



The “2.8 ka BP Cold Event” Indirectly Influenced the Agricultural Exploitation During the Late Zhou Dynasty in the Coastal Areas of the Jianghuai Region

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As a global cooling event, many of the climatic and socio-cultural mechanisms that resulted in changes after the 2.8 ka BP event remain unclear. In China, this period roughly corresponds with the Zhou Dynasty (1046–212 BC), a critical period when ancient Chinese civilization was experiencing significant cultural and technological changes, including the movement of people to modern-day Jiangsu Province, where they intensively used the natural resources found in this the coastal area. Recent archaeobotanical evidence, and two radiocarbon dates on wheat and foxtail millet, indicate that the Datongpu site, which dates around 2,600 cal a BP, was occupied during this period of transition around the 2.8 ka BP climate event. In total, our investigations recovered 3,399 carbonized seeds from seventy-four flotation samples, of which rice, foxtail millet, broomcorn millet, and wheat seeds were predominant along with 2,296 weed seeds. Additionally, we identified several rice spikelets and wheat rachises. The high number of carbonized rice grains indicates that rice farming was the primary crop in an otherwise mixed rice-dry farming system at Datongpu. In addition, we argue that the “2.8 ka BP cold event” probably influenced population growth and caused food shortages throughout Central China, leading people to migrate southeastward along the Huai River to the coastal areas of Jianghuai Region. We argue that this abrupt shift in the climate indirectly facilitated the exploitation and emergence of large-scale agriculture in this area. Our study provides an example for the indirect impact of climate change in areas with relatively favorable climate conditions.

Keywords: archaeobotany, bronze age, wheat, abrupt climate, cultural communication

INTRODUCTION

In the past, changes in climatic regimes have had a profound impact on economic development, the distribution of ethnic groups, social stability, and geopolitics [Intergovernmental Panel on Climate Change (IPCC), 2013; Carleton and Hsiang, 2016; Chen S. et al., 2016; FAO, 2016; Hallegatte et al., 2016; Jia et al., 2017a, 2019; Sellers et al., 2019], as well as human migrations, the emergence of social complexity, and, in China, the patterns of dynastic succession (Weiss and Bradley, 2001; Zhang et al., 2008; Buckley et al., 2010; Pederson et al., 2014; Chen et al., 2015a; Timmermann and Friedrich, 2016; Evans et al., 2018). The “2.8 ka BP cold event” was a rapid global climate cooling event, which likely transformed pre-existing social patterns in a variety of ways (Geel et al., 2004; Sophie, 2006). Some transformations thought to be related to this event include technological innovation, population migration, and novel subsistence strategies. The nomadic population migrated toward the south in the pursuit of better meadows around 2.8 ka BP, which accelerated the formation of the Chinese northern nomadic cultural belt (Zhang et al., 2019). This abrupt climate event also led to an increase in the adoption of wheat as a staple crop in the Central Plains of China (Central and Northern Henan Province, southern Shanxi Province, Southern Hebei Province, and central Shaanxi Province), further promoting population growth and socio-political complexity around 2.8 ka BP (Li et al., 2020). However, the relationship between this climate event and human activities in southern China is less clear, because climate changes do not have a significant or direct impact on human activities in areas with high temperature and large amounts of precipitation. Some scholars have argued that rice’s low tolerance to cold temperatures in the lower reaches of the Yangtze River (e.g., Chen et al., 2020; Muhammad et al., 2021) coupled with millet and wheat’s higher tolerance to cold temperatures in northern China (e.g., Ji et al., 2021; Xiao et al., 2021), influenced the gradual adoption of millet and wheat in southern diets post 2.8 ka BP.

One way to explore the answer to this question is to use archaeobotany to understand cropping patterns in prehistory, which in many ways act as a bridge between climatic processes and ancient societal changes (Mercuri, 2008; Zeder, 2008; Chen et al., 2015b; Jia et al., 2016; Pokharia et al., 2017; Wang et al., 2021). After crops were first domesticated, people transported them all around the world (Jones et al., 2011). Many of the hypotheses regarding origins and diffusion of domesticated crops put climate change as a crucial role (Dalfes et al., 1997; Bawden and Reycraft, 2002; Staubwasser et al., 2003; Bar-Yosef, 2011; Jia et al., 2016, 2021a; Dong et al., 2019). Technological innovation played an important role in accelerating social transformations and human-environmental interactions during the period between the third and first millennium BCE (Diamond and Bellwood, 2003; Chen et al., 2015b; Dong et al., 2017a).

China has a long Neolithic tradition that is divided along geographic lines: the domestication of millet occurred in Northern China (Zhao, 2004a; Lu et al., 2009; Yang et al., 2012; Zhao et al., 2020) and rice was domesticated in the middle and lower Yangtze area of Southern China (Zhao,

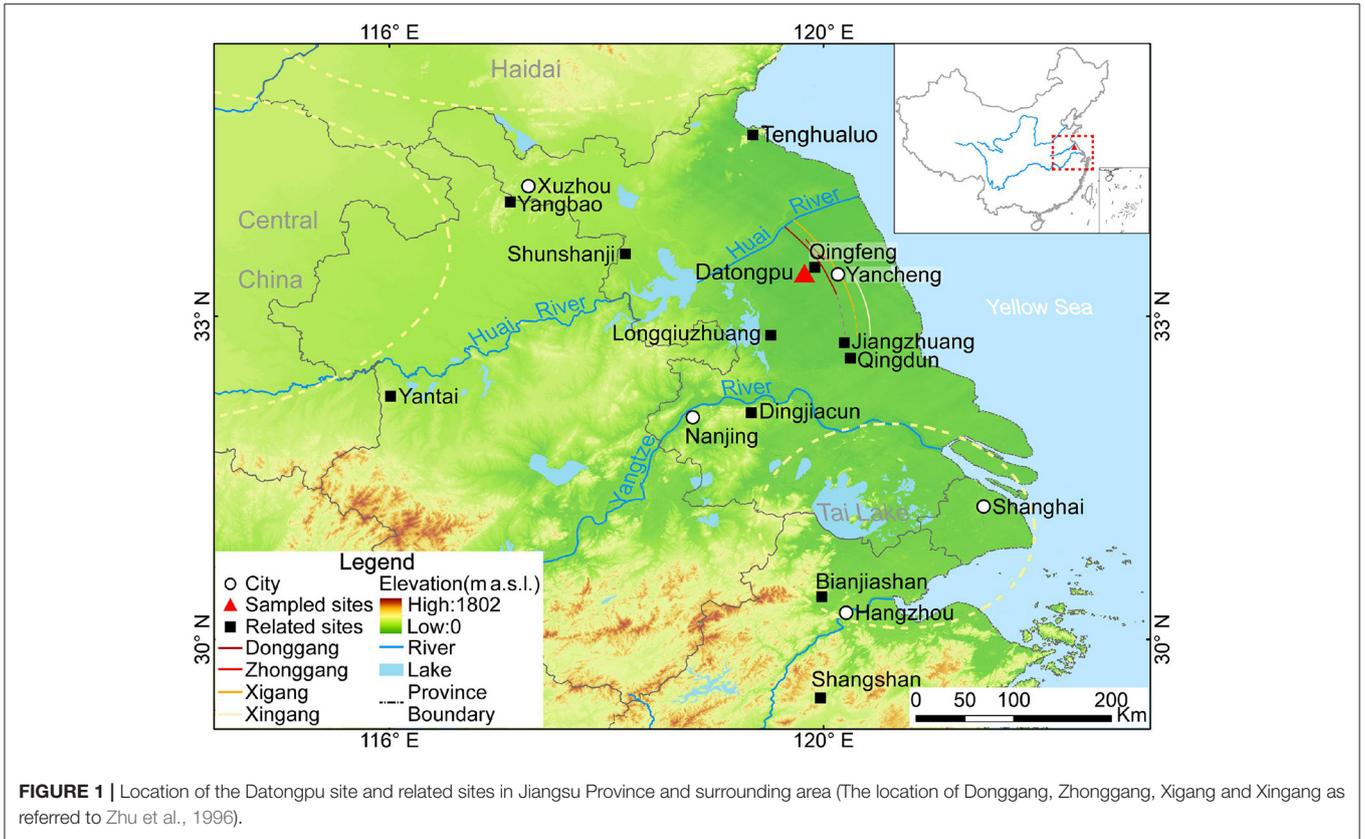
1998; Fuller et al., 2009; Wu et al., 2014b), respectively, and then later diffused around the world. However, many studies focused on the diffusion of millet to the West (Jones et al., 2011; Motuzaitė-Matuzevičiūtė et al., 2013; Miller et al., 2016; Dong et al., 2017b) and rice to the South (Fuller, 2011; Deng et al., 2018; Gao et al., 2020), while the adoption of different agricultural systems is understudied in the areas between these two centers of domestication, particularly in the coastal areas of the Jianghuai Region.

A relatively stable shallow sea environment dominated the coastal area of eastern China due to the continuous rise of sea level from 9 to 7 ka BP. After 7 ka BP, sea level regressed and land gradually expanded and advanced in the direction of the ocean (Zheng et al., 2018). As a result, the flat coastal plain of eastern China gradually came into form around 7–6 ka BP (Ling, 1990; Xue, 2002; Li, 2014). Rice farming was the primary subsistence strategy after 5 ka BP in the coastal areas of Jianghuai Region after the land was exposed, which was verified by rice paddy fields at the Tenghualuo site (Lin and Zhang, 2005; Nanjing Museum, 2014) and the rice remains at the Qingdun (Guo, 2000) and Jiangzhuang sites (Wu et al., 2019). However, the transgression likely prevented large-scale human activities until 3,000 BP in the coastal areas of Jianghuai Region, owing to several marine transgressions which occasionally re-occurred before 3 ka BP (Zhao et al., 1994; Li, 2014). The cropping pattern in this area during this time is unclear due to the lack of written records and archaeobotanical evidence, which restricts our ability to examine the relationship between climate change, sea-level fluctuations, cropping patterns, and human settlement.

Nevertheless, new archaeobotanical data from the Datongpu site (**Figure 1**), enables us to reconstruct the cropping structure during the Zhou Dynasty (1046–221 BC) as the Jianghuai region was reestablished as a coastal area. Combined with paleoclimate records, we are also able to discuss the mechanisms shaping agricultural cropping structures and crop diffusions.

STUDY AREA AND SITE DESCRIPTION

The Datongpu site (119.82°E, 33.41°N, 0.1 m a.s.l.) is in Yancheng, Jiangsu Province, in the central coastal area of eastern China and is 73 km away from the coast of the Yellow Sea in the eastern China (**Figure 1**). There is only about 16 km between the Datongpu site and the ancient coastal sandbars, named Donggang, Zhonggang, Xigang and Xingang (**Figure 1**) (Zhu et al., 1996). The climate in the coastal areas of Jianghuai Region is in a transitional zone from the subtropical climate in the south to the warm temperate climate in the north, with an average annual precipitation of 785–1,310 mm and a temperature of 13.7–14.5°C (Yancheng Local Chronicles Compilation Committee, 1998). The vegetation type is a mix of deciduous broad-leaf and evergreen broad-leaf vegetation in the north subtropical zone (Yancheng Local Chronicles Compilation Committee, 1998). The main crops include rice, wheat, corn, soybean and rapeseed, and the main animal foods included pigs, sheep, cattle, rabbits, and some aquatic animals (Yancheng Local Chronicles Compilation Committee, 1998).



The coastal areas of the Jianghuai Region are located along the western coast of the Yellow Sea, which are adjacent to the areas between the Haidai Cultural Zone in the north and the Tai Lake cultural zone in the south (Figure 1). The altitude of Central China is higher in the west, and the Huai River was likely a channel of cultural diffusion eastward from Central China. In addition, the flat coastal terrain (1–8.5 m a.s.l.) was likely conducive to the cultural exchange between the north Haidai culture and the south Tai Lake culture. Due to the diverse climatic conditions, dry farming dominated the cropping pattern in Central China and the Haidai zone in the north during the Neolithic, at roughly the same period, rice farming played an important role around the Tai Lake zone in the south (Zhao, 2020).

Datongpu site covers an area of nearly 100,000 m² (Figure 2). In August 2018, the School of History of Nanjing University has started a 5-year long excavation campaign. Many artifacts were recovered through excavation, including pottery, proto-porcelain, bronze, bone, and porcelain. The representative artifacts that date to the Shang and Zhou periods (1600–256 BC) are bronze knives, primitive porcelain cups, pottery *dou* vessel (a type of footed grain serving vessel), and bone hooks. In addition, a large number of animal remains have been found, such as antlers and tortoise shells.

METHODS

A total of 74 soil samples with a volume of 537 liters were collected during the excavation at the Datongpu site in September–December 2019. These soil samples were first placed in buckets, after soaking and cleaning, the light fraction (carbonized plant remains) was collected with a sieve with 80 mesh (aperture size of 0.2 mm) (Zhao, 2004b). Then, the samples were dried in the shade and sorted. The identification on carbonized plant remains was carried out in the Laboratory of Environmental Archaeology, School of Geography, Nanjing Normal University.

The carbonized seeds (wheat from H13③ and foxtail millet from H54②) were selected for radiocarbon dating with accelerator mass spectrometry (AMS) by Beta Analytic in Miami, Florida, USA. The IntCal20 curve (Reimer et al., 2020) and the Libby half-life of 5,568 years were used to calculate all dates, with the calibration performed using the OxCal 4.4 program (<https://c14.arch.ox.ac.uk/oxcal/OxCal.html>). All ages reported are relative to AD 1950 (referred to as “cal a BP”).

RESULTS

Radiocarbon Dating

Two calibrated ¹⁴C ages from wheat and foxtail millet collected from the Datongpu site are shown in Table 1. These two calibrated ¹⁴C ages indicated the age of the site was around 2,600 cal a BP years ago. One calibrated ¹⁴C age is within the range of 2,738–2,493 cal a BP and belongs to the Chunqiu Period (Early Eastern Zhou Dynasty, 770–476 BC). The other ones are within the range of 2,707–2,365 cal a BP and date to the transition period from the Spring and Autumn Period to the Warring States Period.

Flotation

A total of 5,146 carbonized plant remains were identified from all 74 soils samples, including 3,399 carbonized plant seeds, 1,738 rice spikelet bases and 9 wheat rachises. There are 1,103 crops seeds, which only account for 32.45% of all carbonized seeds, such as foxtail millet (*Setaria italica*), broomcorn millet (*Panicum miliaceum*), wheat (*Triticum aestivum*) and rice (*Oryza sativa*) (Figure 3). Among them, foxtail millet and rice seeds were dominant, followed by wheat and broomcorn millet. Twenty-four types of weed seeds were also found (2,296), including *Setaria viridis* (L.) Beauv., *Echinochloa crusgalli* (Linn.) Beauv., *Chenopodium album* and *Rumex acetosa* L. et al., account for 67.55% of all carbonized seeds. Among them, the seeds of *Rumex acetosa* L. dominated the weed seeds assemblage (74.8%). The quantity of charred seeds collected from the Datongpu site is shown in Table 2. In addition, a total of 52.255 g of carbonized wood (larger than 1 mm) were also floated from the soil samples from the Datongpu site, with an average of 0.97 g/10 L.

One thousand seven hundred rumex seeds were collected from one unit of H13③, which was likely a dump pit with pieces of broken pottery pieces. The use of rumex may be due to a special type of behavior, which we will study in the future. After excluding the sample of H13③, crop seeds account for 64.92% of the total assemblage, and are the dominant part of the macrobotanical assemblage.

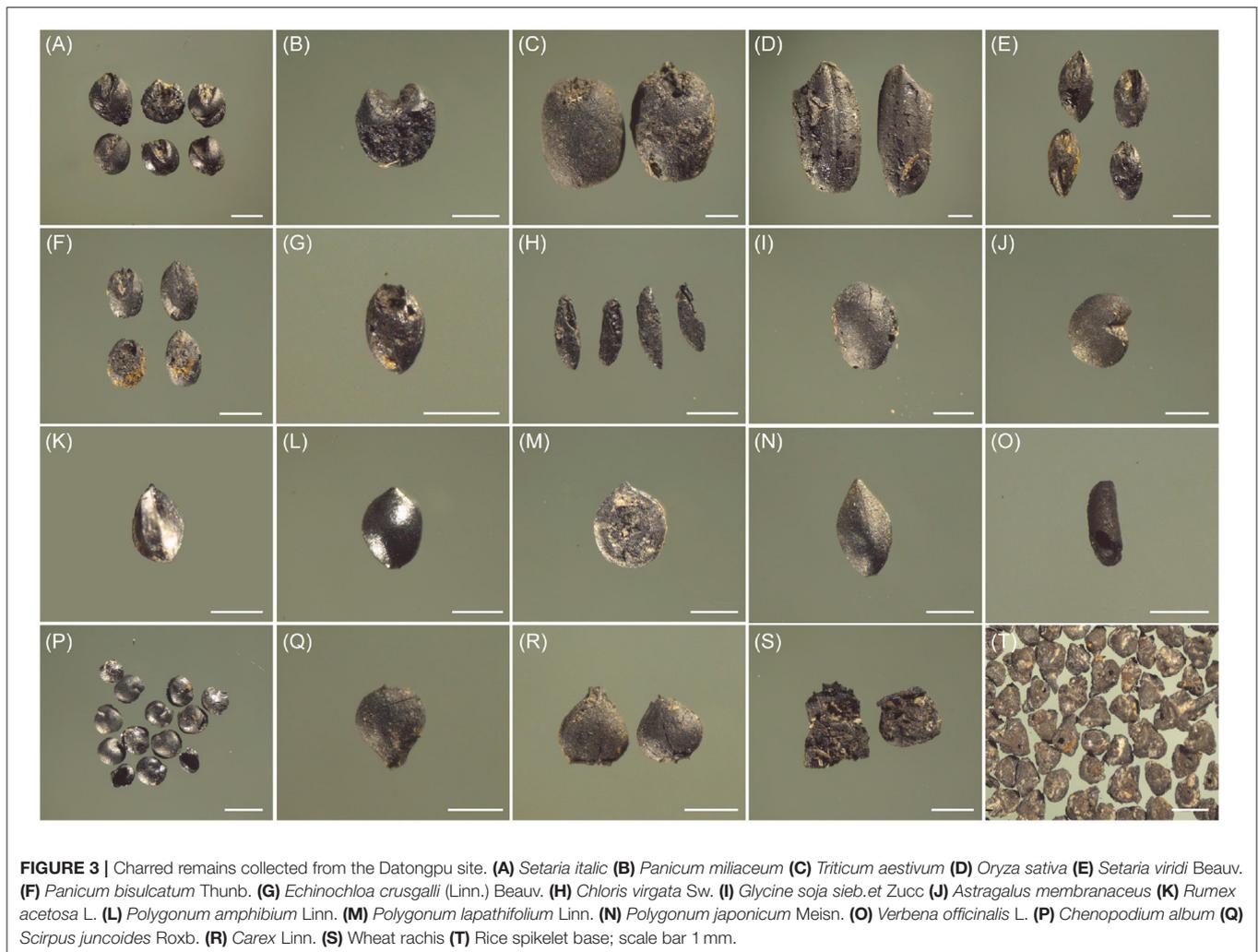
DISCUSSION

Rice Farming Dominated Subsistence Strategies in the Coastal Area of Jiangsu Province Around 2,600 cal a BP

The proportion and the ubiquity (81.08%) of samples indicates that agriculture dominated the subsistence strategies at the Datongpu site. The 1,103 carbonized grains include foxtail millet

TABLE 1 | ¹⁴C dates from the Datongpu site.

Sample no.	Laboratory no.	Methods	Material	¹³ C/ ¹² C (‰)	¹⁴ C date (BP)	Calibrated age (cal a BP)	
						1σ range	2σ range
JS-YC-JH-DTP-H13(3)-W	Beta-566084	AMS	wheat	−23.1	2,460 ± 30	2,699–2,434	2,707–2,365
JS-YC-JH-DTP-H54(2)-F	Beta-566085	AMS	foxtail millet	−9.3	2520 ± 30	2,724–2,518	2,738–2,493



(496), broomcorn millet (6), wheat (132) and rice (469). In addition, there were also 1,738 rice spikelet bases and nine wheat rachises. The 469 carbonized rice seeds and 1,738 spikelet bases were identified from 58 samples, and account for 78.38% of all 74 samples. This ubiquity was higher than the ones of foxtail millet (496, 43.24%), wheat (132 seeds, 9 rachises, 35.14%) and broomcorn millet (6, 4.05%). The carbonized plant assemblages demonstrated that rice agriculture dominated the agricultural activities at the Datongpu site, and dry farming also occupied a subordinate position, including foxtail millet, wheat, and broomcorn millet.

Rice farming originated in the middle-lower reaches of the Yangtze River around 10,000 years ago (Zhao, 2011a; Wu et al., 2014b; Zuo et al., 2017) and occupied most of the area south of the Yellow River around 8,500 BP, including the Haidai cultural zone (Crawford et al., 2013; Wu et al., 2013; Jin et al., 2014) and Central China (Zhao and Zhang, 2009; Deng and Gao, 2012; Zhang et al., 2018; Jia et al., 2021b). Rice domestication was also recognized through the identification of starch grains and phytoliths around 8,500 BP at the Shunshanji site in the north area of Jiangsu Province (Zhang et al., 2014; Yang et al., 2016).

Afterwards, the earliest carbonized rice remains were identified around 7,000 cal a BP from the Longqiuzhuang site in central Jiangsu Province (Wang and Zhang, 1998; Archaeology Team of Longqiuzhuang Site, 1999). Previous studies considered that rice farming predominated in Jiangsu Province since the Bronze Age (Li et al., 2021) and included the coastal areas of the Jianghuai Region represented by the Datongpu site.

Foxtail millet and broomcorn millet were domesticated in Northern China around 10,000 BP (Lu et al., 2009; Yang et al., 2012; Zhao et al., 2020). Millet agriculture was widespread during the Neolithic to Bronze Age in the Chinese Loess Plateau area (He et al., 2017) and was also scattered throughout Taiwan (Tsang et al., 2017), Fujian (Fu et al., 2016; Zhou et al., 2017; Deng et al., 2018; Dai et al., 2021) and Jiangxi (Chen et al., 2015; Deng et al., 2020). In addition, wheat agriculture was also introduced into Central China at least 3,500 years ago (Zhao, 2011b; Chen, 2016). Dry farming was found at many archaeological sites belonging to the Shang and Zhou dynasties in the upper and middle reaches of Huai River, including Chengyao (Zhong et al., 2018), Guanzhuang (Lan and Chen, 2014), Wangchenggang (Zhao and Fang, 2007), Yangbao (Cheng Z. J. et al., 2016), and

TABLE 2 | Number of identified carbonized seeds from Datongpu site.

Plant types	Number (grain)	Abundance ratio (%)	Percentage of crop seeds/weed seeds (%)	Ubiquity (%)
Crops	1,103	32.45	100.00	81.08
<i>Setaria italica</i>	496	14.59	44.97	43.24
<i>Panicum miliaceum</i>	6	0.18	0.54	5.41
<i>Triticum aestivum</i>	33	0.97	2.99	14.86
<i>Triticum aestivum frags</i>	99	2.91	8.98	27.03
Wheat rachis	9	0.26		8.11
<i>Oryza sativa</i>	53	1.56	4.81	24.32
<i>Oryza sativa frags</i>	416	12.24	37.72	62.16
Rice spikelet base	1,738	51.32		62.16
Weeds	2,296	67.55	100.00	74.32
<i>Astragalus membranaceus</i>	1	0.03	0.04	1.35
<i>Avena sativa</i> L.	1	0.03	0.04	1.35
<i>Carex</i> Linn.	11	0.32	0.48	5.41
<i>Chenopodium album</i>	82	2.41	3.57	17.57
<i>Chloris virgata</i> Sw.	9	0.26	0.39	5.41
<i>Digitaria sanguinalis</i> (L.) Scop.	2	0.06	0.09	1.35
<i>Echinochloa crusgalli</i> (L.) Beauv.	23	0.68	1.00	9.46
<i>Galium aparine</i> L. var. <i>tenerum</i> (Gren.et Godr.) Rebb.	2	0.06	0.09	2.70
<i>Glycine soja</i> Sieb.et Zucc	18	0.53	0.78	5.41
<i>Lespedeza bicolor</i> Turcz	1	0.03	0.04	1.35
<i>Melilotus albus</i>	1	0.03	0.04	1.35
<i>Panicum bisulcatum</i> Thunb.	16	0.47	0.70	8.11
<i>Patrinia scabiosaefolia</i> Fisch	3	0.09	0.13	4.05
<i>Physali alkekengi</i> L.	1	0.03	0.04	1.35
<i>Polygonum japonicum</i> Meisn.	1	0.03	0.04	1.35
<i>Polygonum lapathifolium</i> Linn.	1	0.03	0.04	1.35
<i>Polygonum amphibium</i> Linn.	4	0.12	0.17	5.41
<i>Potamogeton distinctus</i> A.Bennett	1	0.03	0.04	1.35
<i>Rumex acetosa</i> L.	1,719	50.57	74.87	18.92
<i>Scirpus juncoides</i> Roxb.	2	0.06	0.09	2.70
<i>Setaria viridis</i> (L.) Beauv.	386	11.36	16.81	21.62
<i>Sporobolus fertilis</i> (Steud.) W. D. Clayt.	3	0.09	0.13	4.05
<i>Verbena officinalis</i> L.	1	0.03	0.04	1.35
<i>Zizania caduciflora</i> (Turcz.ex Trin.) Hand. -Mazz	1	0.03	0.04	1.35
Unknown	6	0.18	0.26	5.41
Total	5,146	100.00		82.43

Yantai (Anhui Institute of Cultural Heritage Archaeology, 2010). Dry farming was also found at many archaeological sites before 3,000 BP in the middle reaches of Yangtze River, including Xiezidi (Tang et al., 2014), Chengzishan (Tang et al., 2017) and Yejiamiao (Wu et al., 2010). However, evidence of dry farming is rare in the lower reaches of the Huai River (Datongpu site) and Yangtze River (Dingjiacun site, Wu et al., 2017) until 3,000 BP, except for some sporadic evidence from the Shangshan site (Zhao and Jiang, 2016), Bianjiashan site (Zheng, 2014) and Jiangzhuang site (Wu et al., 2019). Therefore, dry farming likely expanded from

the west to the east along the Huai River and the Yangtze River basins, which includes the area around the Datongpu site.

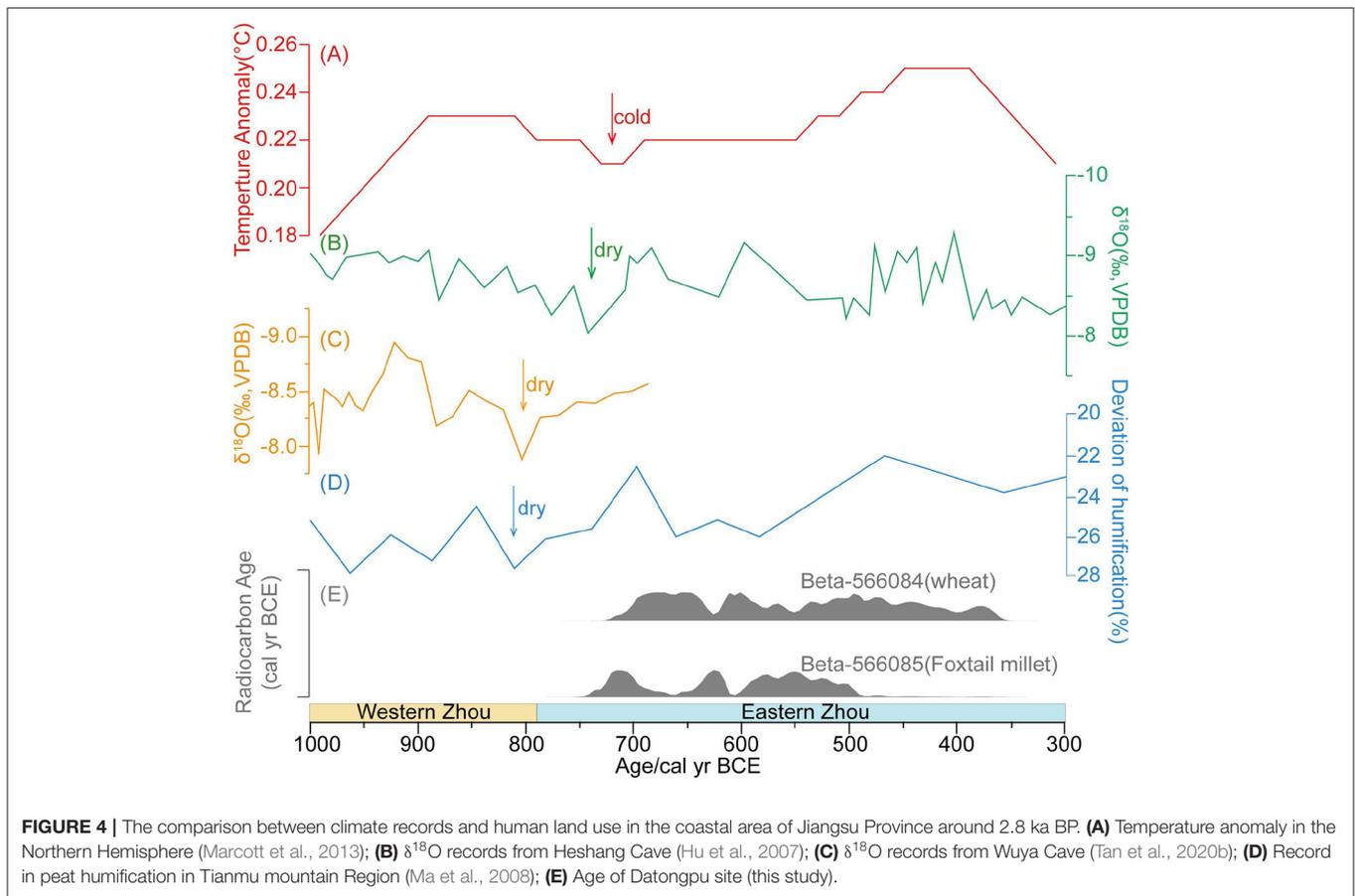
In addition, all crop seeds (1,103) accounted for 32.45% of all carbonized seeds (3,399) found at the Datongpu site. If H13³ were removed from the total assemblage, due to its position as an outlier with many rumex seeds (1,700), all crop seeds (1,035) accounted for 75.77% of all carbonized seeds (1,366) found at the Datongpu site. The comparison of crops and weeds was used as an indicator of agricultural intensification, the larger quantity of crop seeds, the higher degree of agricultural intensification (Zhao and Xu, 2004). The proportion of crop seeds at the Datongpu site was lower than other sites that date to the Spring and Autumn Period, e.g., Shenmingpu (Liu et al., 2017), Nanwa (Wu et al., 2014a) and Guanzhuang (Lan and Chen, 2014) sites in Henan Province, Zhuguogucheng (Ma et al., 2019) and Kanjiashai (Chen et al., 2018) sites in Shandong Province. Therefore, the degree of agricultural intensification was relatively low in Datongpu site. Although these Neolithic people engaged in rice-dry farming in Datongpu site, this agricultural structure was likely designed as a response to the specific environment rather than designed as a strategy to obtain as much food as possible.

The plant assemblage found at the Datongpu site indicates that agriculture was dominated by rice farming and supplemented by dry farming around 2,600 cal a BP in the coastal area of Jianghuai Region. Rice farming in this area likely continued from the Neolithic Age in Jiangsu Province, whereas dry farming may have spread along the Huai River from west to east.

The “2.8 ka Cold BP Event” Indirectly Facilitated Human Exploitation in the Coastal Area of Jiangsu Province

Abrupt climate changes in the past often led to the serious challenges for empires throughout the world (e.g., Weiss and Bradley, 2001; Buckley et al., 2010; Chen et al., 2015a; Jia et al., 2017b; Evans et al., 2018; Xu et al., 2019; Tan et al., 2020a), while favorable climatic conditions promoted the emergence of new civilizations, cultural prosperity and social development again (e.g., Yancheva et al., 2007; Chen et al., 2015a; Putnam et al., 2016; Jia et al., 2017b; Xu et al., 2019). The “2.8 ka cold event” was a strong cold event in the late Holocene (Wanner and Buetikofer, 2008; Vinther et al., 2009; Wang, 2011; Lecavalier et al., 2017; Tan et al., 2020b), which probably corresponded to a significant adjustment in the settlement patterns of human society (e.g., Di Cosmo, 2002; Zhang et al., 2008; Kuzmina, 2015; Li et al., 2020). However, as a pivotal transitional zone between the Haidai cultural zone and the Tai Lake Cultural Zone, the relationship between the “2.8 ka cold event” and human activities in the coastal area of Jianghuai Region, is difficult to define because there are few written records and little archaeological data.

Owing to the relatively stable shallow sea environment which dominated the coastal area of eastern China, the land was submerged during the Holocene Optimum in the eastern coastal area of China (Figure 1), and gradually accumulated sediment and was exposed after 7–6 ka BP (Ling, 1990; Xue, 2002; Li, 2014; Zheng et al., 2018). People began to move eastward to the coastal areas of Jianghuai Region after 5 ka BP (Li et al.,



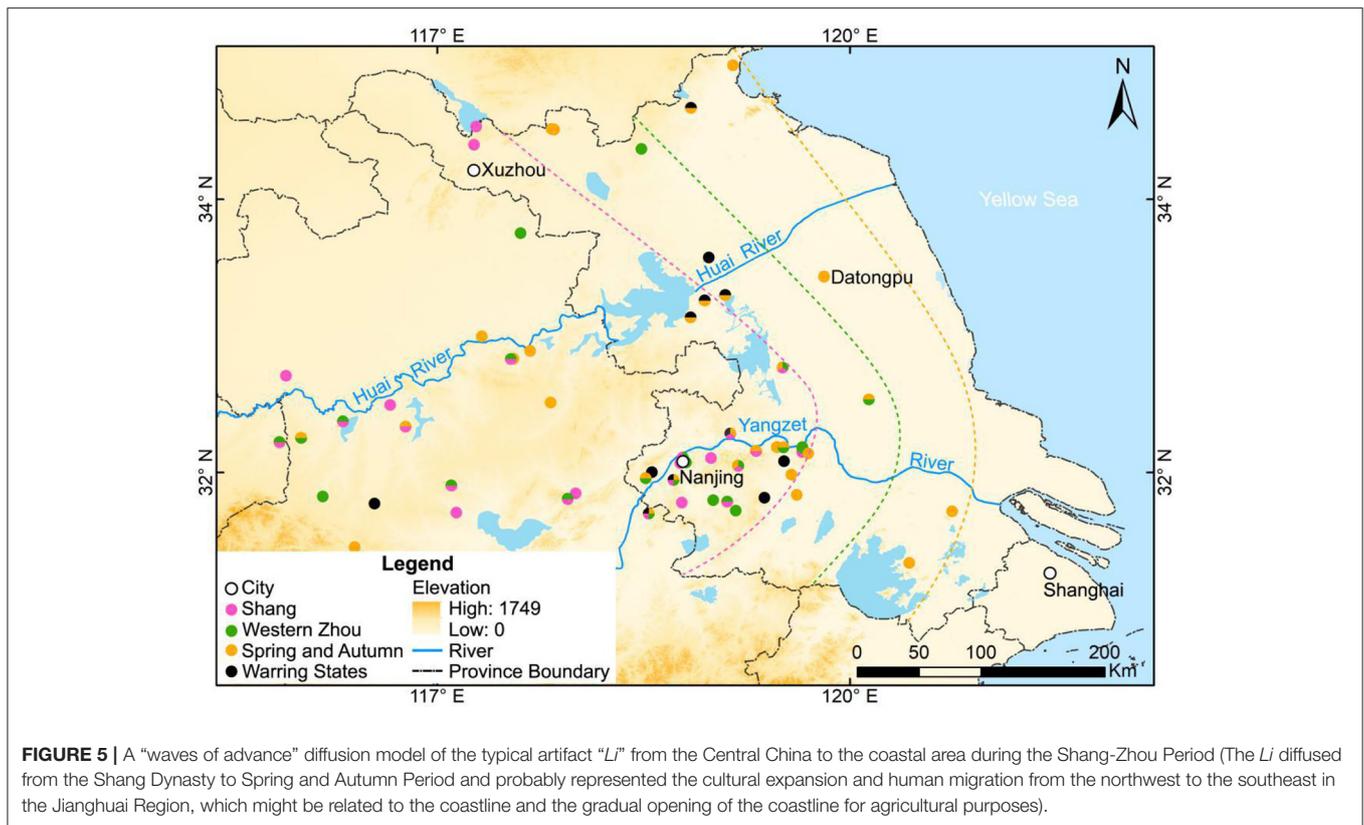
2021). However, owing to the occasional marine transgression, few people settled in this area and instead settled in regions with slightly higher elevations, such as the piedmont area (e.g., Tenghualuo site in Lianyungang City) or knolls (e.g., Qingdun site in Hai'an County) (Li et al., 2021). People engaged in rice farming to ensure the development of civilization after 5 ka BP at the Tenghualuo site (Lin and Zhang, 2005; Nanjing Museum, 2014) and the Qingdun site (Guo, 2000). However, the stratigraphic profiles at the Qingfeng and Qingdun sites indicate that the high sea level decreased around 2.8 ka BP (Zhao et al., 1994; Li, 2014). Further, the Gangxi profile which was 15 km far from Datongpu site, indicates that the sedimentary environment translated to freshwater shallow lake after 2,880 cal a BP, and the Donggang dike developed in the east of Zhonggang (Shu et al., 2021). Therefore, marine transgressions likely prevented large-scale activities until the late Zhou Dynasty in the coastal areas of Jianghuai Region. After that, people may have settled down in the coastal area of the Jianghuai Region without the threat of marine transgression.

Climate change had a limited impact on human activities along the coastal areas of Jianghuai Region since the warm and wet climate was favorable for supporting most agricultural activities. Climatic cooling and drought indirectly influenced human activities by sparking migrations from other places, which was a different than the impact that climate changes had on

human societies in northern China. A global climate cooling event occurred around 2.8 ka BP (Wanner and Buetikofer, 2008; Vinther et al., 2009; Lecavalier et al., 2017), which was also indicated in the paleoclimatic records in China (Wang et al., 2005; Wang, 2011; Xu et al., 2019; Tan et al., 2020b) (Figure 4). This event was also recorded in a historical document named the “*Zhushu Jinian*” (竹书纪年) which was a chronicle written during the Warring States periods (475–221 BC):

“Frost occurred in July which was the hottest month of the year (779 BC), peach and apricot fruited in October 2 months later than the normal year (772 BC).”

The “2.8 ka BP cold event” likely indirectly facilitated human exploitation in the coastal area of the Jianghuai Region. Some evidence from human bone isotopes indicated that human diets transformed from C₄-based foods in 1000–800 BC to C₃-based foods during the Eastern Zhou (770–221 BC) in Central China (Li et al., 2020). The transformations of food structure likely promoted grain production (Li et al., 2020), which led to an increased population. Aside from a small number of studies that argue that the population of the Xia and Shang dynasties was over 10 million people (Zhao and Xie, 1988; Colin and Richard, 1992), most studies agree that the population ranged in the millions, rather than the tens of millions (Jiang, 1988; Pang, 1988; Wang, 1990; Song, 1991). The population increased to more than 10 million during the Spring and Autumn Period (770–476 BC)



(Pang, 1988; Lu and Teng, 1999; Jiao, 2007) and reached up to more than 30 million people in the Warring States period (476–221 BC) (Zhao and Xie, 1988; Lu and Teng, 1999; Ge, 2002; Jiao, 2007). Given this rapid population increase and the climate event, it is possible that the “2.8 ka BP cold event” may have triggered conflicts and wars more frequently in Central China, leading to food shortages, and likely led to the fall of the Western Zhou Dynasty (1046–771 BC) (Ge, 2010). Therefore, people began to migrate from the Central Plain to the border areas to avoid the disaster of war, seek new resources and exploit new habitats (Wang and Huang, 2002; Li, 2014; Chao, 2018). Sporadic historical data also show that people mainly from Shandong and Henan fled southward through the Jianghuai region in this period. The people of the state of Xu continued to migrate southward because of the expedition of the people of the state of Zhou and may migrated southward through the Jianghuai region and finally reach the present Zhejiang Province (Xu, 2013). Due to the lack of written records from this proto historic period, we must rely on archaeological evidence to explore the potential for cultural diffusion and human migration. *Li* (鬲, an ancient cooking tripod with hollow legs) was a typical pottery vessel used in Central China during the Shang-Zhou Dynasties (Ge and Ge, 2009; The Palace Museum, 2014). The emergence of the *Li* dates to roughly 4,500 years ago in the Yellow River Basin (Zhang, 1997; Shan, 2015). After that, it was brought to many regions with the expansion of culture, until it disappeared during the Warring States Period. The *Li* diffused from the Shang Dynasty to Spring and Autumn Period and probably represented

the cultural expansion and human migration from northwest to southeast in the Jianghuai Region (Figure 5). Humans likely moved eastward along the Huai River from Central China to the coastal areas of Jianghuai Region, and dry farming was also brought to supply the rice farming system. Finally, the mixed agricultural pattern appeared widely after 2.8 ka BP in the coastal areas of Jianghuai Region.

Additionally, changes in the East Asian summer monsoon climate caused a decrease from southeast to northwest, and the difference in receiving solar radiation resulted the temperature increased from north to south (Ding, 2021). Therefore, the cold and dry climate may have compelled people to migrate eastward or southward to the comparatively warm and wet conditions in Southern China and Eastern China, which includes the coastal area of Jianghuai Region. As one of the channels for human migration eastward away from the Central Plains, humans likely emigrated eastward along the Huai River from Central China to the coastal areas of the Jianghuai Region, and dry farming was also brought in to supply a rice farming system. Finally, the mixed cropping pattern appeared widely after 2.8 ka BP in the coastal areas of Jianghuai Region.

CONCLUSIONS

The utilization of plant resources was reconstructed in the coastal area of Jianghuai Region based on the charred seeds obtained from Datongpu sites in Yancheng, Jiangsu Province. Rice farming

dominated the mixed rice-dry farming around 2,600 cal a BP in the coastal area of Jianghuai Region, and the main crops were rice, wheat, foxtail millet and broomcorn millet.

The “2.8 ka BP cold event” may have intensified the gap between population growth and food storage in Central China, creating a food shortage thus compelling people to migrate eastward or southward to warmer regions. Some people brought dry farming and moved eastward along the Huai River into the coastal areas of Jianghuai Region. The gradual land formation and marine transgression provided a large area of land for human activities after 2.8 ka BP. Their arrival promoted the early exploitation and the emergence of large-scale agriculture and development in the eastern coastal area. Our study provides an example for the indirect impact of climate change in areas with relatively favorable climate conditions.

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 author/s.

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AUTHOR CONTRIBUTIONS

XJ, DZ, and MS: conceptualization and validation. HS, ZL, LS, and QW: data curation and software. XJ, DZ, MS, GB, ZH, and HL: formal analysis and writing—review and editing. XJ and HL: funding acquisition. XJ, DZ, ZH, and HL: investigation. XJ, DZ, MS, and HL: methodology. XJ and DZ: resources and writing—original draft. XJ: supervision. All authors contributed to the article and approved the submitted version.

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