3,600–2,400 BP)	Zhenjiang Museum, (1979)
Xiaodanyang	D	—	—	Hushu (3,600–2,400 BP)	Yi, (1988); Chen, (2013)
Lishuixian	D	—	—	Hushu (3,600–2,400 BP)	Han, (1997)
Phase IV (<2,300 BP)					
Miaotaizi	C	C	C	Han dynasty (202 BC–220 AD)	Wu et al. (2021), in press
Chu and Yue	+	—	—	Qin and Han dynasties (221 BC–AD 202)	Shi Ji, Shihuozi
Jiangnan	+	—	—	Qin and Han dynasties (221 BC–AD 202)	The Geographical Records of the Han Shu
Wu Country	+	—	—	Three Kingdoms (AD 220–AD 280)	Records of the Three Kingdoms, Wu shu
Dongjing Jun	—	—	+	Wei, Jin and the southern and northern dynasties (AD 220–AD 589)	Song Shu, Biography of Emperor Xiaowu
Hailingxian	+	—	—	Wei, Jin and the southern and northern dynasties (AD 220–AD 589)	Naturalis Historia
Xiaoxian and Suqian	+	—	—	Wei, Jin and the southern and northern dynasties (AD 220–AD 589)	Records of the Three Kingdoms, Wei shu
Jianghuai	+	—	—	Sui and Tang dynasties (AD 581–AD 907)	Xin Tang Shu, Monograph on Food and Currency
Yangzhou	+	—	—	Sui and Tang dynasties (AD 581–AD 907)	Xin Tang Shu, Biography of Emperor Xuanzong
Zhenjiang	—	—	+	Sui and Tang dynasties (AD 581–AD 907)	Pentasyllabic regulated verse Xian Ju Meng Xia Ji Shi
Chuodun	P	—	—	Song dynasty (AD 960–AD 1279)	Ding, (2004); Qin, (2011) Fuller, (2011) Cao et al. (2007)
Jiangbei	+	—	+	Song and Yuan dynasties (AD 960–AD 1368)	Song History, Monograph on Food and Currency
Jiangnan	+	—	—	Song and Yuan dynasties (AD 960–AD 1368)	Song History, Monograph on Food and Currency
Jianghuai	+	—	—	Song and Yuan dynasties (AD 960–AD 1368)	Song History, Monograph on Food and Currency
Liangzhe	+	—	—	Song and Yuan dynasties (AD 960–AD 1368)	Song History, Monograph on Food and Currency
Kunshan	+	—	+	Song and Yuan dynasties (AD 960–AD 1368)	Wu Jun Zhi Tao Shan Ji
Hailing	+	—	+	Song and Yuan dynasties (AD 960–AD 1368)	Wu Jun Tu Jing Xu Ji
Wuzhong	+	—	+	North Song dynasty (AD 960–AD 1127)	Dao Pin
Suzhou	+	—	+	Ming dynasty (AD 1,368–AD 1,644)	Bu Nong Shu Jiao Shi
Jiangnan	+	—	+	Ming dynasty (AD 1,368–AD 1,644)	Jiang Nan Cui Geng Ke Dao Bian
Wujun	+	—	+	Qing dynasty (AD 1,636–AD 1,912)	Jiang Nan Cui Geng Ke Dao Bian
Jiangnan	+	—	+	Qing dynasty (AD 1,636–AD 1,912)	

P, phytolith; C, charred seeds collected by system archaeobotanical work; D, discovered plant remains during the archaeological excavation; S, starch grains; “+” represent the crop was recorded in historical documents. See ESM 1 for more detailed information.

sites with rice remains (25) nearly doubled during this time (Table 1; Figure 1). Systematic archaeobotanical work demonstrates that charred rice dominates the macrobotanical seed assemblages between 6,000 and 4,000 BP. For example, the proportion of rice grains increases from 20% in 7,000–6,300 BP to 80% in 6,300–5,500 BP at the Longqiuchuang site, while proportions of the *Euryale ferox* and water caltrop fell from more than 80% to around 20% (Tang, 1999; Tang and Zhang, 1996; Wang, 1999). Next, the number of rice grains was also much higher than that of other weeds in the subsequent Liangzhu period (5,300–4,000 BP), including the Jiangzhuang site in Taizhou (Wu et al., 2019), Jiangli site in Wuxi (Qiu et al., 2013; Qiu Z. W. et al., 2014), and Zhumucun site in Kunshan (Qiu Z. et al., 2014). Extensive cultivation of rice was also confirmed by excavated rice paddy fields at many Liangzhu period sites, including the Tenghualuo site in Lianyungang (Lin and Zhang, 2005), the Jiangli site in Wuxi (Qiu et al., 2013; Qiu Z. W. et al., 2014), the Zhumucun and Chuodun sites in Kunshan (Cao et al., 2007; Qiu Z. et al., 2014), the Chenghu site in Suzhou (Fuller, 2011; Qin, 2011), and the Luotuodun site in Yixin (Lin et al., 2003). During this time, millet farming also spread southeastward from the Haidai or Central Plains culture area to the northern Jiangsu Plain. 19 carbonized foxtail millets, 17 carbonized

broomcorn millets, and 407 carbonized rice seeds were identified at the Wanbei site in Shuyang during the Dawenkou period (6,000–4,600 BP) (Cheng et al., 2020). However, millet agriculture seems to be blocked by the Huai River as there are no millet remains in the Jianghuai and southern Jiangsu area. We conclude that between 6,000 and 4,000 BP rice agriculture developed rapidly and was firmly established in Jiangsu Province, while millet agriculture was introduced on the northern Jiangsu plain.

Millet farming began to expand southward to the Jianghuai and southern Jiangsu areas between 4,000 and 2,300 BP. Simultaneously wheat crops originating in western Asia were introduced to southern China. Between 4,000 and 2,300 BP a mixed agricultural system had formed in Jiangsu Province including the integrated farming of millets, rice, wheat, barley, and soybean. Charred foxtail millet, broomcorn millet, wheat, rice, and soybean seeds were found together in the Shang and Zhou cultural layers (3,600–2,256 BP) at Miaotaizi site in Xuzhou (Wu et al., 2021, in press). Charred foxtail millet, broomcorn millet, rice, wheat, and barley were also unearthed from the Shang cultural layers (3,600–3,046 BP) at Wanbei site in Shuyang (Cheng et al., 2020). The co-existence of foxtail millet, broomcorn millet, wheat, rice, and soybean were also recovered from the Hushu culture layer (3,600–2,400 BP) at Dingjiacun site in Zhengjiang (Wu et al., 2017b). Notably, in

spite of the integration, the most ubiquitous crops were different at these three sites. The ratio and ubiquity of crop remains reveal that foxtail millet, rice, and wheat were the dominant crops in the Miaotaizi site, Wanbei site, and Dingjiacun site, respectively, (Wu et al., 2017b; Cheng et al., 2020; Wu et al., 2021, in press).

Agricultural systems shifted in Jiangsu Province once more after 2300 BP. Due to little archaeobotanical research covering this period (Li et al., 2006; Wu et al., 2021, in press), we draw on historical documents to inform agricultural systems during the imperial period. Particular crops were often recorded by multiple historic documents in the region, indicating that it was widespread and common. The Chinese character “稻” (rice plant body) and “米” (rice caryopsis) were recorded in many Jiangsu historical documents, such as the “*Shi Ji, Huo Zhi Biography*”, “*Records of the Three Kingdoms, Wei shu*”, “*Jiang Nan Cui Geng Ke Dao Bian*” etc (Table 1; Supplementary Table S1). These records indicate that rice was common in Jiangsu Province from the Qin (221–207 BC) to Qing (AD 1636–AD 1912) dynasties (Table 1). The Chinese character “麦” (wheat) was also recorded in many historical documents in Jiangsu, such as the “*Song Shu, Biography of Emperor Xiaowu*”, “*Song History, Monograph on Food and Currency*”, “*Tao Shan Ji*” etc (Table 1; Supplementary Table S1), suggesting that wheat was also commonly found in Jiangsu Province. Millet and soybean had withdrawn from much of Jiangsu Province, and only were planted in some relatively dry areas in Jiangnan, Zhejiang, Jinghu and similar areas, recorded by the “*Song History, Monograph on Food and Currency*”. From this evidence, after 2,300 BP people were primarily engaged in the production of rice and wheat after in Jiangsu, and millet and soybeans only planted sporadically in some drylands.

In summary, rice farming first emerged in Jiangsu Province around 8,500 BP, and dominated subsistence strategies between 6,000 and 4,000 BP. With the introduction of millet, mixed agriculture was practiced between 4,000 and 2,300 BP, including rice, millet, wheat and soybean. Agricultural practices shifted after 2,300 BP, when rice and wheat were predominately grown, while sporadic millet agriculture remained in a few dry areas. It is worth noting that the existence of differences in subsistence from the north and south of the Huai River. Rice agriculture emerged around 8,500 BP in the north of the Huai River, which was 1,500 years earlier than its appearance south of the Huai River. Millet was introduced north of the Huai River between 6,000 and 4,000 BP, and was introduced with wheat south of the Huai River only between 4,000 and 2,300 BP. After 2,300 BP, a mixed cropping pattern continued north of the Huai River in Jiangsu Province including rice, foxtail millet, broomcorn millet, wheat, and soybean, while millet farming disappeared. South of the Huai river, rice, and wheat agriculture remained the dominant agricultural subsistence.

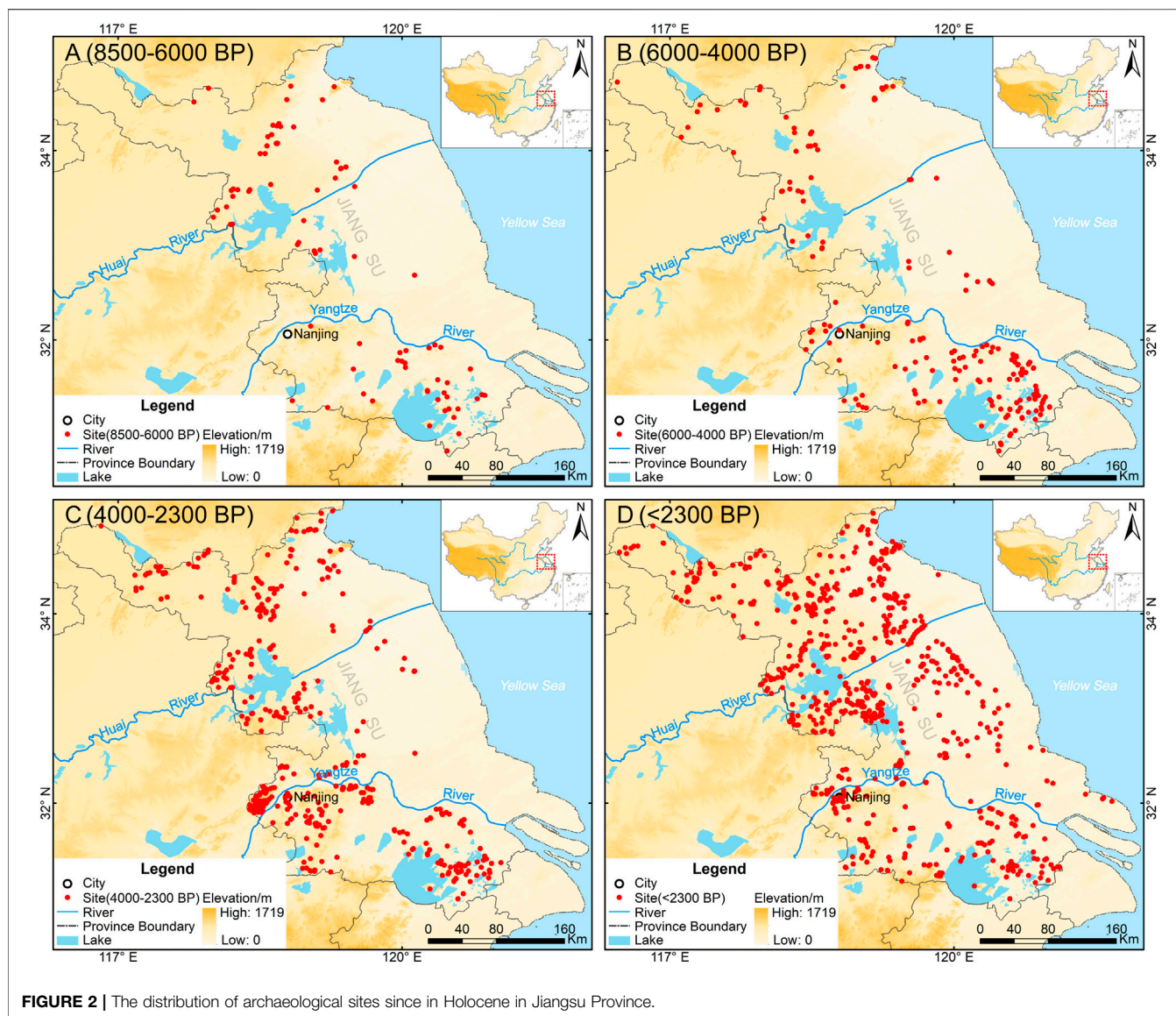
Influential Factors on Human Settlement and Agricultural Systems in Holocene in Jiangsu Province

The beginning of plant domestication is often argued to be related to the warm climate transformations of the early Holocene (Zeder, 2008; Willcox et al., 2009; d’Alpoim Guedes and Bocinsky, 2018). Similarly, the emergence of agriculture is also

often argued to be a result of a warm climate during the Holocene Optimum (Richerson et al., 2001; Feynman and Ruzmaikin, 2007; Atahan et al., 2008). Many previous paleoclimate studies indicated that a warmer and wetter climate was present between 8,500 and 4,000 BP in the lower Yangtze River (Wang et al., 1996; Qu et al., 2000; Wang and Gong, 2000; Hori et al., 2001; Tao et al., 2006; Atahan et al., 2008; Chen et al., 2009; Ma et al., 2009; Qiu et al., 2020). The emergence of rice farming likely benefited from the warm climate between 8,500 and 6,000 BP in its original centers of domestication. A recent study showed that the increase of rice pollen in the Tai Lake Basin may be related to the emergence of rice agriculture during the warm and wet climate between 8,500 and 6,000 BP (Qiu et al., 2020). Similarly, the warm and wet climate potentially supported the emergence and adoption of rice farming in Jiangsu between 8,500 and 6,000 BP, with increasing food production facilitating a growing population. In this time people settled far from the current coastline of Yellow Sea (Figure 2A) owing to the amount of land covered by the sea during this period (Li et al., 2008; Li et al., 2009).

Formal agriculture was established in China by 6,500–6,000 BP, likely benefiting from the warm and wet Holocene Optimum (Fuller et al., 2009; Zhao Y., 2011; Qin, 2012; Zhao, 2014). The favorable climate conditions likely promoted the adoption of agriculture with a resulting population expansion in northern China in this time. The population expansion on the Central Plains of China is likely mirrored, the migration and expansion of the Yangshao culture southeastward (An et al., 2004). Southeastward migration brought millet farming to the northern Jiangsu plain, verified by archaeobotanical evidence (36 charred millets) at Wanbei site in Shuyang County during the Dawenkou period (6,000–4,600 BP) (Cheng et al., 2020). Therefore, the warm and wet climate promoted the establishment of rice agriculture in Jiangsu between 6,000 and 4,000 BP, and indirectly facilitated the development of millet agriculture on the northern Jiangsu plain. Some scholars have argued that the marine regression process increased available land for human activities in the Liangzhu cultural period. This would further encourage rapid development and establishment of rice agriculture in Jiangsu Province (Zhang et al., 2004; Zhang, 2005; Li et al., 2008, Li et al., 2009). The establishment of agricultural systems likely led to populations increasing in Jiangsu Province during 6,000–4,000 BP, where the number of archaeological sites increased from 86 in 8,500–6,000 BP to 213 in 6,000–4,000 BP (Figures 2A,B).

Around 4,200 BP, the “Holocene Event 3”, an extreme cold and dry climate event, commenced, impacting climate across the world (Bond et al., 1993; Bond et al., 2001; DeMenocal, 2001). This event has been argued to lead to the demise of some ancient states, such as the Akkad Empire and the Harappa civilization (Weiss et al., 1993; Kerr, 1998; Cullen et al., 2000; Staubwasser et al., 2003). This event also played a significant impact on the transformation of civilization in China (Wu and Liu, 2001, Wu and Liu, 2004; Sun et al., 2019), and is argued to have led to significant culture change and transformations of subsistence strategies in China (Wu and Liu, 2001, Wu and Liu, 2004; Wang, 2004; Chen et al., 2015; Jia et al.,



2016). In particular, the collapse of the Liangzhu Culture is considered a result of this event in southeastern China (Stanley et al., 1999; Li et al., 2010; Sun et al., 2019). This climate event potentially caused southward human migration, bringing millet and wheat dry-land farming to Jiangsu Province. During this time mixed agriculture was prevalent in Jiangsu Province, verified by the archaeobotanical evidence from the Miaotaizi site in Xuzhou (Wu et al., 2021, in press), the Wanbei site in Suqian (Cheng et al., 2020), the Datongpu site in Yancheng (Liu et al., 2021; Under review) and the Dingjiacun site in Zhenjiang (Wu et al., 2017b) (Table 1). Mixed agriculture potentially increased food production, and indirectly improved the human ability to respond the environmental risks. Concurrent with these changes between 4,000 and 2,300 BP is the transition in Chinese societies from the late Neolithic, to Bronze Age, and to the Iron Age. This transformation is confirmed by bronze-iron implements obtained from the archaeological excavation in various cemeteries during

4,000–2,300 BP in Jiangsu Province (Liao, 1982; Liang, 1986; Wu, 2011). Productivity and grain production were greatly improved by the widespread utilization of bronze-iron implements. Therefore, mixed agriculture and the revolutionary implements jointly increased food resources in Jiangsu Province, leading to widespread population growth between 4,000 and 2,300 BP, illustrated by multiple archaeological sites (616) (Figure 2C).

Human settlement peaked after 2,300 BP in Jiangsu Province (Figure 2D). According to the “Zizhi Tongjian”, “Xin Tang Shu”, and “Song Shi”, the increasing population was considered a result of the shifting of the provincial economic center from the Central Plain to the Jiangnan area (southern Jiangsu) (Zheng, 2003; Cheng, 2004). Over time recurrent wars in northern China led to a large scale of migration southward, such as the Yongjia rebellion (AD 311), the rebellion of An Lushan (AD 757), and the Jingkang rebellion (AD 1127) (Zhang, 2008; Sun and Liu, 2011; You, 2018). Some scholars further argue that two cold climatic events compelled human

migration southward from northern China during the Tang Dynasty (AD 710–750 and AD 780–860) (Fang, 1989; Man, 2009; Ge et al., 2014). With the human migration southward, revolutionary tools and technology were introduced into southern China. A variety of advanced agricultural tools such as “lóu chē” (a sowing tool), two advanced crop planting techniques such as “lí-pá-lóu” (a kind of soil preparation technology) and “sōu zhòng fǎ” (a sowing technology) (Min, 1986; Zeng, 2005; Wang et al., 2019). According to the “*Leisi Jing*,” the advanced farming tools and techniques were introduced from the northern China into the southern Jiangsu Province during the late Tang dynasty, and led to people discarding extensive farming practices, leading to the era of intensive farming. With the introduction of new tools and technologies, larger areas of land were cultivated in southern China, leading to agricultural production increasing and a doubling of income. According to the *Xin Tang Shu*, *Song Shi*, *Nung Sang Chi Yao*, and *Agricultural Administration book*, the government also carried out a series of policies to increase agricultural production in south China, such as draining lakes, building terraces, and “wéi tián” (low-lying paddy fields surrounded with dikes). The state’s economic center gradually shifted to the Jiangnan Area (southern Jiangsu area) after the dredging on Beijing-Hangzhou Grand Canal in the Sui-Dynasty (AD 581–AD 618). With an increasing population, crops with higher productive yields were preferred in Jiangsu Province after 2,300 BP, such as rice and wheat, while millet and other crops were gradually abandoned owing to their relatively low yield.

In summary, the warm and wet climate encouraged the emergence of rice agriculture after 8,500 BP, facilitating human settlement in Jiangsu Province. Between 6,000 and 4,000 BP rice agriculture was firmly established, encouraged by the continuous warm and humid climate and marine regression process, and ultimately contributing to large-scale human settlement in Jiangsu. Millet agriculture was also brought into northern Jiangsu plains in this time. This is indirectly attributed to the warm and humid climate conditions in northern China, increasing food production supported by a favorable climate led to greater population growth and migration. Dry-farming was introduced into Jiangsu after 4,000 BP, which was likely the result of human migration southeastward from northern China from the “Holocene event 3”. Mixed agriculture and the revolutionary implements jointly increased food production in Jiangsu Province, leading to higher population increases between 4,000 and 2,300 BP. After 2,300 BP, frequent wars in northern China caused large migrations southward to Jiangsu Province, facilitating the introduction of new agricultural tools and farming innovations into southern China. Rice and wheat replaced millet as the principle crops owing to their low yield in southern China. These transformations led to the enhancement of agricultural productivity and yield in southern China, ultimately shifting the national economic center southward.

CONCLUSION

Rice agriculture first appeared in Jiangsu Province around 8,500 BP, and was firmly established between 6,000 and 4,000 BP. Millet agriculture was brought to the northern Jiangsu plain around 6,000 BP, with millet and wheat

introduced into southern Jiangsu after 4,000 BP. After 2,300 BP, millet agriculture disappears from Jiangsu Province, while a mixed rice and wheat agricultural system remained.

The warm and wet climate promoted the emergence of rice agriculture and settlement after 8,500 BP in Jiangsu Province. Benefiting from a continually warm and wet climate between 6,000 and 4,000 BP, rice agriculture was firmly established and spread rapidly, supporting greater human settlement in Jiangsu Province. The introduction of millet after 6,000 BP to the northern Jiangsu plain may also be a result of the southward migration of northern people caused by the warm and wet climate. Between 4,000 and 2,300 BP, a mixed agricultural system formed in Jiangsu Province due to the introduction of dry farming from northern China. Meanwhile, the introduction of bronze and iron farming tools improved human productivity and expanded the scale of human settlement. In the end, the new agricultural tools and farming techniques were brought southward after 2,300 BP, and led to the overall increase of the agricultural productive yield in the South, and finally promoted the scale of human settlement to the peak.

In addition, the difference of agricultural patterns was simple and rough in several different geographical units owing to the lack of systematic archaeobotanical research in Jiangsu Province. With further long term systematic archaeobotanical work, our understanding of these long-term transformations will be enriched.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding authors.

AUTHOR CONTRIBUTIONS

The study was designed by HML and XJ. The data was collected by ZL, XSL and analyzed by HML, XJ, YL, ZJH, HWS, and LQS. HML, YL, NJ, and XJ wrote the manuscript.

FUNDING

This research was supported by the National Natural Science Foundation of China (Grant Nos. 41771223, 41772369), the State Key Laboratory of Loess and Quaternary Geology, Institute of Earth Environment, CAS (Grant Nos. SKLLQG 2015), and the Fundamental Research Funds for the Central Universities (Grant No. SKYC2021011).

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/feart.2021.661684/full#supplementary-material>

REFERENCES

- An, C.-B., Tang, L., Barton, L., and Chen, F.-H. (2005). Climate Change and Cultural Response Around 4000 Cal Yr B.P. In the Western Part of Chinese Loess Plateau. *Quat. Res.* 63, 347–352. doi:10.1016/j.yqres.2005.02.004
- An, C., Feng, Z., and Tang, L. (2004). Environmental Change and Cultural Response between 8000 and 4000 Cal. Yr BP in the Western Loess Plateau, Northwest China. *J. Quat. Sci.* 19, 529–535. doi:10.1002/jqs.849
- Atahan, P., Itzstein-Davey, F., Itzstein-Davey, F., Taylor, D., Dodson, J., Qin, J., et al. (2008). Holocene-aged Sedimentary Records of Environmental Changes and Early Agriculture in the Lower Yangtze, China. *Quat. Sci. Rev.* 27, 556–570. doi:10.1016/j.quascirev.2007.11.003
- Barker, G., and Goucher, C. (2015). *The Cambridge World History, Volume II: A World with Agriculture, 12,000 BCE–500 CE*. London: Cambridge University Press
- Bond, G., Broecker, W., Johnsen, S., McManus, J., Labeyrie, L., Jouzel, J., et al. (1993). Correlations between Climate Records from North Atlantic Sediments and Greenland Ice. *Nature*. 365, 143–147. doi:10.1038/365143a0
- Bond, G., Kromer, B., Beer, J., Muscheler, R., Evans, M. N., Showers, W., et al. (2001). Persistent Solar Influence on north Atlantic Climate during the Holocene. *Science*. 294, 2130–2136. doi:10.1126/science.1065680
- Cao, Z. H., Yang, L. Z., Lin, X. G., Hu, Z. Y., Dong, Y. H., Zhang, G. Y., et al. (2007). Morphological Characteristics of Paddy fields, Paddy Soil Profile, Phytolith and Fossil rice Grain of the Neolithic Age in Yangtze River Delta (In Chinese). *Acta Pedologica Sinica* 44, 838–847.
- Chen, F. H., Dong, G. H., Zhang, D. J., Liu, X. Y., Jia, X., An, C. B., et al. (2015). Agriculture Facilitated Permanent Human Occupation of the Tibetan Plateau after 3600 B.P. *Science*. 347, 248–250. doi:10.1126/science.1259172
- Chen, J. Y. (1995). Analysis of the Primitive Agricultural Factors in the Neolithic Site of Xudun, Changzhou (In Chinese). *Agric. Archaeology* 1, 101–103.
- Chen, W., Wang, W.-M., and Dai, X.-R. (2009). Holocene Vegetation History with Implications of Human Impact in the Lake Chaohu Area, Anhui Province, East China. *Veget. Hist. Archaeobot.* 18, 137–146. doi:10.1007/s00334-008-0173-7
- Chen, Y. (2013). *On The Development of Early Agricultural in Ningzhen Region (7000-2500 BP)*. PhD Dissertation (In Chinese). Nanjing (China): Nanjing Agricultural University.
- Cheng, M. S. (2004). *Economic History of Northern China (In Chinese)*. Beijing: People's Publishing House
- Cheng, Z. J., Yang, Y. Z., Gan, H. Y., Lin, L. G., and Zhang, J. Z. (2020). The Macro-Plant Remains from Wanbei Site, Shuyang City, Jiangsu Province (In Chinese). *Agricul. Hist. Chin.* 39, 35–44.
- Crawford, G. W., Chen, X., Luan, F., and Wang, J. (2016). People and Plant Interaction at the Houli Culture Yuezhuang Site in Shandong Province, China. *The Holocene*. 26, 1594–1604. doi:10.1177/0959683616650269
- Cullen, H. M., deMenocal, P. B., Hemming, S., Hemming, G., Brown, F. H., Guilderson, T., et al. (2000). Climate Change and the Collapse of the Akkadian empire: Evidence from the Deep Sea. *Geology*. 28, 379–382. doi:10.1130/0091-7613(2000)028<0379:ccatco>2.3.co;2
- Dai, J., Cai, X., Jin, J., Ge, W., Huang, Y., Wu, W., et al. (2021). Earliest Arrival of Millet in the South China Coast Dating Back to 5,500 Years Ago. *J. Archaeological Sci.* 129, 105356. doi:10.1016/j.jas.2021.105356
- Dalfes, H. N., Kukla, G., and Weiss, H. (1997). Third Millennium BC Climate Change and Old World Collapse. *Springer Sci. Business Media*. 49, 1–14. doi:10.1007/978-3-642-60616-8_10
- d'Alpoim Guedes, J. (2011). Millets, Rice, Social Complexity, and the Spread of Agriculture to the Chengdu Plain and Southwest China. *Rice*. 4 (3), 104–113. doi:10.1007/s12284-011-9071-1
- d'Alpoim Guedes, J., and Bocinsky, R. K. (2018). Climate Change Stimulated Agricultural Innovation and Exchange across Asia. *Sci. Adv.* 4, eaar4491–12. doi:10.1126/sciadv.aar4491
- DeMenocal, P. B. (2001). Cultural Responses to Climate Change during the Late Holocene. *Science*. 292, 667–673. doi:10.1126/science.105928710.1126/science.1059827
- Diamond, J., and Bellwood, P. (2003). Farmers and Their Languages: The First Expansions. *Science*. 300, 597–603. doi:10.1126/science.1078208
- Ding, J. L. (2004). The Origin of rice fields and rice Farming in the Neolithic Age of the Lower Reaches of the Yangtze River (In Chinese). *South. Cult.* 2, 19–31.
- Ding, J. L., and Zhang, T. J. (2004). Discovery of Paddy Field in Songze Period at Chenghu Site (In Chinese). *Chin. Cult. heritage* 1, 72–73.
- Dong, G., Li, R., Lu, M., Zhang, D., and James, N. (2019). Evolution of Human-Environmental Interactions in China from the Late Paleolithic to the Bronze Age. *Prog. Phys. Geogr. Earth Environ.* 44 (1), 233–250. doi:10.1177/0309133319876802
- Dong, G., Li, T., Zhang, S., Ren, L., Li, R., Li, G., et al. (2021). Precipitation in Surrounding Mountains Instead of Lowlands Facilitated the prosperity of Ancient Civilizations in the Eastern Qaidam Basin of the Tibetan Plateau. *CATENA*. 203, 105318. doi:10.1016/j.catena.2021.105318
- Dong, G., Yang, Y., Han, J., Wang, H., and Chen, F. (2017). Exploring the History of Cultural Exchange in Prehistoric Eurasia from the Perspectives of Crop Diffusion and Consumption. *Sci. China Earth Sci.* 60, 1110–1123. doi:10.1007/s11430-016-9037-x
- Dong, G., Yang, Y., Liu, X., Li, H., Cui, Y., Wang, H., et al. (2018). Prehistoric Trans-continental Cultural Exchange in the Hexi Corridor, Northwest China. *The Holocene*. 28, 621–628. doi:10.1177/0959683617735585
- Fan, Y. B. (2011). *On the Development of rice Farming in Tai lake Area during the Neolithic Age of China*. Master Thesis (In Chinese). Nanjing (China): Nanjing Agricultural University
- Fang, J. Q. (1989). The Influence of Climate Change on Population Migration in Historical Period of China (In Chinese). *Geographical Environ. Res.* 2, 41–48.
- Feynman, J., and Ruzmaikin, A. (2007). Climate Stability and the Development of Agricultural Societies. *Climatic Change*. 84, 295–311. doi:10.1007/s10584-007-9248-1
- Frachetti, M. D., Spengler, R. N., Fritz, G. J., and Mar'yashev, A. N. (2010). Earliest Direct Evidence for Broomcorn Millet and Wheat in the central Eurasian Steppe Region. *Antiquity*. 84, 993–1010. doi:10.1017/S0003598X0006703X
- Fuller, D. Q. (2011). Pathways to Asian Civilizations: Tracing the Origins and Spread of Rice and Rice Cultures. *Rice*. 4, 78–92. doi:10.1007/s12284-011-9078-7
- Fuller, D. Q., Qin, L., Zheng, Y., Zhao, Z., Chen, X., Hosoya, L. A., et al. (2009). The Domestication Process and Domestication Rate in Rice: Spikelet Bases from the Lower Yangtze. *Science*. 323, 1607–1610. doi:10.1126/science.1166605
- Ge, Q. S., Fang, X. Q., and Zheng, J. Y. (2014). The Impact of Climate Change in Chinese History and its Response to Enlightenment (In Chinese). *Adv. Earth Sci.* 29, 23–29.
- Gignoux, C. R., Henn, B. M., and Mountain, J. L. (2011). Rapid, Global Demographic Expansions after the Origins of Agriculture. *Proc. Natl. Acad. Sci.* 108, 6044–6049. doi:10.1073/pnas.0914274108
- Gu, J. X., Zou, H. B., Li, M. C., Tang, L. H., Ding, J. L., and Yao, Q. D. (1998). Preliminary Understanding of rice Farming at Caoxieshan Site in Majiabang Period (In Chinese). *South. Cult.* 3, 15–24.
- Guedes, J. d. A., Jiang, M., He, K., Wu, X., and Jiang, Z. (2013). Site of Baodun Yields Earliest Evidence for the Spread of rice and Foxtail Millet Agriculture to South-West China. *Antiquity*. 87, 758–771. doi:10.1017/S0003598X00049449
- Guo, Y. B. (2000). Analysis of Neolithic Agricultural Economy in the East of Jianghuai River (In Chinese). *Agricul. Hist. Chin.* 19, 3–8.
- Han, P. Z. (1997). *Nanjing Cultural Relics (In Chinese)*. Beijing: Local records Publishing House
- Hori, K., Saito, Y., Zhao, Q., Cheng, X., Wang, P., Sato, Y., et al. (2001). Sedimentary Facies and Holocene Progradation Rates of the Changjiang (Yangtze) delta, China. *Geomorphology*. 41, 233–248. doi:10.1016/S0169-555X(01)00119-2
- Jia, X., Dong, G., Li, H., Brunson, K., Chen, F., Ma, M., et al. (2013). The Development of Agriculture and its Impact on Cultural Expansion during the Late Neolithic in the Western Loess Plateau, China. *The Holocene*. 23 (1), 85–92. doi:10.1177/0959683612450203
- Jia, X., Sun, Y., Wang, L., Sun, W., Zhao, Z., Lee, H. F., et al. (2016). The Transition of Human Subsistence Strategies in Relation to Climate Change during the Bronze Age in the West Liao River Basin, Northeast China. *The Holocene*. 26 (5), 781–789. doi:10.1177/0959683615618262
- Jiang, A. J., Xiang, Y., Peng, H. Y., and Wang, B. M. (2006). The Analysis of Jiangsu Climate Variety in Forty Years. *Scien. Meteorol. Sin.* 26, 525–529.
- Jin, G., Wagner, M., Tarasov, P. E., Wang, F., and Liu, Y. (2016). Archaeobotanical Records of Middle and Late Neolithic Agriculture from Shandong Province, East China, and a Major Change in Regional Subsistence during the Dawenkou Culture. *The Holocene*. 26 (10), 1605–1615. doi:10.1177/0959683616641746

- Jones, M., Hunt, H., Kneale, C., Lightfoot, E., Lister, D., Liu, X., et al. (2016). Food Globalisation in Prehistory: The Agrarian Foundations of an Interconnected Continent. *Jba*. 4, 73–87. doi:10.5871/jba/004.073
- Jones, M., Hunt, H., Lightfoot, E., Lister, D., Liu, X., and Motuzaite-Matuzeviciute, G. (2011). Food Globalization in Prehistory. *World Archaeology*. 43, 665–675. doi:10.1080/00438243.2011.624764
- Kearns, G. (2010). Geography, Geopolitics and Empire. *Trans. Inst. Br. Geogr.* 35, 187–203. doi:10.1111/j.1475-5661.2009.00375.x
- Kerr, R. A. (1998). Archaeology: Sea-Floor Dust Shows Drought Felled Akkadian Empire. *Science*. 279, 325–326. doi:10.1126/science.279.5349.325
- Lev-Yadun, S., Gopher, A., and Abbo, S. (2000). ARCHAEOLOGY: Enhanced: The Cradle of Agriculture. *Science*. 288, 1602–1603. doi:10.1126/science.288.5471.1602
- Li, H. M., and Dong, G. H. (2018). The Adoption of Wheat and Barley as Major Staples in Northwest China during the Early Bronze Age. *Far from the Hearth Essays in Honour of Martin Jones Chapter*. 16, 189–198. doi:10.17863/CAM.38307
- Li, L., Zhu, C., Jiang, F., Zhao, Q., and Lin, I. (2008). Research on the Disappearance Causes of the Tenghualuo Site in Lianyungang, Jiangsu Province, China. *Sci. Bull.* 53, 161–176. doi:10.1007/s11434-008-5016-5
- Li, L., Zhu, C., Lin, L., Zhao, Q., Shi, G., Zheng, C., et al. (2009). Evidence for marine Transgression between 7500–5400BC at the Luotuodun Site in Yixing, Jiangsu Province. *J. Geogr. Sci.* 19, 671–680. doi:10.11821/xb20081100810.1007/s11442-009-0671-2
- Li, Y., Wu, J., Hou, S., Shi, C., Mo, D., Liu, B., et al. (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. doi:10.1016/j.quaint.2010.05.015
- Liang, Y. (1986). Brief Talk on the Metal Farm Tools in the Middle and Lower Reaches of the Yangtze River during the Spring and Autumn Period and the Warring States Period (In Chinese). *J. Guangxi Normal Univ. (PHILOSOPHY SOCIAL SCIENCES)*. 2, 63–70.
- Liao, Y., Lu, P., Mo, D., Wang, H., Storozum, M. J., Chen, P., et al. (2019). Landforms Influence the Development of Ancient Agriculture in the Songshan Area, central China. *Quat. Int.* 521, 85–89. doi:10.1016/j.quaint.2019.07.015
- Liao, Z. H. (1982). Discussion. *Agric. Archaeology*. 18, 114. doi:10.1111/j.1475-1305.1982.tb01910.x
- Lin, L. G., Gan, H. Y., and Yan, L. (2014). A Report on the Excavation of the Neolithic Site in Shunshanji, Sihong, Jiangsu Province (In Chinese). *Acta Archaeol. Sin.* 4, 519–562.
- Lin, L. G., and Tian, M. L. (2009). Excavation Report of Luotuodun Site in Yixing, Jiangsu Province (In Chinese). *South. Cult.* 5, 26–44.
- Lin, L. G., Tian, M. L., and Xu, J. Q. (2003). Excavation of Luotuodun Neolithic Site in Yixing City, Jiangsu Province (In Chinese). *Archaeology* 7, 5–11.
- Lin, L. G., and Wang, Q. Z. (2000). Excavation of Zuohu Site in Zhenjiang City, Jiangsu Province (In Chinese). *Archaeology* 4, 14–33.
- Lin, L. G., and Zhang, W. X. (2005). Study on Ancient rice at Tenghualuo and Houdatang Sites during Longshan Cultural in Huang Huai Region (In Chinese). *South. Cult.* 1, 15–19.
- Liu, X., Jones, P. J., Motuzaite Matuzeviciute, G., Hunt, H. V., Lister, D. L., An, T., et al. (2019). From Ecological Opportunism to Multi-Cropping: Mapping Food Globalisation in Prehistory. *Quat. Sci. Rev.* 206, 21–28. doi:10.1016/j.quascirev.2018.12.017
- Lu, H., Zhang, J., Liu, K.-b., Wu, N., Li, Y., Zhou, K., et al. (2009). Earliest Domestication of Common Millet (*Panicum Miliaceum*) in East Asia Extended to 10,000 Years Ago. *Proc. Natl. Acad. Sci.* 106, 7367–7372. doi:10.1073/pnas.0900158106
- Luo, W., Yang, Y., Yao, L., Chen, Z., Li, J., Yin, C., et al. (2016). Phytolith Records of rice Agriculture during the Middle Neolithic in the Middle Reaches of Huai River Region, China. *Quat. Int.* 426, 133–140. doi:10.1016/j.quaint.2016.03.010
- Ma, C., Zhu, C., Zheng, C., Yin, Q., and Zhao, Z. (2009). Climate Changes in East China since the Late-Glacial Inferred from High-Resolution Mountain Peat Humification Records. *Sci. China Ser. D-earth Sci.* 52, 118–131. doi:10.1007/s11430-009-0003-5
- Ma Yu-qian, G. L., Li Guang-hua, J. Y., Zhang Cheng-muo, J. L., Qian Yue-min, G. L., Xiao Qian-yi, fnm., Lu Zhu-guo, fnm., et al. (1990). The Energy Spectrum of Cygnus X-1. *Chin. Astron. Astrophysics*. 14, 1–9. doi:10.1016/0275-1062(90)90002-u
- Man, Z. M. (2009). *Research on Climate Change in Chinese Historical Period*. Shandong, China: Shandong Education Press
- Mannion, A. M. (1999). Domestication and the Origins of Agriculture: an Appraisal. *Prog. Phys. Geogr.* 23, 37–56. doi:10.1191/030913399677315626
- Min, Z. D. (1986). Rice History of Jiangsu Province (In Chinese). *Agric. Archaeology*. 1, 254–266.
- Nakamura, S.-i. (2010). The Origin of rice Cultivation in the Lower Yangtze Region, China. *Archaeol Anthropol. Sci.* 2, 107–113. doi:10.1007/s12520-010-0033-0
- Nanjing Museum Lianyungang Museum (2015). *Tenghualuo Site: Archaeological Excavation Report of Neolithic Sites in Lianyungang (In Chinese)*. Beijing: Science Press
- National Museum of China Nanjing Museum Sihong Museum (2018). 2015 and 2016 Excavations Report of the Hanjing Site in Sihong, Jiangsu Province (In Chinese). *South. Cult.* 261, 28–39.
- Overton, N. J., and Taylor, B. (2018). Humans in the Environment: Plants, Animals and Landscapes in Mesolithic Britain and Ireland. *J. World Prehist.* 31, 385–402. doi:10.1007/s10963-018-9116-0
- Pei, Q., Lee, H. F., Zhang, D. D., and Fei, J. (2019). Climate Change, State Capacity and Nomad-Agriculturalist Conflicts in Chinese History. *Quat. Int.* 508, 36–42. doi:10.1016/j.quaint.2018.10.022
- Price, T. D., and Bar-Yosef, O. (2011). The Origins of Agriculture: New Data, New Ideas. *Curr. Anthropol.* 52, S163–S174. doi:10.1086/659964
- Qin, L. (2011). *Chuodun Site and Some Plant Remains Unearthed from Chenghu Site (In Chinese). Chuodun Site in Kunshan*. Beijing: Suzhou Institute of Archaeology Cultural Relics Publishing House, 334–342.
- Qin, L. (2012). Research and prospect of Archaeobotany on the Origin of Agriculture in China (In Chinese). *Archaeol. Res.*, 260–315.
- Qin, L. (2016). “Analysis of Plant Remains Unearthed from Dongshancun Site (In Chinese),” in *Dongshancun Site: Excavation Report of Neolithic site Nanjing Museum, Zhangjiagang Cultural Management Office (Zhangjiagang Museum (Beijing: Cultural Relics Publishing House))*, 605–624.
- Qiu, Z. W., Jiang, H. E., and Ding, J. L. (2013). Study on Neolithic Plant Remains in Jiangli Site, Kunshan, Jiangsu (In Chinese). *Cult. Relics*. 1, 90–96.
- Qiu, Z., Jiang, H., Ding, J., Hu, Y., and Shang, X. (2014). Pollen and Phytolith Evidence for rice Cultivation and Vegetation Change during the Mid-late Holocene at the Jiangli Site, Suzhou, East China. *PLoS One*. 9, e97541. doi:10.1371/journal.pone.0097541
- Qiu, Z. W., Ding, J. L., Jiang, H. E., and Hu, Y. W. (2014). Analysis on Plant Remains from Rice Paddy Fields of the Liangzhu Culture at the Zhumucun Site, Kunshan, Jiangsu (In Chinese). *South. Cult.* 2, 57–67.
- Qiu, Z., Jiang, H., Ding, L., and Shang, X. (2020). Late Pleistocene-Holocene Vegetation History and Anthropogenic Activities Deduced from Pollen Spectra and Archaeological Data at Guxu Lake, Eastern China. *Sci. Rep.* 10, 9306. doi:10.1038/s41598-020-65834-z
- Qiu, Z., Liu, B., Li, Y., Shang, X., and Jiang, H. (2016). Analysis of Plant Remains at the Neolithic Yangjia Site, Wuxi City, Jiangsu Province (East China). *Sci. China Earth Sci.* 59, 1803–1816. doi:10.1007/s11430-016-5326-4
- Qiu, Z. W., Zhuang, L. N., and Lin, L. G. (2018). Phytolith Evidence for Rice Domestication of the Hanjing Site in Sihong, Jiangsu Province and the Related Issues (In Chinese). *South. Cult.* 261, 71–80.
- Qu, W., Xue, B., Dickman, M. D., Wang, S., Fan, C., Wu, R., et al. (2000). A 14 000-year Record of Paleoenvironmental Change in the Western basin of China's Third Largest lake, Lake Taihu. *Hydrobiologia*. 432, 113–120. doi:10.1023/A:1004079220926
- Ren, X., Lemoine, X., Mo, D., Kidder, T. R., Guo, Y., Qin, Z., et al. (2016). Foothills and Intermountain Basins: Does China's Fertile Arc Have 'Hilly Flanks'? *Quat. Int.* 426, 86–96. doi:10.1016/j.quaint.2016.04.001
- Richerson, P. J., Boyd, R., and Bettinger, R. L. (2001). Was Agriculture Impossible during the Pleistocene but Mandatory during the Holocene? A Climate Change Hypothesis. *Am. Antiq.* 66, 387–411. doi:10.2307/2694241
- Sheets, P., Bawden, G., and Reycraft, R. M. (2002). Environmental Disaster and the Archaeology of Human Response. Garth Bawden and Richard Martin Reycraft, Editors. *Anthropological Papers, Vol. 7. Maxwell Museum of Anthropology, University of New Mexico, Albuquerque, 2000. X + 228 pp., Figures, Tables, Bibliography, index. \$34.95 (Paper). Latin Am. Antiq.* 13 (2), 238–239. doi:10.2307/971917
- Shen, Z. Z. (2009). Studies on Prehistoric Agriculture in the Eastern Jianghuai Region (In Chinese). *Agricul. Hist. Chin.* 4, 46–55.

- Sheng, P., Shang, X., Sun, Z., Yang, L., Guo, X., and Jones, M. K. (2018). North-south Patterning of Millet Agriculture on the Loess Plateau: Late Neolithic Adaptations to Water Stress, NW China. *The Holocene*. 28 (10), 1554–1563. doi:10.1177/0959683618782610
- Sherratt, A. G. (2006). “The Trans- Eurasian Exchange: The Prehistory of Chinese Relations with the West,” in *Contact and Exchange in the Ancient World*. Editor V. H. Mair (Honolulu, HI: Hawaii University Press), 32–53.
- Spengler, R., Frachetti, M., Doumani, P., Rouse, L., Cerasetti, B., Bullion, E., et al. (2014). Early Agriculture and Crop Transmission Among Bronze Age mobile Pastoralists of Central Eurasia. *Proc. R. Soc. B*. 281, 20133382. doi:10.1098/rspb.2013.3382
- Stanley, D. J., Chen, Z., and Song, J. (1999). Inundation, Sea-Level Rise and Transition from Neolithic to Bronze Age Cultures, Yangtze Delta, China. *Geoarchaeology*. 14, 15–26. doi:10.1002/(sici)1520-6548(199901)14:1<15::aid-gea2>3.0.co;2-n
- Staubwasser, M., Sirocko, F., Grootes, P. M., and Segl, M. (2003). Climate Change at the 4.2 Ka BP Termination of the Indus valley Civilization and Holocene South Asian Monsoon Variability. *Geophys. Res. Lett.* 30, 1425. doi:10.1029/2002gl016822
- Stevens, C. J., Murphy, C., Roberts, R., Lucas, L., Silva, F., and 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. doi:10.1177/0959683616650268
- Sun, L. Q., and Liu, D. S. (2011). Yongjia Rebellion and the Change of Northern Political Pattern (In Chinese). *Hebei Acad. J.* 31, 66–70. doi:10.3969/j.issn.1003-7071.2011.03.013
- Sun, Q., Liu, Y., Wünnemann, B., Peng, Y., Jiang, X., Deng, L., et al. (2019). Climate as a Factor for Neolithic Cultural Collapses Approximately 4000 Years BP in China. *Earth-Science Rev.* 197, 102915. doi:10.1016/j.earscirev.2019.102915
- Tang, L. H. (2016). “Analysis of Carbonized rice (In Chinese),” in *Shendun Site in LiyangNanjing Museum, Changzhou Museum, Liyang Culture, Radio, Television and Sports Bureau* (Beijing: Cultural Relics Publishing House), 483–487.
- Tang, L. H. (1999). “Identification and Analysis of rice Remains in Longqiuzhuang Site (In Chinese),” in *Longqiuzhuang: A Report on the Excavation of Neolithic Sites in the East of Jianghuai RiverArchaeological Team of Longqiuzhuang Site* (Beijing: Science Press), 440–448.
- Tang, L. H., Yokichiro, S., Udatsu, T., and Sun, J. X. (1999). Types of Ancient rice Seeds at Caoxieshan Site in China (In Chinese). *Jiangsu J. Agric. Sci.* 15, 193–197. doi:10.1023/a:1006701600323
- Tang, L. H., and Zhang, M. (1996). The Original rice Cultivation at Longqiuzhuang Site in Gaoyou. *Acta Crop Sinica*. 22, 608–612.
- Tang, L. H., Zhou, J. S., Wang, C. L., and Li, H. J. (1992). Investigation of Ancient rice Cultivation at Longnan Site in Meinian, Jiangsu Province (In Chinese). *Agric. Archaeology* 1, 78–81.
- Tao, J., Chen, M.-T., and Xu, S. (2006). A Holocene Environmental Record from the Southern Yangtze River delta, Eastern China. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* 230, 204–229. doi:10.1016/j.palaeo.2005.07.015
- Tian, M. L., Tan, G. H., Xu, J. Q., and Zhou, R. K. (2009). Summary of Excavation of Xixi Site in Yixing, Jiangsu (In Chinese). *South. Cult.* 5, 59–62.
- Udatsu, T., Tang, L. H., Wang, C. L., Zheng, Y. F., Yanagisawa, K., Sasa, T., et al. (1998). Exploration of Paddy Field Heritage in China (In Chinese). *Agric. Archaeology*. 1, 138–153.
- Wang, C. L. (1999). “Analysis of rice Plant Opal from Longqiuzhuang Site (In Chinese),” in *Longqiuzhuang: A Report on the Excavation of Neolithic Sites in the East of Jianghuai RiverArchaeological Team of Longqiuzhuang Site* (Beijing: Science Press), 448–458.
- Wang, C. L., and Ding, J. L. (1999). Research on Ancient rice Cultivation at Dongshansun Site in Zhangjiagang (In Chinese). *Agric. Archaeology* 3, 88–97.
- Wang, C. L., and Ding, J. L. (2000). Plant Opal Analysis of Shaoqingshan Site in Kunshan City, Jiangsu Province (In Chinese). *Archaeology* 4, 89–94.
- Wang, C. L., and Ding, J. L. (2001). Study on Ancient rice Cultivation at Guangfu Village Site in Wujiang (In Chinese). *Agric. Archaeology* 3, 97–103.
- Wang, C., Lu, H., Gu, W., Wu, N., Zhang, J., Zuo, X., et al. (2017). The Spatial Pattern of Farming and Factors Influencing it during the Peiligang Culture Period in the Middle Yellow River valley, China. *Sci. Bull.* 62, 1565–1568. doi:10.1016/j.scib.2017.10.003
- Wang, C. L., Zhou, Y. X., Wang, Z. G., and Zhang, J. X. (2013). Plant Opal Analysis of Xuecheng Site in Gaochun, Jiangsu Province. *Commemorating The 110th Anniversary of Mr Cultivation*. Zhou Shilu’s birth and the International Symposium on the origin of rice, 55–61.
- Wang, J. H., He, H. S., Xie, C. Z., and Zhou, J. H. (2002). The Second Excavation of Fenghuangshan Site in Danyang (In Chinese). *South. Cult.* 3, 43–49.
- Wang, G. F., and Zhang, J. (2004). Sanxingcun Neolithic Site in Jintan, Jiangsu Province (In Chinese). *Cult. Relics*. 2, 4–26.
- Wang, J. H. (2007). New Archaeological Discoveries in Southern China in 2006 (In Chinese). *South. Cult. Relics*. 4, 19–87.
- Wang, S., and Gong, D. (2000). Climate in China during the Four Special Periods in the Holocene. *Prog. Nat. Sci.* 10, 379–386.
- Wang, S. M., Lu, Y., Liu, X. Q., Li, X. S., He, H. Z., and Shen, Z. Z. (2019). *The History of World Agricultural Civilization Chinese*. (Beijing: China Agriculture Press)
- Wang, S., Yang, X., Yan, M. A., Pan, H., Tong, G., and Wu, X. H. (1996). Environmental Change of Gucheng Lake of Jiangsu in the Past 15 Ka and its Relation to Palaeomonsoon. *Sci. China, Ser. D: Earth Sci.* 39, 144–151. doi:10.1007/BF01079756
- Wang, W. (2004). A Discussion on the Reason of Large-Scale Cultural Changes in China Around 2000 BC. *Archaeology*. 1, 67–77.
- Wang, Z. G., Li, W. M., and Qian, F. (1982). Excavation of Sidun Site in Wujin, Changzhou, Jiangsu Province (In Chinese). *Archaeology* 2, 15–35+100.
- Weiss, H., Courty, M.-A., Wetterstrom, W., Guichard, F., Senior, L., Meadow, R., et al. (1993). The Genesis and Collapse of Third Millennium north Mesopotamian Civilization. *Science*. 261, 995–1004. doi:10.1126/science.261.5124.995
- Willcox, G., Buxo, R., and Herveux, L. (2009). Late Pleistocene and Early Holocene Climate and the Beginnings of Cultivation in Northern Syria. *The Holocene*. 19 (1), 151–158. doi:10.1177/09596836080898961
- Wu, R. Z. (2011). Research on Bronze Farm Tools in the Lower Reaches of the Yangtze River during the Spring and Autumn and Warring States Periods (In Chinese). Annual Meeting of Chinese Archaeological Society: Chinese Archaeological Society. Zhejiang Provincial Bureau of cultural relics, Conference Papers
- Wu, W. W., Lin, L. G., Gan, H. Y., and Jin, G. Y. (2017a). Environment and Subsistence of the Second Phase of Shunshanji Site: Evidence from Phytolith Analysis. *Agricul. Hist. Chin.* 36, 3–14.
- Wu, W. W., Si, H. W., Wang, S. M., and Li, Y. J. (2017b). Preliminary Analysis of the Carbonized Plant Remains from the Dingjiacun Site in Zhenjiang, Jiangsu Province (In Chinese). *South. Cult.* 5, 78–88. doi:10.3969/j.issn.1001-179X.2017.05.009
- Wu, W. W., Lin, L. G., Gan, H. Y., and Yan, L. (2019). The Conscious Production of Liangzhu Culture at Jiangzhuang Site from the Macro-Remains Perspective (In Chinese), *Agricul. Hist. Chin.* 6, 3–16.
- Wu, W. W., Yuan, F., and Tian, E. W. (2021). Archaeobotanical Analysis of the Settlement Subsistence of the Miaotaizi Site in Xuzhou (In Chinese). *Agricul. Hist. Chin.* in press
- Wu, W. X., and Liu, D. S. (2004). 4000A B.P. Changes of East Asian Monsoon and Decline of Neolithic Culture Around central China (In Chinese). *Quat. Sci.* 24, 278–284.
- Wu, W. X., and Liu, D. S. (2001). Cooling Events Around 4000A B.P. And the Birth of Chinese Civilization (In Chinese). *Quat. Sci.* 21, 443–451.
- Xhaufclair, H., Revel, N., Vitales, T. J., Callado, J. R., Tandang, D., Gaillard, C., et al. (2017). What Plants Might Potentially Have Been Used in the Forests of Prehistoric Southeast Asia? an Insight from the Resources Used Nowadays by Local Communities in the Forested highlands of Palawan Island. *Quat. Int.* 448, 169–189. doi:10.1016/j.quaint.2017.02.011
- Xi, C. P. (2003). *Excavation Results of Shaoqingshan Site (In Chinese)*. Chuodun Mountain: A Collection of Papers on Chuodun Site. Nanjing, China: Nanjing Museum/Southeast culture press
- Xia, L., Zhang, Q., Sun, N., Zhai, Y. J., and Wang, S. H. (2015). Climate Change Characteristics in Jiangsu Province, 1960–2012. *J. Glaciology Geocryology* 37, 1480–1489.
- Xinying, Z., Xiaoqiang, L., Dodson, J., and Keliang, Z. (2016). Rapid Agricultural Transformation in the Prehistoric Hexi Corridor, China. *Quat. Int.* 426, 33–41. doi:10.1016/j.quaint.2016.04.021

- Xu, D. D. (2016). *Statistic Analysis of Spatial and Temporal Characteristics of Precipitation in Jiangsu Province. PhD Dissertation (In Chinese)*. Nanjing (China): Nanjing University of Information Science & Technology
- Yang, Y., Li, W., Yao, L., Cheng, Z., Luo, W., Zhang, J., et al. (2016). Plant Food Sources and Stone Tools' Function at the Site of Shunshanji Based on Starch Grain Analysis. *Sci. China Earth Sci.* 59, 1574–1582. doi:10.1007/s11430-016-5321-9
- Yi, D. (1988). *Discovery of Ancient Sites in Xiaodanyang Town, Jiangning (In Chinese)*. South: Cult. Z1, 194
- Yin, H. Z., Zhang, Z. X., and Ji, Z. Q. (1964). Report on Excavation of Dadunzi Site in Pixian County, Jiangsu Province (In Chinese). *Acta Archaeol. Sin.* 2, 12–59+208.
- You, B. (2018). *The Change of Jingkang: The Decline of the Northern Song Dynasty (In Chinese)*. Changsha: Hunan People's Publishing House
- You, X. L. (2001). Identification of Carbonized rice from Weidun Site (In Chinese). *Acta Archaeol. Sin.* 1, 109–110.
- Zeder, M. A. (2008). Domestication and Early Agriculture in the Mediterranean Basin: Origins, Diffusion, and Impact. *Proc. Natl. Acad. Sci.* 105, 11597–11604. doi:10.1073/pnas.0801317105
- Zeng, X. S. (2005). An Analysis of the Theory of “Double Cropping of rice and Wheat” in Song Dynasty (In Chinese). *Hist. Stud.* 1, 86–106.
- Zhang, D. D., Pei, Q., Lee, H. F., Zhang, J., Chang, C. Q., Li, B., et al. (2015). The Pulse of imperial China: a Quantitative Analysis of Long-term Geopolitical and Climatic Cycles. *Glob. Ecol. Biogeogr.* 24 (1), 87–96. doi:10.1111/geb.12247
- Zhang, J. G. (2008). *Research on the Influence of Anlushan Rebellion on the Economic Development of Tang Dynasty (In Chinese)*. Beijing: Chinese financial & Economic Publishing House
- Zhang, J., Zhang, X., and Xia, Z. (2014). Research on Charred Plant Remains from the Neolithic to the Bronze Age in Luoyang Basin. *Chin. Sci. Bull.* 59, 3388–3397. doi:10.1360/N972013-00022
- Zhang, Q., Zhu, C., Liu, C. L., and Jiang, T. (2004). Environmental Changes in the Yangtze Delta since 7000 a BP (In Chinese). *Acta Geogr. Sin.* 59, 534–542.
- Zhang, R. H. (2005). Sporopollen Record in Chuodun Site in Suzhou, Jiangsu and Palaeoenvironment in Taihu Region (In Chinese). *Acta Palaeontol. Sin.* 44, 314–321.
- Zhang, Y., and Zhu, C. (2008). “Environmental Archaeology of the Dachang Region in the Daning Valley, the Three Gorges Reservoir Region of the Yangtze River, China, *Sci. Bull.*” in *Anthology of Prehistoric Rice Research*. Editors A. P. Pei and W. X. Zhang (Beijing: Science Press), 53, 140–152. doi:10.1007/s11434-008-5012-9
- Zhao, Y. (2011). *Jiangsu Geography (In Chinese)*. Beijing: Beijing Normal University Press
- Zhao, Z. (2011). New Archaeobotanic Data for the Study of the Origins of Agriculture in China. *Curr. Anthropol.* 52, S295–S306. doi:10.1086/659308
- Zhao, Z. J. (2014). The Process of Origin of Agriculture in China: Archaeological Evidence from Flotation Results (In Chinese). *Quat. Sci.* 34, 7–84. doi:10.3969/j.issn.1001-7410.2014.10
- Zhao, Z. J. (2020). Origin of Agriculture and Archaeobotanical Works in China (In Chinese). *Agricul. Hist. Chin.* 39, 3–9.
- Zheng, X. M. (2003). *The Southward Shift of Economic center in Ancient China and Economic Study of Jiangnan in Tang-Song Dynasties*. Changsha: Yuelu Press
- Zheng, Y. F., and Chen, X. G. (2006). An Archaeological Study on the Origin of Muskmelon-On The Seeds of Muskmelon from the Lower Reaches of the Yangtze River (In Chinese). *Journal of Zhejiang Institute of Cultural Relics and Archaeology*, Vol. 8. Beijing: Zhejiang Institute of cultural relics and Archaeology Science Press, 78–585.
- Zheng, Y. F., You, X. L., Xu, J. M., and Bian, Q. J. (1994). Plant Opal Analysis of Longnan Neolithic Site (In Chinese). *Rice Sci. China* 8, 55–56.
- Zhenjiang Museum (1979). Mound Tomb of Fushanguoyuan in Jurong, Jiangsu Province (In Chinese). *Archaeology.* 2, 13–24+103.
- Zhong, M. (1987). Dianjiangtai Site in Tangshan, Jiangning (In Chinese). *South. Cult.* 3, 38–50.
- Zhou, Q., and Han, Y. H. (2008). *New Theory on Jiangsu Geography (In Chinese)*. Nanjing: Nanjing University Press
- Zhu, C., Zhang, Y., Zhang, Q., and Lu, J. F. (2003). Archaeological Stratigraphy of the Neolithic Site in Qitoushan, Jiangyin, Jiangsu Province (In Chinese). *J. Stratigr.* 27, 314–317.
- Zohary, D., and Hopf, M. (2000). *Domestication of Plants in the Old World: The Origin and Spread of Cultivated Plants in West Asia*. New York: Oxford University Press
- Zohary, D., Hopf, M., and Weiss, E. (2012). *Domestication of Plants in the Old World: The Origin and Spread of Domesticated Plants in Southwest Asia, Europe, and the Mediterranean Basin*. New York: Oxford University Press

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The handling editor declared a past collaboration with one of the authors (HL).

Copyright © 2021 Li, Liu, James, Li, Hu, Shi, Sun, Lu and Jia. This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY). The use, distribution or reproduction in other forums is permitted, provided the original author(s) and the copyright owner(s) are credited and that the original publication in this journal is cited, in accordance with accepted academic practice. No use, distribution or reproduction is permitted which does not comply with these terms.