agronomy

MDPI

Article

Long-Term Responses to a 5.3-ka BP Climate Event and the Absolute Dominance of Foxtail Millet in Early Longshan (4800–4300 BP), Southern Loess Plateau, China

Zejuan Sun [1], Xiaoyi Wang [2], Xiaojuan Wang [3], Qingzhu Wang [1], Yang Liu [1], Bingyan Wang [1], Lin Guo [4] and Xuexiang Chen [1,*]

1 Joint International Research Laboratory for Environmental and Social Archaeology, Shandong University, Qingdao 266237, China; szj518@mail.sdu.edu.cn (Z.S.); qz.wang@sdu.edu.cn (Q.W.); liuyang164@mail.sdu.edu.cn (Y.L.); bywang@mail.sdu.edu.cn (B.W.)
2 Shanxi Provincial Archaeology Research Institute, Taiyuan 030001, China; wxy75@163.com
3 School of History and Culture, Shanxi University, Taiyuan 030006, China; wxj84@sxu.edu.cn
4 School of History and Culture, Shandong University, Jinan 250100, China; guolin123789@sina.com
* Correspondence: xxchen@sdu.edu.cn

Abstract: Abrupt climate events profoundly impact human societies, both environmentally and socially. However, existing research predominantly concentrates on immediate responses, overlooking long-term consequences. This study, centered on the Guojiazaoyuan site in the southern Loess Plateau, explores the enduring effects of a 5.3-ka BP climate event that transformed the local subsistence system. Through detailed analysis of archaeobotanical evidence, specifically floral remains dating to 4800–4300 BP obtained via flotation, significant post-event shifts in agricultural practices and food strategies are revealed. Notably, there is a clear prioritization of foxtail millet cultivation, a shift towards diversified food sources, and the introduction of new livestock. These changes represent strategic adaptations aimed at bolstering resilience and reducing vulnerability to future climatic challenges. The southern Loess Plateau developed an agricultural pattern with foxtail millet as the dominant crop, although different patterns were observed in surrounding regions during the early Longshan period (4800–4300 BP). Emphasizing the importance of a long-term perspective, particularly in agriculture and food security, the findings contribute to a broader understanding of how ancient societies coped with environmental changes. These insights are pertinent to ongoing discussions on climate resilience and sustainable agriculture.

Keywords: Guojiazaoyuan site; foxtail millet; early Longshan period; southern Loess Plateau

Citation: Sun, Z.; Wang, X.; Wang, X.; Wang, Q.; Liu, Y.; Wang, B.; Guo, L.; Chen, X. Long-Term Responses to a 5.3-ka BP Climate Event and the Absolute Dominance of Foxtail Millet in Early Longshan (4800–4300 BP), Southern Loess Plateau, China. *Agronomy* **2024**, *14*, 105. https://doi.org/10.3390/agronomy14010105

Academic Editors: Xinyi Liu and Giedrė Motuzaitė Matuzevičiūtė

Received: 19 November 2023
Revised: 25 December 2023
Accepted: 29 December 2023
Published: 31 December 2023

1. Introduction

A growing body of evidence shows that climatic and environmental factors influenced ancient human society and agricultural development [1,2]. Favorable climates promote agricultural growth, population expansion, and societal growth. Climatic events can adversely impact agricultural development, prompting ancient people to adjust and employ subsistence strategies to address the crises originating from such impacts. However, few scholars investigate the long-term adaptive changes that communities can make to reduce their vulnerability to future climate conditions [3,4]. During severe climatic events, people try to survive by altering their subsistence strategies and improving their production techniques. After a disaster, the unfavorable memory of the impact of past climate events would drive people to enhance their resilience during the harsh time. As a result, it is essential to apply a long-term perspective to observe the social-ecological responses to climate impacts [4–6]. Archaeobotanical research can offer valuable information about the long-term changes in local subsistence, thus allowing us to investigate how societies developed new strategies to reduce the vulnerability of their subsistence systems and enhance community resilience.

As independent centers of millet and rice domestication, China could offer valuable information about how people adjusted their agricultural strategies to survive climate events and increase their resilience for future events. However, the most extensive research has focused on the immediate responses of societies to either favorable or detrimental climate events. For example, the favorable climate conditions around 6000–5500 BP impacted the transition of millet agriculture [7–9] and the collapse and re-organization of Late Neolithic societies during the 4.2-ka BP climate event [10]. Insufficient research has been conducted on the long-term impacts of climate events on the development of agriculture and societies.

Focusing on the archaeobotanical evidence from the Guojiazaoyuan site, we examine the long-term consequences of a 5.3-ka BP climate event (lasting from 5500 BP to 4900 BP or later) that eventually transformed the local subsistence system at the southern Loess Plateau. The radiocarbon data indicate that the Guojiazaoyuan site was dated to 4850–4400 cal. BP, right after the 5.3-ka BP event. Based primarily on the floral evidence obtained through flotation, we argue that the local people at Guojiazaoyuan established new subsistence strategies. These strategies included prioritizing foxtail millet, maintaining a diversified food supply, and introducing new livestock to increase resilience and reduce the vulnerability of society. Foxtail and broomcorn millet were the two most important crops in northern China during the Neolithic period [11]. Though substantial archaeobotanical works have been conducted in the Southern Loess Plateau [12–18], the exact timing, background, and mechanisms behind the establishment of the absolute dominance of foxtail millet in the region remain unclear. The results from Guojiazaoyuan can help to elucidate foxtail millet cultivation during the early Longshan period (4800–4300 BP) and examine crop choices and agricultural development patterns. The research argues for a long-term perspective to examine the impact of and responses to past climate events.

2. Research Area

The southern Loess Plateau, including the southern areas of the Shanxi and Shaanxi provinces, is one of the core regions for the origin and development of complex societies in China. The geographical units of the southern Loess Plateau encompass the Linfen Basin, the Yuncheng Basin in the southern Shanxi province (Jinan region), and the Weinan Basin in the southern Shaanxi province (Guanzhong region). The major rivers in the area include the Yellow, Fen, and Wei Rivers. The soil is fertile, and there is an abundant water supply. The Neolithic period in this area has a well-established chronology: the early Yangshao (7000–6000 BP), middle Yangshao (6000–5500 BP), late Yangshao (5500–4800 BP), early Longshan (4800–4300 BP), and late Longshan period (4300–3800 BP) [19,20].

The Guojiazaoyuan site (111°01′26″ E, 35°26′05″ N) is located southwest of Xiawangyin village, Jishan County, Yuncheng City, Shanxi Province, China (Figure 1). It is situated at the southern end of the Linfen Basin on the Emei Platform, with the Fen River flowing into the Yellow River north of the site [21]. The total area of the site is approximately 1,000,000 m^2. In September 2009, the Shanxi Provincial Institute of Archaeology excavated the site, covering an area of approximately 2300 m^2. The site has rich cultural content, primarily from the Neolithic period [22]. The late Yangshao and Maidigou II culture remains of the site were challenging to differentiate and were quite similar in terms of dating. Thus, this study classified them as belonging to the early Longshan period (4800–4300 BP).

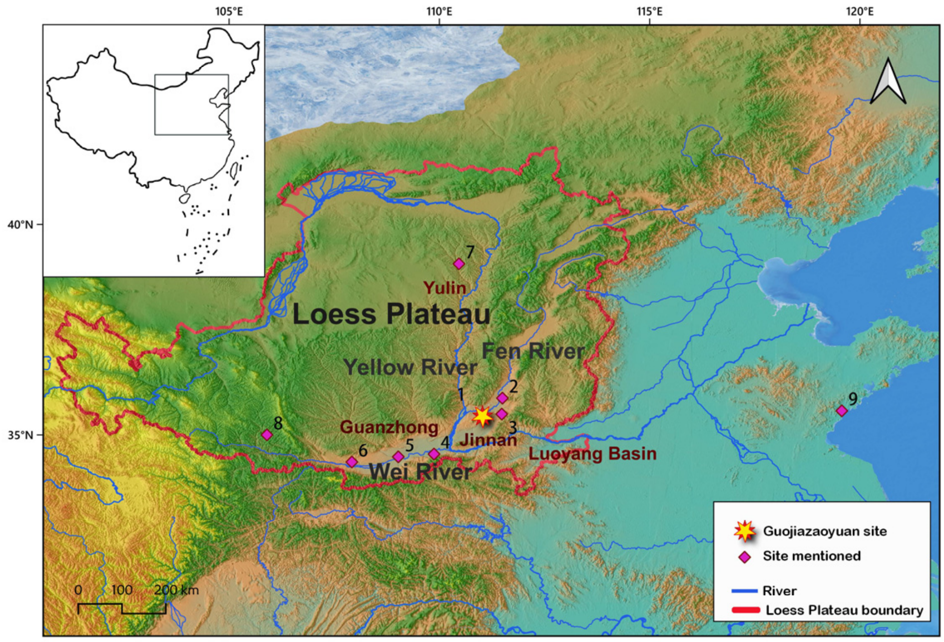

Figure 1. Map showing the locations of the Guojiazaoyuan site (star) and other sites (diamond) mentioned in this article: 1. Guojiazaoyuan; 2. Taosi; 3. Zhoujiazhuang; 4. Quanhu; 5. Yangguanzhai; 6. Anban; 7. Shimao; 8. Dadiwan; 9. Liangchengzhen.

3. Materials and Methods

The research materials used in this study were obtained from the excavation of the Guojiazaoyuan site in 2009, and we focused on the Neolithic period. Flotation samples were collected during the excavation. A total of 43 samples were obtained, sourced from 39 different archaeological features, with a combined volume of 446 L. On average, each sample amounted to 10.37 L. One flotation sample was obtained from a kiln, and the remaining were from ash pits (Table 1).

Table 1. The context of Flotation Samples from the Guojiazaoyuan site.

Unit Type	Number of Units	Number of Samples	Sample Volume (L)
Ash Pit	38	42	426
Kiln	1	1	20
Total	39	43	446

The small-bucket flotation [23] method was employed to collect charred plant remains from flotation samples. Subsequently, classification, identification, statistical analysis, and photography were conducted in the Archaeobotany Laboratory at Shandong University. The plant remains were primarily observed using a Nikon SMZ-645 stereomicroscope (Nikon Corporation, Nanjing, Jiangsu Province, China), and the photos of the seeds were taken with a Leica S9I microscope (Leica Corporation, Wetzlar, Germany) and LAS X 3.0.14 software. These plant remains were compared with modern plant seed specimens in the laboratory's collection. In addition, plant identification was aided by referencing relevant botanical identification manuals and guidelines [23–27].

4. Results

4.1. Chronology

Six samples of charred plant seeds from the Guojiazaoyuan site were sent to the Beta laboratory for AMS ^{14}C dating (Table 2). Among these, the radiocarbon dating result of a charred wheat sample from ash pit H38 indicated a recent disturbance, whereas the calibrated dating data of the remaining five samples fell within the 4850–4400 BP range. The radiocarbon dating aligns with the chronology derived from archaeological remains.

Table 2. Radiocarbon dating results of charred plant seeds from the Guojiazaoyuan site.

Lab Code	Dated Material	Context No.	Uncalibrated ^{14}C Date (BP)	Calibrated Data (Cal. BP)
				2σ (95.4%)
Beta-333389	Foxtail Millet	H100	4180 ± 30	4590–4840
Beta-333387	Foxtail Millet	H70	4150 ± 30	4580–4830
Beta-628155	Rice	H38	4120 ± 30	4526–4817
Beta-333388	Foxtail Millet	H38	4070 ± 30	4440–4800
Beta-628158	Soybean	H117	4060 ± 30	4423–4792
Beta-628156	Wheat	H38	170 ± 30	0–290

4.2. Charred Plant Remains

The charred plant remains excavated from the Guojiazaoyuan site included charred wood fragments, plant seeds, and fruits. Charred wood fragments larger than 1 mm were selected and weighed; their total weight was 34.7 g. The average density of these fragments was approximately 0.08 g/L.

A total of 34,420 charred plant seeds and fruits were found in the samples. Among these, there were 2512 fragments of unidentifiable charred plant seed fragments. These fragments varied in size and were mostly the remains of millet and legume seeds. Due to severe damage, the unidentifiable fragments were excluded during data analysis to avoid affecting the data of other plant seeds. This amounted to 31,908 charred plant seeds and fruits with a density of approximately 72 pieces per liter (Table 3). Sample FX027, from ash pit H70, contained 22,866 charred foxtail millet seeds. After excluding this outlier, the density of charred plant seeds and fruits was 20 pieces per liter (Figure 2).

Table 3. Summary of charred macro-botanical remains from the Guojiazaoyuan Site.

Category	Plant Taxa	Counts	Percentage (n = 31,908)	Number of Samples	Ubiquity (n = 43)
Crops	*Setaria italica*	29,505	92.47%	38	88.37%
	Panicum miliaceum	1034	3.24%	21	48.84%
	Triticum aestivum	3	0.01%	1	2.33%
	Oryza sativa	1	0.01%	1	2.33%
	Glycine max	80	0.25%	3	6.98%
Weeds	Fabaceae				
	Lespedeza sp.	645	2.02%	15	34.89%
	Melilotus sp.	201	0.63%	14	32.56%
	Kummerowia striata	2	0.01%	1	2.33%
	Cassia nomame	1	0.01%	1	2.33%
	Other	1	0.01%	1	2.33%
	Panicoideae				
	Setaria viridis	338	1.06%	10	23.26%
	Digitaria sanguinalis sanguinalis	2	0.01%	1	2.33%
	Other	4	0.01%	1	2.33%
	Chenopodiaceae				
	Chenopodium sp.	11	0.03%	4	9.30%
	Kochia scoparia	2	0.01%	1	2.33%
	Euphorbiaceae				
	Acalypha australis	5	0.02%	3	6.98%
	Polygonaceae	3	0.01%	2	4.65%
	Compositae	1	0.01%	1	2.33%

Table 3. *Cont.*

Category	Plant Taxa	Counts	Percentage (n = 31,908)	Number of Samples	Ubiquity (n = 43)
Nuts and fruits	*Vitis* sp.	1	0.01%	1	2.33%
	Nutshells	1	0.01%	1	2.33%
Unknown	Unknown	67	0.21%	9	20.93%
Total		31,908	100.00%		

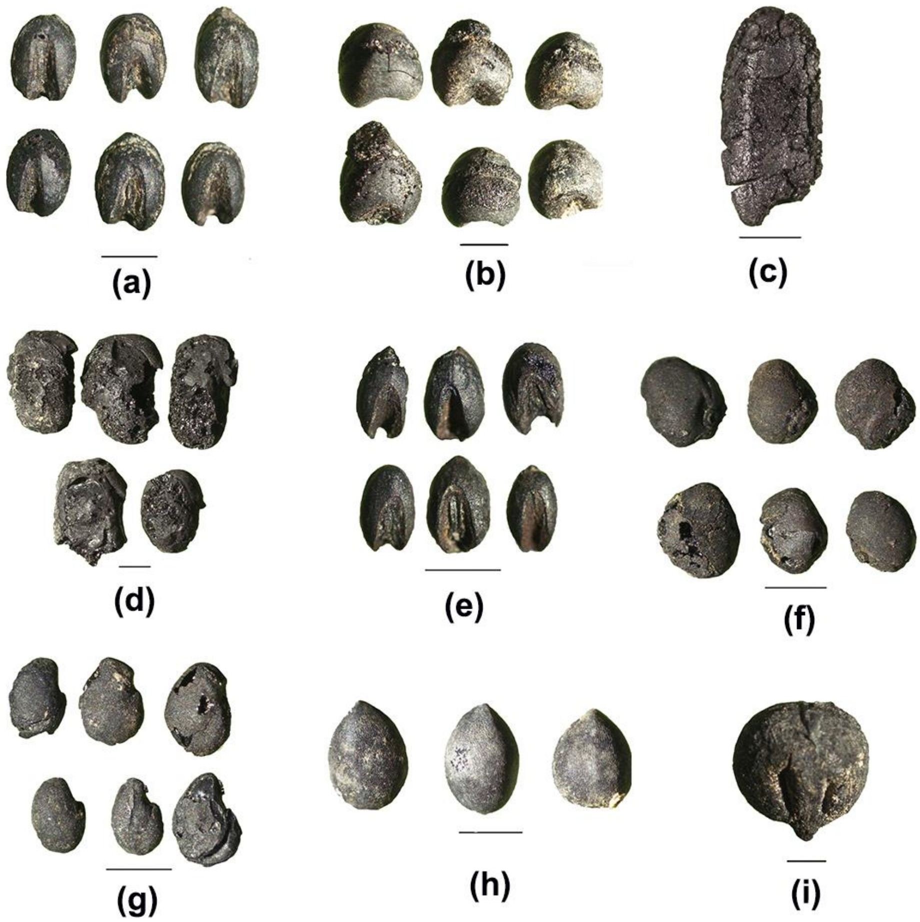

Figure 2. Selection of charred plant remains from Guojiazaoyuan. (**a**) foxtail millet (*Setaria italica*); (**b**) broomcorn millet (*Panicum miliaceum*); (**c**) rice (*Oryza sativa*); (**d**) soybean (*Glycine max*); (**e**) green foxtail (*Setaria viridis*); (**f**) Lespedeza (*Lespedeza* sp.); (**g**) Melilotus (*Melilotus* sp.); (**h**) copperleaf (*Acalypha australis)*; (**i**) grape genus (*Vitis* sp.) (Scale bar: 1 mm).

A total of 30,623 crop remains were found, significantly outnumbering other types. They accounted for 95.57% of the total macro-botanical remains (31,908). In one unit, 22,866 foxtail millet pieces were found; however, after excluding this outlier, the crop count was 7757, accounting for 85.79% of the total plant remains (9042). The ubiquity of crops and other macro-botanical remains did not significantly differ. The ubiquity of crops and others was 88.37% and 65.12%, respectively (Figure 3).

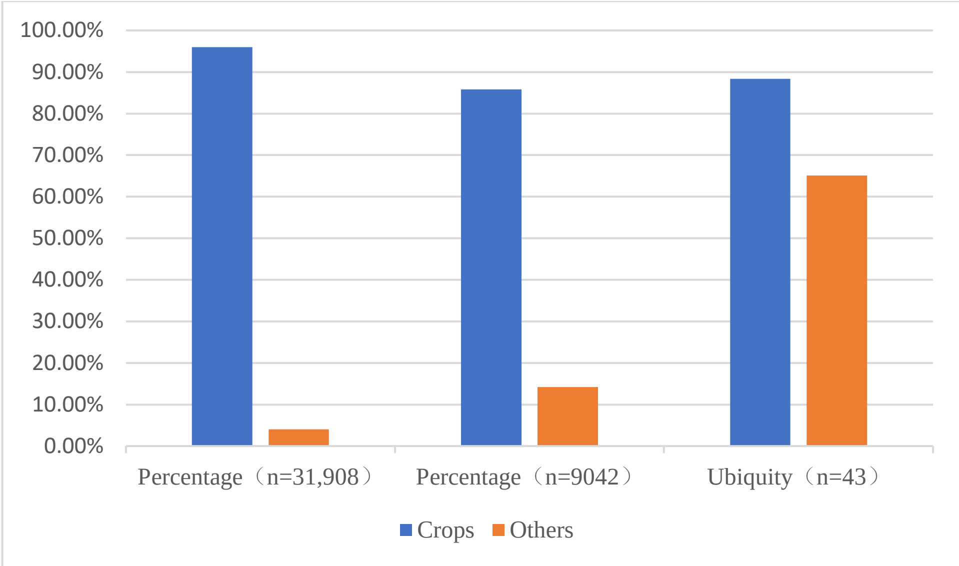

Figure 3. The percentage and ubiquity of crops and others (other macro-botanical remains, including weeds, nuts, fruits, and unknowns).

4.2.1. Crops

There were 30,623 crop remains, which were reduced to 7757 after excluding outliers. The remains included foxtail millet (*Setaria italica*), broomcorn millet (*Panicum miliaceum*), rice (*Oryza sativa*), and soybean (*Glycine max*), with wheat (*Triticum aestivum*) as a late intrusion (Figure 4).

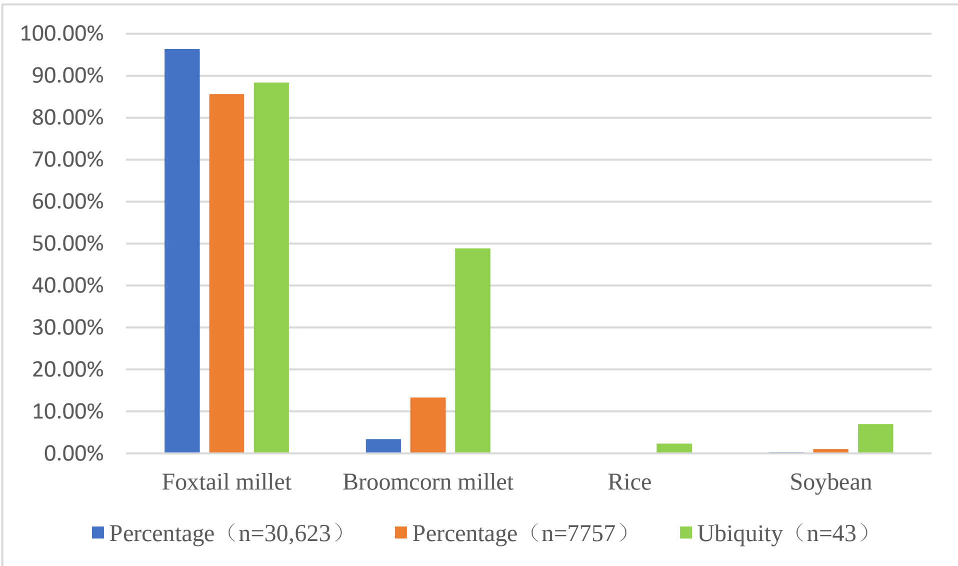

Figure 4. The percentage and ubiquity of different crops.

Foxtail millet (29,505) accounted for 96.35% of the crop remains, and 77.5% of the carbonized foxtail millet was unearthed from ash pit H70. Even after excluding outliers, it still accounted for a high percentage of 85.59%. The ubiquity of foxtail millet was also extremely high (88.37%).

The broomcorn millet contained 1034 grains, accounting for 3.37% of the crop remains, with a ubiquity of 48.84%. Broomcorn millet was relatively concentrated; 68.67% was discovered in ash pit H100, totaling 710 grains.

Only one grain of rice was found; the grain, which came from ash pit H38, originated 4526–4817 cal BP according to radiocarbon dating. This rice grain is flat and small (3.51 mm long, 1.69 mm wide, and 1.13 mm thick, with a length-to-width ratio of 2.08).

There were 80 soybeans, 77 of which were obtained from ash pit H117. The soybeans exhibit a high degree of bursting and contain more voids after carbonization. Some of them retain remnants of the seed coat and hilum. Among these soybeans, 15 were relatively intact, whereas 65 were fragmented. The charred soybeans are relatively long, and the bean cotyledons are slightly flattened. Among them, eight soybeans have lengths and widths of 3.34–4.17 and 1.92–2.64 mm, respectively. The average length and width are 3.74 and 2.15 mm, respectively.

Only three wheat grains were found; one is intact, and two are partially damaged. All of them were obtained from ash pit H38. Wheat originated in West Asia and was introduced to China approximately 5000 years ago [28,29]. However, the intact grain was radiocarbon-dated to the modern period, approximately 135–230 cal BP, suggesting that the wheat remains were late intrusions or contaminants.

4.2.2. Weeds, Nuts, and Fruits

The non-crop remains mainly comprised of weed seeds, with few nuts and fruits. A total of 1216 weed seeds were found, representing 3.81% of the charred plant remains with a ubiquity of 51.16%. The weed species included Panicoideae, Fabaceae, Chenopodiaceae, Polygonaceae, Compositae, and Euphorbiacea (Figure 5).

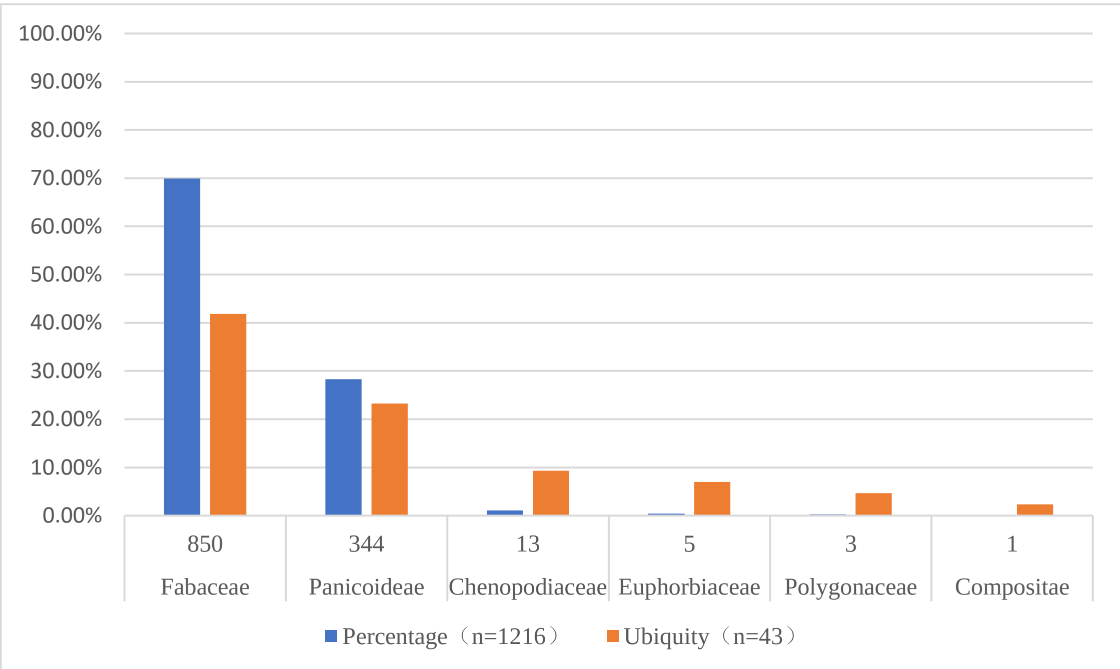

Figure 5. The percentage and ubiquity of different families of weed seeds.

A total of 850 legume weed seeds were identified, accounting for 69.9% of the weed seeds, with an emergence ubiquity of 41.86%. Lespedeza and Melilotus seeds were the most abundant and were primarily concentrated in ash pits H117 and H127. A total of 344 grains from Panicoideae were identified, accounting for 28.29% of the weed seeds, with an emergence ubiquity of 23.26%. Among these, green foxtail (*Setaria viridis*) was the predominant species. Furthermore, 67.75% of the green foxtail seeds were unearthed from ash pit H127, and 11 and 5 grains of Chenopodium and copperleaf (*Acalypha australis*) were identified, respectively.

In addition to weed seeds, non-crop plant remains included a few nuts and fruits, including one grape seed and one nutshell.

5. Discussion

5.1. The 5.3-ka BP Climate Event and Its Immediate Social Impact

The relationship between human society, climate, and environment has always been a focal point across multiple disciplines. Approximately 5500–5000 years ago, multi-index environmental records indicated significant climate fluctuations. The impact of this climate event varied by region, and environmental changes temporally differed in certain regions. The analysis of the multi-index environmental records of the Holocene loess section in the Weinan basin of the Guanzhong region suggested a brief cold and arid period during 5500–5000 BP [30]. This might be related to the decline of the Yangshao culture, which flourished for over 2000 years, by the Longshan culture [30].

Based on the analysis of sedimentary materials from the Yuncheng Salt Lake, it was referred to as the 5.3-ka BP climate event [31]. Its impact on the ancient culture of the Yuncheng Basin was reflected in the reduction of Yangshao late-stage Xiwangcun-type sites and a decrease in their distribution elevation [31]. However, other scholars have referred to it as the 5-ka BP climate event and argued that it manifested in various areas of China's monsoon region [32]. The most distinct records are in the northern monsoon region and the Tibetan Plateau, represented by significant aridity. This event began around 5.6–5.5 ka BP and peaked at approximately 5.0 ka BP [32]. The end time is not mentioned by scholars [33,34], but most likely after 4.9 ka BP in the southern loess plateau because of the decrease in site number observed in the Linfen Basin after 4.9 ka BP [35].

This climate event had some impacts on the development of society. Some archaeologists believe that the 5-ka BP extreme dry-cold event caused significant shifts in cultural patterns, resulting in a long-term "void" in agricultural culture in the central-southern region of Inner Mongolia after 5000 BP [36]. In the Linfen Basin of Shanxi Province, the number of Xiwangcun culture sites per century plummeted from 0.21 to 0.034 after 4.9 ka BP [35]. Since 5500 BP, the early core areas of China, South Shanxi, and West Henan Provinces, have relatively declined [37]. Cultural variations were observed in the northern region and central-southern Henan, and cultures east of the Taihang Mountains have become more prominent. A significant expansion of the Dawenkou culture in the Haidai region has been observed. The cooling around 5500 BP sparked a new migration wave in prehistoric China [38]. This migration primarily manifested as movement from the periphery to the central areas and from the highlands to dry and habitable lowlands. The result of migration was the exploitation of resources, implying that multiple social communities partitioned the same resources. Regional systematic archaeological surveys in the central-eastern area of the Luoyang Basin showed that the number of late-Yangshao-period sites significantly exceeds that of the middle-Yangshao-period sites [39]. The archaeological cultural features indicate a late-Yangshao-period trend of "chasing deer in the Central Plain" (competing for dominance in the Central Plain).

5.2. Revive after Recession

Following the 5.3-ka BP climate event was the early Longshan Period (4800–4300 BP) with a warm climate [30,40–42]. Based on the archaeobotanical results from the Guojiazaoyuan site, we argue that, despite inhabiting a favorable climate, the lingering impact of severe climatic events compelled people to develop a new subsistence strategy. This adaptation aimed to bolster their resilience in the face of adverse climatic conditions. They chose foxtail millet as their primary crop because of its high annual yield and suitability for long-term storage. Following the establishment of foxtail millet as the absolute dominant crop, people at the site developed sophisticated storage techniques. Meanwhile, they also maintained a diversified crop structure and introduced cattle and sheep husbandry as a new subsistence practice.

5.2.1. Foxtail Millet as the Absolute Dominant Crop

A substantial number of charred plant seeds and fruits were identified at the Guojiazaoyuan site during the Neolithic period, with crops being the predominant finding.

The crops included foxtail millet, broomcorn millet, rice, and soybeans, representing a typical early dryland farming tradition. However, at the Guojiazaoyuan site, foxtail millet established an absolute advantage in terms of quantity and ubiquity. Following foxtail millet are small proportions of broomcorn millet, rice, and soybeans.

The quantity of foxtail millet at the Guojiazaoyuan site was about 28 times that of broomcorn millet. The proportion of foxtail millet was notably high (almost 30,000 grains), with one sample from an ash pit containing nearly 23,000 grains. Throughout the southern Loess Plateau, the quantity of foxtail millet significantly increased during the early Longshan period, with a foxtail millet to broomcorn millet ratio of 7.67, considerably higher than that of the late Yangshao period (3.23) (Figure 6). The dominance of foxtail millet was firmly established at this time. After the disaster, people chose foxtail millet as their primary cultivation crop. Agricultural development was evident in the increased proportion of foxtail millet and in the significant increase in crop seed density during the early Longshan period, which was 36.82 grains/L, considerably higher than that of the late Yangshao period (8.82 grains/L). The density of foxtail millet increased from 6.86 to 31.29 grains/L, whereas broomcorn millet increased only slightly, from 1.89 to 4.13 grains/L (Figure 7). The increased seed density per unit of flotation sample was closely related to the improved crop yield. (The data used to analyze Figures 6–10 came from a dataset of archaeobotanical macro-remains reported by He [7], with several newly reported site details added here).

We argue that people chose foxtail millet as their primary crop type for several reasons. First, foxtail has a higher potential to increase annual yield compared to broomcorn millet [43–45]. Although foxtail millet requires more water to grow and is less tolerant to cold and drought, its annual yield could significantly increase with more labor input, i.e., irrigation and fertilization. For broomcorn, however, even with additional labor input, the annual yield does not make much difference [46]. Thus, with the warm and wet climate following the 5.3-ka BP event, people would prefer to use foxtail millet for higher yields.

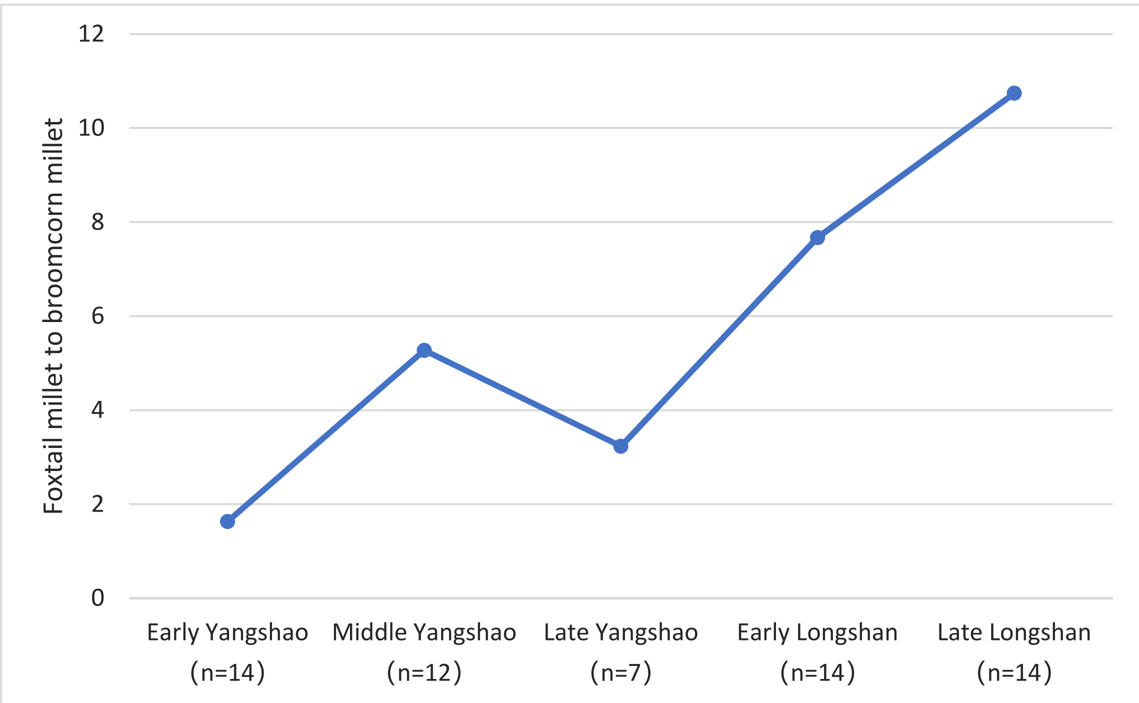

Figure 6. Historical changes of the average ratio of foxtail millet to broomcorn millet in the southern Loess Plateau. (Average of ratios of foxtail millet to broomcorn millet from different sites).

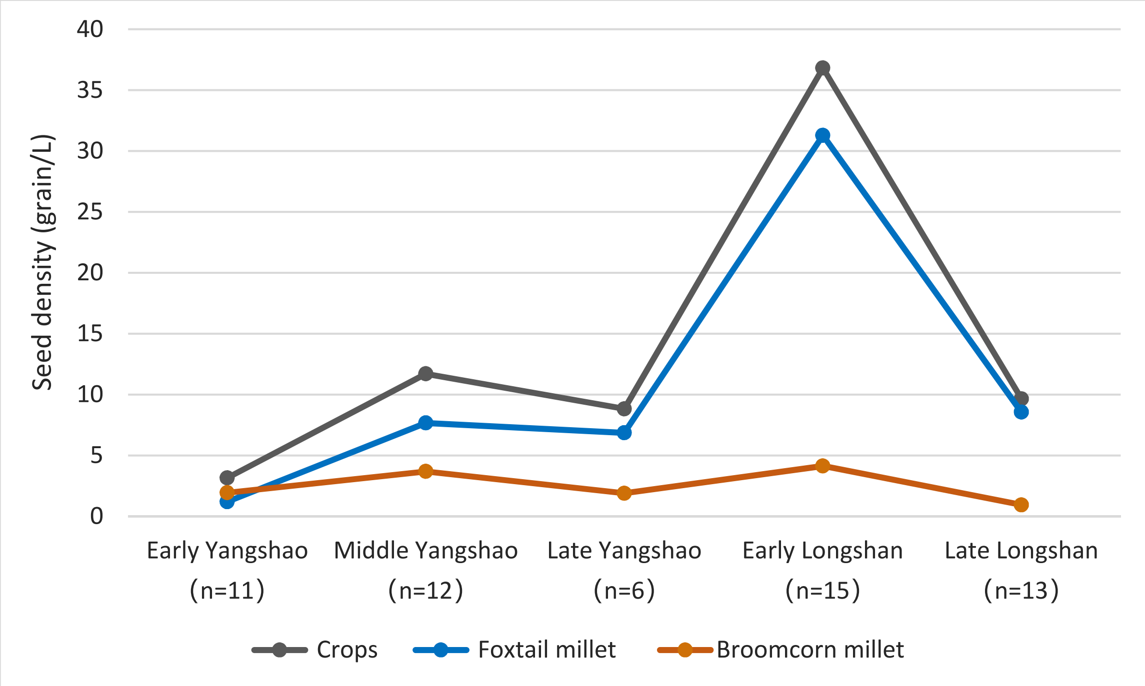

Figure 7. The average seed density of crops, foxtail millet, and broomcorn millet, in the southern Loess Plateau during different periods. (Average of densities from different sites).

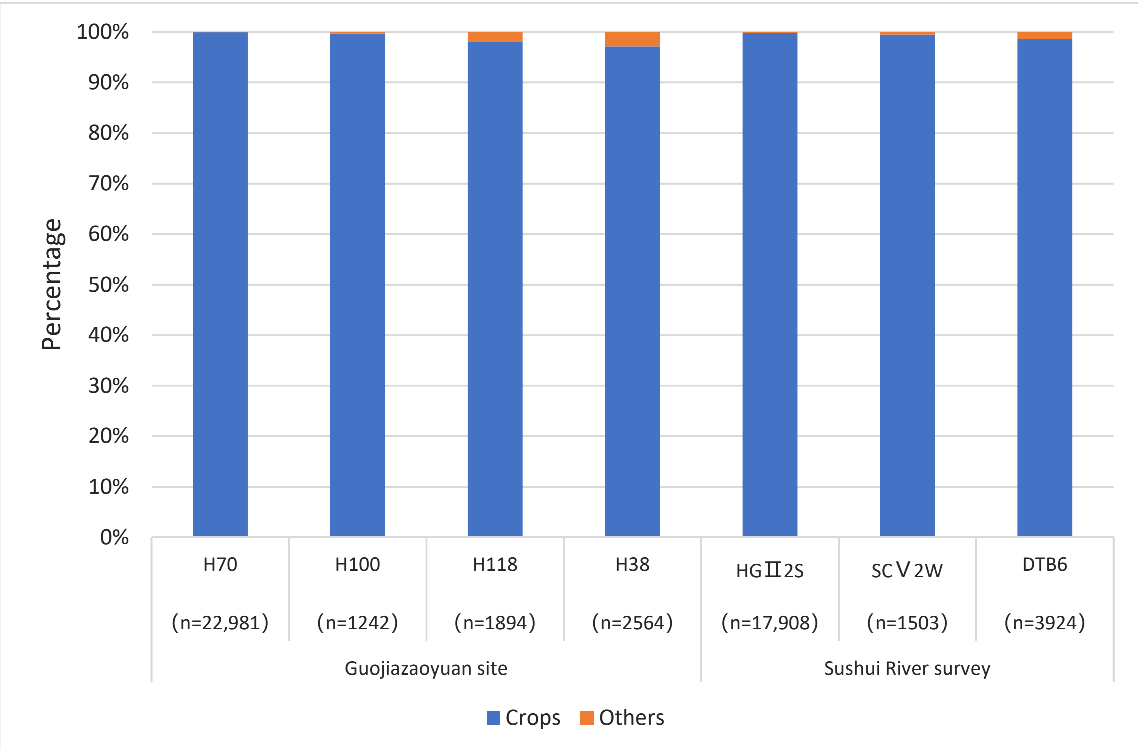

Figure 8. Concentrated distribution of crops in key contexts from the Guojiazaoyuan site and Sushui River survey in the Early Longshan period.

Second, after surviving the climate events, people developed new techniques to manage their farmland and were willing to input more labor for a higher outcome. One effective method is to apply fertilization techniques in farm management to alleviate the limitations of the soil fertility of the Loess Plateau. Research at the Dadiwan site in the Loess Plateau and the Baishui River Valley in Shaanxi Province revealed a significant increase in nitrogen isotope values in millet, indicating persistent fertilization practices that began 5500 years ago [47,48], more or less contemporaneous with the beginning of the 5.3-ka BP event. With the successful experience of surviving the harsh time, people on the Loess Plateau must have realized that fertilization promoted the development of millet farming, thereby increasing crop yield. The significant increase in foxtail millet yields at the Guojiazaoyuan site suggests that fertilization techniques were being practiced. The proportion of broomcorn millet was significantly lower than that of foxtail millet during the early Longshan period. It is reasonable to speculate that people at the time enhanced new farmland management methods and increased labor investment to promote the yield of foxtail millet. Thus, foxtail millet received increasing attention and became the preferred crop.

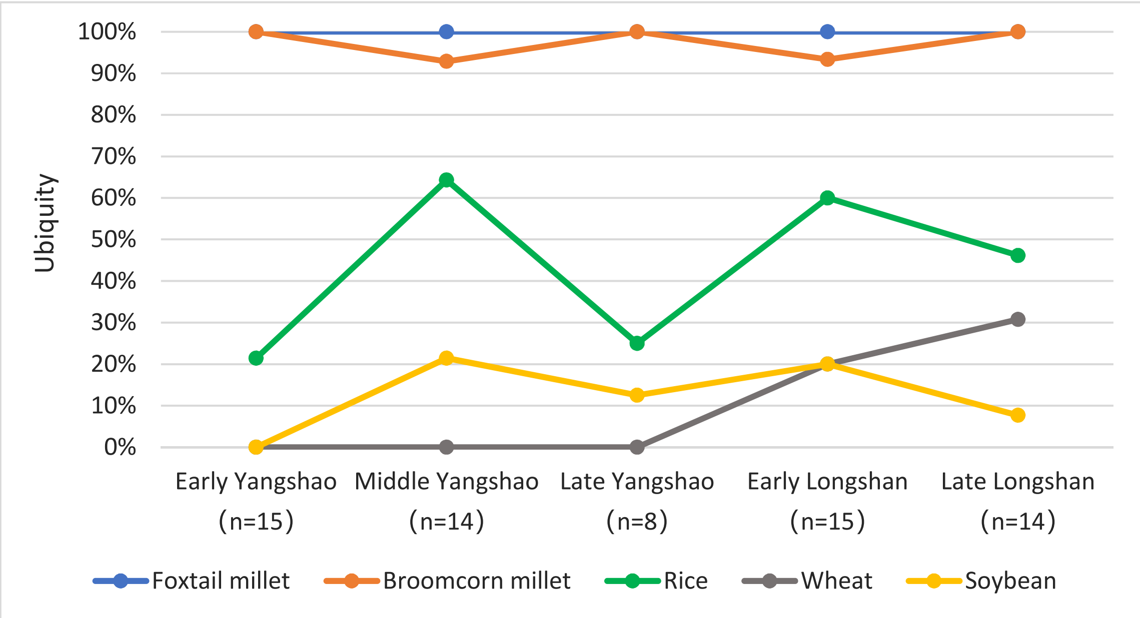

Figure 9. The ubiquity of crops from different periods in the Southern Loess Plateau. (Number of sites unearthing specific charred crop seeds/number of sites with macro-plant remains work).

The third reason is that foxtail is more suitable for long-term storage. Abundant food storage is an essential method for surviving unexpected climatic and social situations. This is especially important for people with memories of hunger during times of scarcity. According to Wang Zhen Nong Shu (Wang Zhen's treatise on agriculture), foxtail millet is among the most durable grains, capable of withstanding aging for long-term storage, and the recommended method for such storage is utilizing underground cellars [49]. Wang noted that the deep and fertile soils in the northern regions made it favorable to excavate underground cellars to store grains, enabling them to remain intact for several decades without deterioration.

At the Guojiazaoyuan site, 77.5% of all foxtail millet, 22,866 grains (flotation unit FX027), were found in pit H70. There were almost no cultural artifacts. It is speculated that this pit was an underground storage chamber for grains. The proportions of cultivated crops among all the charred plant seeds in ash pits H70, H100, H118, and H38 at the site exceeded 97% (Figure 8). Concentrated crop distribution was relatively common in the early Longshan period on the southern Loess Plateau. The results of the Sushui River survey show that outlier units (units with extremely high crop concentration) were observed in the early Longshan period, and the number of crops in the HGII2S unit was 17,873, 91% of which were foxtail millet [18]. There are three archaeological units (HGII2S, SCV2W, and

DTB6) in which the proportion of crops exceeded 90% (Figure 8). These ash pits may be related to storage practices. In contrast, such units were rarely reported in the pre-Longshan period. In fact, only one case was found at the Yuhuazhai site [7,12]. The presence of outlier units indicates an improvement in ancient storage techniques.

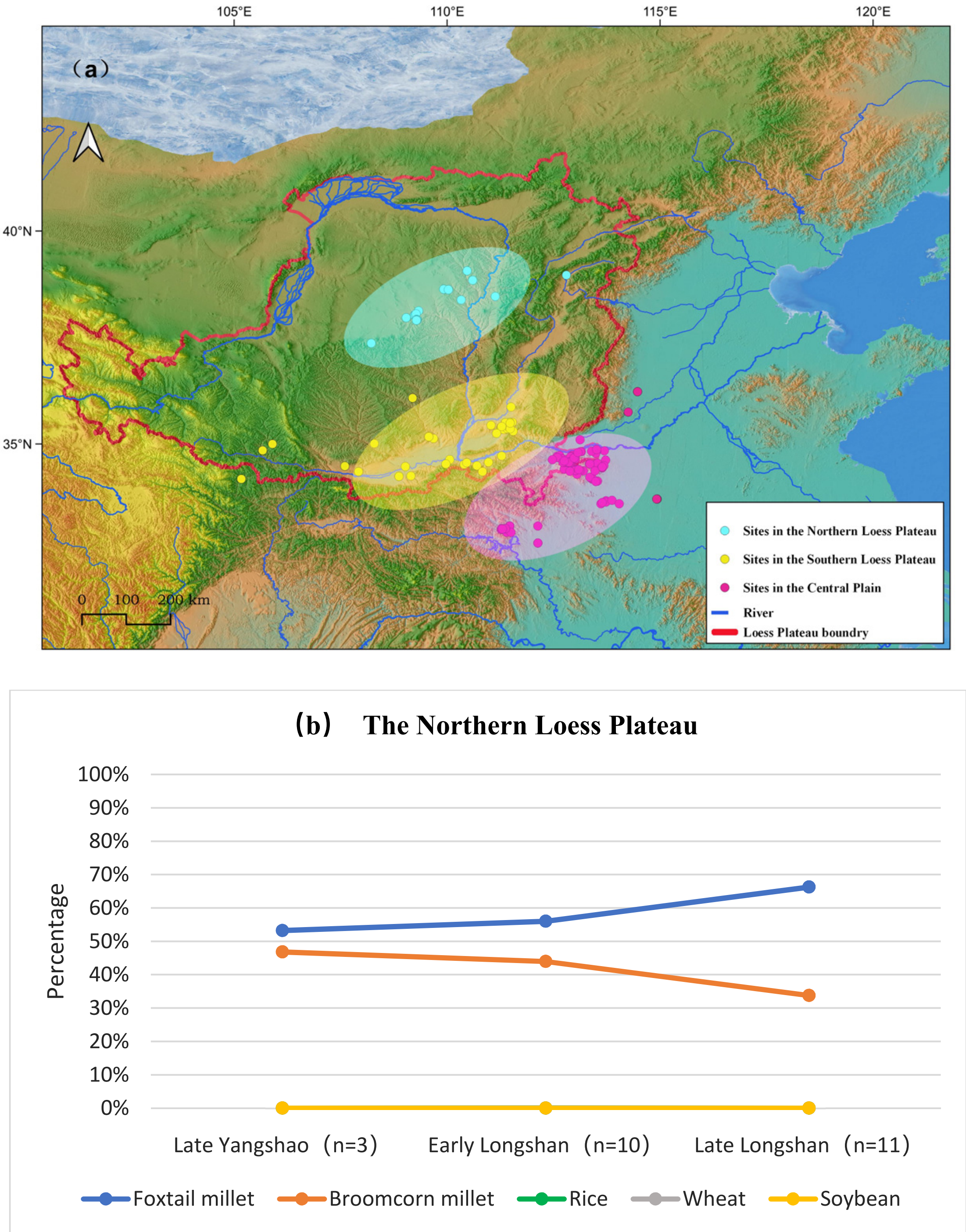

Figure 10. *Cont*.

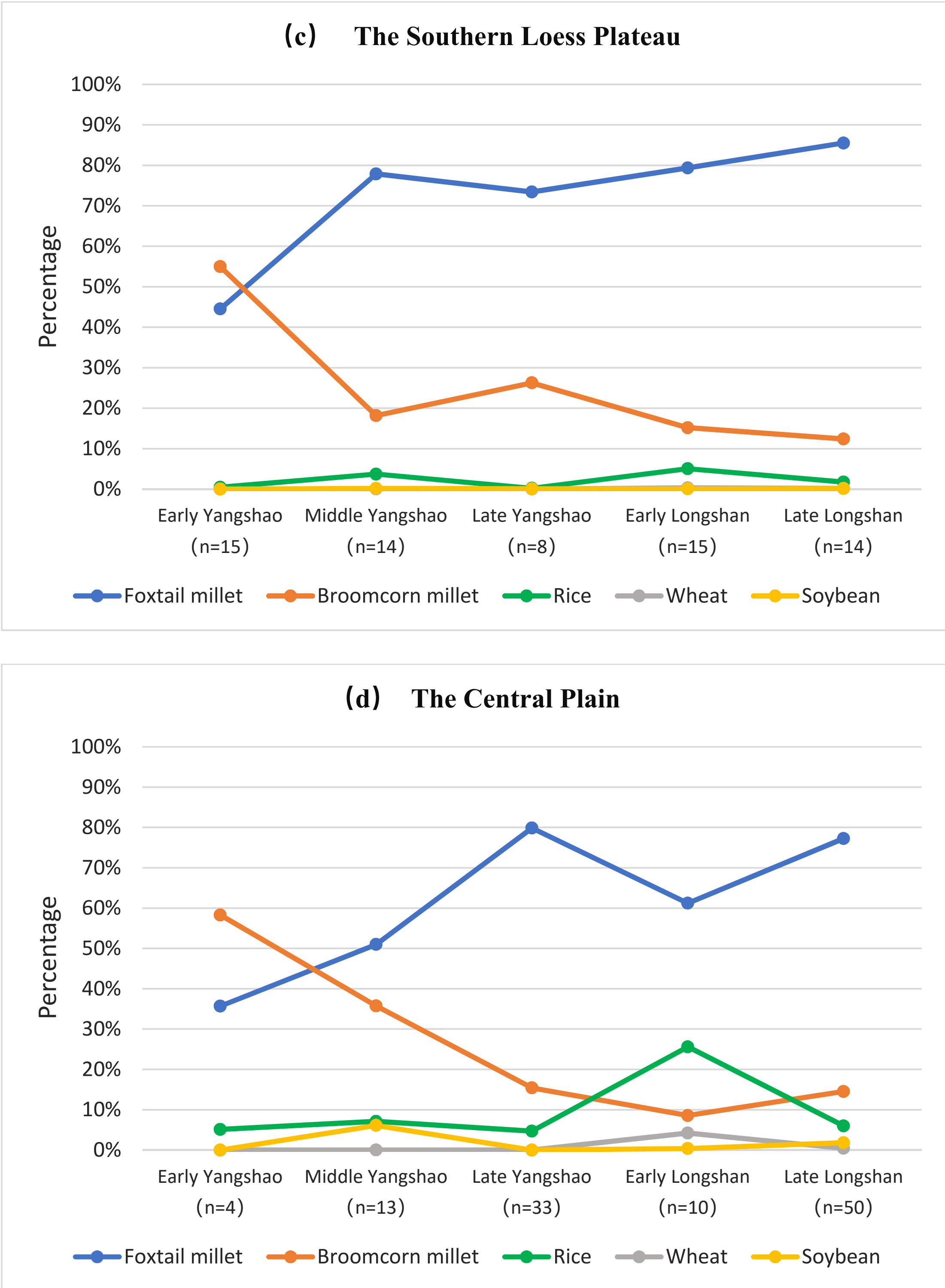

Figure 10. Three regions and their agricultural patterns. (**a**) The location of the three regions (sites with macro-plant remains). (**b**) The percentage of crops in the northern Loess Plateau from different periods (average of percentages from different sites). (**c**) The percentage of crops in the Southern Loess Plateau. (**d**) The percentage of crops in the Central Plain.

Additionally, culinary preferences might also contribute to the choice of foxtail millet. Boiling and steaming were the basis of the Eastern Eurasian culinary tradition [50–52]. The non-sticky types of foxtail millet are easier to digest and more tasty.

5.2.2. Diversified Crop Assemblage to Increase Resilience

Despite choosing foxtail millet as the primary crop, the individuals at Guojiazaoyuan retained the practice of maintaining a diverse crop structure. As mentioned previously, in addition to foxtail millet, there are also broomcorn millet, rice, and soybeans, representing a diversified crop assemblage beginning in the Yangshao period [53]. Charred broomcorn millets have been discovered in the southern part of the Loess Plateau at the Dadiwan site of the Peiligang period (9000–7000 BP) [54]. During the Yangshao culture period (7000–4800 BP), the cultivation of millets rapidly developed, rendering them the primary crops. Over time, the quantity of foxtail millet grown gradually surpassed that of broomcorn millet [7,8]. Certain archaeological sites have begun to reveal the presence of rice and soybeans, although their quantities have remained relatively low. During the early Longshan period, crop diversity was maintained at the Guojiazaoyuan site, and the tradition of diverse crop structures was maintained in the region (Figure 9). In addition to foxtail and broomcorn millet, there were small quantities of soybeans and rice.

A relatively rich soybean collection was found at the Guojiazaoyuan site during the early Longshan period. The soybean is a vital crop worldwide, serving as a major source of food and oil as it is rich in proteins and oils. It is widely accepted in the domestic and international academic community that soybeans probably originated in China. The lower and middle reaches of the Yellow River have long been regarded as potential origin points for the soybean plant [55]. Soybeans and millets contain various nutrients. They complement each other and have a significant symbiotic relationship [56]. The soybeans discovered at the Guojiazaoyuan site are large, flat, and relatively thin. This may be related to the processing methods, such as boiling, applied to the soybeans before carbonization. After boiling, the shape of the cotyledons of soybean changes, and there are fewer voids after carbonization. These discoveries provide new information for research on soybeans' origin, domestication, and dissemination. By the early Longshan period, soybean cultivation had expanded to the southern Shanxi province.

The cultivation and utilization of rice have a long history on the southern Loess Plateau. Identifying only one rice grain at the Guojiazaoyuan site, located beyond the distribution range of wild rice, suggests that this rice grain was likely domesticated. Rice originated in the middle and lower reaches of the Yangtze River and spread northward to the Yellow River basin [57,58]. Although it originated in southern China, rice has been cultivated in the southern Loess Plateau since the Yangshao period (Figure 9). However, due to climatic factors, the ubiquity of unearthing rice in different periods is subject to fluctuations. In this region, agriculture was primarily dryland farming, with a few specific areas having an abundant water supply and maintaining a mixed farming model of rice and dry crops. Phytolith studies were conducted at several archaeological sites in this region, such as Quanhu [30], Yangguanzhai, and Anban [59], and abundant rice phytoliths were discovered. This suggests that rice had been extensively cultivated in the Guanzhong region by 5500 BP. Rice was valued in northern China. For example, rice was concentrated at the Liangchengzhen site [60]. Various factors influence rice cultivation, including the suitable climate, geographical environment, and abundant water supply necessary for rice farming. Furthermore, the site location, level and scale of the settlement, cultural traditions, and people's choices affect the spread and distribution of rice [61–64].

Although only one rice grain was found at the site, its discovery might not be merely coincidental. Multiple findings about rice have been documented at earlier and contemporaneous sites. As illustrated in Figure 9, the ubiquity of rice increased from 25% to 60% from the late Yangshao to the early Longshan periods in the southern Loess Plateau. Therefore, the likelihood of discovering more rice at the Guojiazaoyuan site is high. Rice was likely one of the diversified crop assemblages. Mixed rice and dry-land farming in the region would enhance food stability. The diverse food supply and consumption strategy gave people options during food crises.

5.2.3. Attempts at Cattle and Sheep Husbandry—Exploring a New Subsistence Strategy

The Guojiazaoyuan site yielded a significant number of leguminous weed seeds, primarily belonging to Lespedeza and Melilotus, totaling 850 grains, accounting for 69.9% of the total number of weed seeds, with a ubiquity of 41.86%. In addition, 6942 legume weed seeds were found during the Longshan period at the Zhoujiazhuang site in the southern Loess Plateau, accounting for 56.2% of the weed seeds, and most of them were Lespedeza and Melilotus [16]. Lespedeza, Melilotus, and other legume plants are high-quality animal feed. Cattle and sheep were initially domesticated in West Asia and introduced into China's territory through the Hexi Corridor and Eurasian grasslands. Approximately 5600–5000 years ago, sheep appeared in the Gansu-Qinghai region, and approximately 5000 years ago, cattle appeared in the eastern part of Gansu Province [65]. Approximately 4500 years ago, the Yulin region in northern Shaanxi gradually began accepting sheep and domesticated cattle from the west through Eurasian grasslands. It soon developed into a dominant livestock economy for local livelihoods. Therefore, the livestock economy in northern China began approximately 4500 years ago [66]. The Taosi site in the southern part of the Loess Plateau yielded a small number of cattle and sheep bones during its early stages [67]. The results of the stable isotope study indicated that the diet of cattle is likely to be supplemented with large amounts of C4 crops, such as cereal grasses. In contrast, sheep mainly forage in the wild, with the former being farmed and the latter being free-range [68]. Sheep and cows have similar diets and love grass. Summarily, a small number of cattle and sheep bones were excavated at the Guojiazaoyuan site, and it is hypothesized that the leguminous weeds identified at the site may be related to cattle and sheep rearing.

Exotic species, such as cattle and sheep, were gradually accepted as important livestock. People developed diverse animal-rearing strategies during the early Longshan period, expanding the subsistence economy. Diverse livelihood patterns can help people cope better with the stress and potential disasters caused by environmental change.

5.3. Resilience to Climate Events: A Long-Term Perspective and Regional Variations

The 5.3-ka climate fluctuation significantly impacted society and agriculture in broad regions, including the Loess Plateau and the Central Plain areas (Figure 10a). However, the long-term responses to the events were likely different. At the southern Loess Plateau, the occurrence of foxtail millet becoming a primary crop while maintaining diversity in crop types is not exclusive to Guojiazaoyuan. In general, from late Yangshao to early Longshan, the proportion of foxtail millet in the crops of the southern Loess Plateau increased from 73.43% to 79.38%, whereas that of broomcorn millet decreased from 26.26% to 15.18% (Figure 10c). The average ratio of foxtail millet to broomcorn millet significantly increased from 3.23 to 7.67 (Figure 6). The percentage of rice also witnessed a slight rise from 0.21% to 5.06% (Figure 10c), likely attributed to the warm and humid climate, which is conducive to rice cultivation. Thus, during the early Longshan period, it is likely that societies in the southern part of the Loess Plateau largely adopted a similar form of dryland agriculture, characterized by the absolute dominance of foxtail millet and the utilization of a diverse crop structure. Throughout the Longshan period, foxtail millet maintained its dominance in the crop structure, solidifying its absolute supremacy.

On the northern Loess Plateau, foxtail and broomcorn millets were more or less equally emphasized during the Neolithic period (Figure 10b). The proportion of foxtail millet is only slightly higher than that of broomcorn millet; nevertheless, their proportions remained comparable, with foxtail millet consistently slightly exceeding 50%. Recently, some archaeobotanical works were conducted in this region [69–71], and the results show the same pattern. On the other hand, in the Central Plain, the early Longshan period witnessed the ongoing advancement of foxtail millet-based dry farming and a notable increase in rice cultivation. Certain areas adopted a combined rice and dry crop cultivation method. During the early Longshan period, the proportion of foxtail millet decreased from 79.87% to 61.23%, whereas that of rice increased from 4.7% to 25.6% (Figure 10d). Such differences are probably also related to geographical and geological factors. Affected by monsoons, the proportion of rice decreased from east to west and south to north, whereas that of broomcorn millet increased.

The experiences gained by people in surviving climate events certainly contributed to the re-adjustment of their subsistence strategies. As societies became more resilient and less vulnerable, population growth ensued, leading to the emergence of complex societies and early states. The northern Loess Plateau had the Shimao culture represented by the Shimao site; the southern Loess Plateau had the Taosi culture represented by the Taosi site; and the Central Plain had a flourishing Longshan culture. The progress of these civilizations was closely related to their local agricultural economies.

6. Conclusions

The 5.3-ka BP climate event significantly impacted society and agricultural development in the southern Loess Plateau. During the late Yangshao period (5500–4800 BP), there was a decline in this region, which was part of early China's core area. During the early Longshan period (4800–4300 BP), there was a shift toward warm and wet climatic conditions, providing agricultural development opportunities. Society and agriculture gradually recovered, and the botanical remains reflected a pattern of rejuvenation following the recession. Nevertheless, there was a pattern of bolstering subsistence resilience, indicating a long-term impact of the challenging experiences from the climate event.

Abundant charred plant seeds and fruits dating back to the early Longshan period (4800–4300 BP) were discovered at the Guojiazaoyuan site, with the number of crops considerably exceeding that of others. The crop structure primarily comprised foxtail millet, followed by broomcorn millet, with small amounts of rice and soybeans. The agricultural economy represented typical early dryland agricultural traditions in northern China.

At Guojiazaoyuan, the number of foxtail millets significantly surpassed that of broomcorn millets. This indicates a substantial increase in yield. The absolute dominance of foxtail millet was firmly established in early Longshan, both at Guojiazaoyuan and the southern Loess Plateau. This development was closely related to favorable climatic conditions, the inherently high yield and profitability of foxtail millet, agricultural management practices, and the fact that foxtail is more suitable for long-term storage. The emergence of outliers in foxtail millet and the concentration of crops may be related to food storage practices. With memories of hunger in times of scarcity, people have gradually improved their food storage techniques. Despite choosing foxtail millet as the primary crop, the individuals at Guojiazaoyuan retained the practice of maintaining a diverse crop structure. The diversification of crop structures can enhance the resilience and food stability of society. The discovery of seeds from Fabaceae weeds may be related to limited cattle and sheep rearing. Although raising cattle and sheep is still in its early stages, it has expanded the agricultural economy, enabling people to adapt to environmental pressures.

The long-term responses to the events were likely different in some regions. Foxtail millet was the primary crop on the southern Loess Plateau during the early Longshan period (4800–4300 BP). It dominated the agricultural structure, surpassing broomcorn millet, establishing its absolute dominance. In the northern Loess Plateau, a coexistence pattern of foxtail and broomcorn millet was observed, with foxtail millet holding a slightly higher status than broomcorn millet. Apart from foxtail and broomcorn millet in the Central Plain, there was a relatively rich presence of rice. The agricultural patterns exhibited diverse characteristics.

This systematic archaeobotanical study at the Guojiazaoyuan site is important for studying the development of prehistoric agriculture. Emphasizing the importance of a long-term perspective, particularly in agriculture and food security, the findings contribute to a broader understanding of how ancient societies coped with environmental changes. These insights are pertinent to ongoing discussions on climate resilience and sustainable agriculture.

Author Contributions: Conceptualization, X.C., X.W. (Xiaoyi Wang), and X.W. (Xiaojuan Wang); writing—original draft preparation and data curation, Z.S.; writing—review and editing, methodol-

ogy, supervision, X.C. and Q.W.; formal analysis, Y.L. and B.W.; software, L.G.; funding acquisition, X.C. and X.W. (Xiaojuan Wang). All authors have read and agreed to the published version of this manuscript.

Funding: This research was funded by the National Key R&D Program of China (2022YFF0903504), the National Social Science Foundation of China (20BKG003 and 17BKG005), and the Taishan Scholar Program of Shandong Province, China.

Data Availability Statement: The data used in the current study are available from the corresponding author.

Acknowledgments: We thank Yonggan Fu (Y.F.) from Henan University (Kaifeng), Yongchao Ma (Y.M.) from Sichuan University (Chengdu), Shi-Yong Yu (S.Y.) from Jiangsu Normal University (Xuzhou), and Mitchell Ma from the University of Toronto (Toronto) for their kind help in the flotation and identification work and useful suggestions on the data analysis. Our gratitude is also extended to the four reviewers, whose constructive comments and suggestions greatly improved this manuscript.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Xu, D.K.; Lu, H.Y.; Chu, G.Q.; Liu, L.; Shen, C.M.; Li, F.J.; Wang, C.; Wu, N.Q. Synchronous 500-year oscillations of monsoon climate and human activity in Northeast Asia. *Nat. Commun.* **2019**, *10*, 4105. [CrossRef] [PubMed]
2. Lu, H.Y. Periodic climate change and human adaptation. *Acta Anthropol. Sin.* **2022**, *41*, 731–748.
3. Barnett, J. Climate change and security. In *A Changing Environment for Human Security: Transformative Approaches to Research, Policy and Action*; Sygna, L., O'brien, K., Wolf, J., Eds.; Routledge: London, UK, 2013.
4. Jackson, R.; Dugmore, A.; Riede, F. Towards a new social contract for archaeology and climate change adaptation. *Archaeol. Rev. Camb.* **2017**, *32*, 276350.
5. Pandolfi, J.M.; Bradbury, R.H.; Sala, E.; Hughes, T.P.; Bjorndal, K.A.; Cooke, R.G.; McClenachan, L.; Newman, M.J.H.; Paredes, G.; Warner, R.R.; et al. Global Trajectories of the Long-Term Decline of Coral Reef Ecosystems. *Science* **2003**, *301*, 955–958. [CrossRef] [PubMed]
6. Riede, F. Climate models: Use in archaeology. *Nature* **2014**, *513*, 315. [CrossRef] [PubMed]
7. He, K.Y.; Lu, H.Y.; Zhang, J.P.; Wang, C. Holocene spatiotemporal millet agricultural patterns in northern China: A dataset of archaeobotanical macro-remains. *Earth Syst. Sci. Data* **2022**, *14*, 4777–4791. [CrossRef]
8. Yang, Y.S.; Wang, J.; Li, G.; Dong, J.J.; Cao, H.H.; Ma, M.M.; Chen, G.K.; Dong, G.H. Shift in subsistence crop dominance from broomcorn millet to foxtail millet around 5500 BP in the western Loess Plateau. *Front. Plant Sci.* **2022**, *13*, 939340. [CrossRef]
9. Wang, C.; Lu, H.Y.; Gu, W.F.; Zuo, X.X.; Zhang, J.P.; Liu, Y.F.; Bao, Y.J.; Hu, Y.Y. Temporal changes of mixed millet and rice agriculture in Neolithic-Bronze Age Central Plain, China: Archaeobotanical evidence from the Zhuzhai site. *Holocene* **2018**, *28*, 738–754. [CrossRef]
10. He, K.Y.; Lu, H.Y.; Jin, G.Y.; Wang, C.; Zhang, H.; Zhang, J.P.; Xu, D.K.; Shen, C.M.; Wu, N.Q.; Guo, Z.T. Antipodal pattern of millet and rice demography in response to 4.2 ka climate event in China. *Quat. Sci. Rev.* **2022**, *295*, 107786. [CrossRef]
11. Zhao, Z.J. The process of origin of agriculture in China: Archaeological evidence from flotation results. *Quat. Sci.* **2014**, *34*, 73–84.
12. Zhao, Z.J. The Development of Agriculture in the Time of Yangshao Culture and the Establishment of Agricultural Society: An Analysis on the Flotation Result of Yuhuazhai Site. *Jianghan Archaeol.* **2017**, 98–108. (In Chinese)
13. Zhao, Z.J. Changes and development of ancient agriculture on Weihe Plain—An analysis of plant remnants excavated from Dongyang site in Huaxian District. *Huaxia Archaeol.* **2019**, *5*, 70–84. (In Chinese)
14. Zhong, H.; Yang, Y.C.; Yao, J.; Zhao, Z.J. The research on the carbonized plant remains from Xinjie site, Lantian County, Shaanxi Province. *Cult. Relics South. China* **2015**, *3*, 36–43. (In Chinese)
15. Liu, X.Y. A Study on the Plant Remains from the Anban Site Excavated in 2012. Master's Thesis, Northwest University, Xi'an, China, 2023. (In Chinese).
16. Jiang, Y.C.; Dai, X.M.; Wang, Y.Z.; Wang, X.Y.; Qin, L. Plant macro-remains reveals the agricultural pattern and regional variation of Shanxi plateau during Longshan Period. *Quat. Sci.* **2019**, *39*, 123–131.
17. Zhao, Z.J.; He, N. Analysis of the Flotation Results of 2002 excavation season from the Taosi site in Xiangfen, Shanxi Province. *Archaeol* **2006**, *5*, 77–86. (In Chinese)
18. Song, J.X.; Wang, L.Z.; Fuller, D.Q. A regional case in the development of agriculture and crop processing in northern China from the Neolithic to Bronze Age: Archaeobotanical evidence from the Sushui River survey, Shanxi province. *Archaeol. Anthropol. Sci.* **2019**, *11*, 667–682. [CrossRef]
19. Dai, X.M. The Formation and Initial Development of Early Complex Society in the Central Plain. *Archaeol. Res.* **2012**, *9*, 481–527. (In Chinese)
20. Dai, X.M. The Process of Social Complexification in the Longshan Era of the Central Plain. *Archaeol. Res.* **2013**, 539–581. (In Chinese)

21. Chinese Archaeological Association. *China Archaeological Yearbook of 2010*; Cultural Relics Press: Beijing, China, 2010; p. 165. (In Chinese)
22. Pei, X.S. A Study on the Neolithic Remains from Guojiazaoyuan Site in Jishan County, Shanxi Province. Master's Degree Dissertation, Shanxi University, Taiyuan, China, 2018. (In Chinese).
23. Zhao, Z.J. *Paleoethnobotany: Theories, Methods, and Practice*; Science Press: Beijing, China, 2010; pp. 35–36. (In Chinese)
24. Liu, C.J.; Jin, G.Y.; Kong, Z.C. *Archaeobotany: Research on Seeds and Fruits*; Science Press: Beijing, China, 2008. (In Chinese)
25. Ma, C.Z. (Ed.) *Identification and Control of Weeds in Farmland*; China Agriculture Press: Beijing, China, 2010. (In Chinese)
26. Institute for the Control of Agrochemicals of the People's Republic of China. *Chinese Colored Weed Illustrated Book*; China Agricultural Science and Technology Press: Beijing, China, 2000. (In Chinese)
27. Editorial Committee of Farmland Weeds in China. *Farmland weeds in China: A Collection of Colored Illustrative Plates*; Agricultural Publishing House: Beijing, China, 1990. (In Chinese)
28. Liu, X.Y.; Lister, D.L.; Zhao, Z.J.; Petrie, C.A.; Zeng, X.S.; Jones, P.J.; Staff, R.A.; Pokharia, A.K.; Bates, J.; Singh, R.N.; et al. Journey to the east: Diverse routes and variable flowering times for wheat and barley en route to prehistoric China. *PLoS ONE* **2017**, *12*, e0187405. [CrossRef]
29. Zhou, X.Y.; Yu, J.J.; Spengler, R.N.; Shen, H.; Zhao, K.L.; Ge, J.Y.; Bao, Y.G.; Liu, J.C.; Yang, Q.J.; Chen, G.H.; et al. 5200-year-old cereal grains from the eastern Altai Mountains redate the trans-Eurasian crop exchange. *Nat. Plants* **2020**, *6*, 78–87. [CrossRef]
30. Lu, H.Y.; Zhang, J.P. Neolithic cultural evolution and Holocene climate change in the Guanzhong Basin, Shaanxi, China. *Quat. Sci.* **2008**, *28*, 1050–1060.
31. Zhang, G.L. Climate Change of Loess Plateau since the Last Deglaciation and Its Environmental Effect. Ph.D. Thesis, University of Chinese Academy of Sciences, Beijing, China, 2018. (In Chinese).
32. Li, D.; Tan, L.C.; An, Z.S. 5 ka BP event in monsoonal China. *J. Earth Environ.* **2016**, *7*, 5. (In Chinese)
33. Shi, Y.F.; Kong, Z.C.; Wang, S.M.; Tang, L.Y.; Wang, F.B.; Yao, T.D.; Zhao, X.T.; Zhang, P.Y.; Shi, S.H. Climatic fluctuations and important events during the Holocene Mega thermal in China. *Sci. China Ser. B* **1992**, *12*, 1300–1308. (In Chinese)
34. Wu, W.X.; Zheng, H.B.; Hou, M.; Ge, Q.S. The 5.5 cal ka BP climate event, population growth, circumscription and the emergence of the earliest complex societies in China. *Sci. China Earth Sci.* **2018**, *61*, 134–148. [CrossRef]
35. Li, T.Y.; Mo, D.W.; Kidder, T.; Zhang, Y.F.; Wang, H.B.; Wu, Y.Q. Holocene environmental change and its influence on the prehistoric culture evolution and the formation of the Taosi site in Linfen basin, Shanxi province, China. *Quat. Int.* **2014**, *349*, 402–408. [CrossRef]
36. Yan, W.M.; Han, J.Y.; Chen, H.H. Archaeological Observations of Environmental Changes in the Neolithic and Bronze Age of the Loess Plateau. In *Water Resources Allocation, Ecological Environment Construction and Sustainable Development Strategy Research in Northwest China: Natural History Volume*; Science Press: Beijing, China, 2004; p. 261. (In Chinese)
37. Han, J.Y. *Early China: The Making of the Chinese Cultural Sphere*; Shanghai Classics Publishing House: Shanghai, China, 2020. (In Chinese)
38. Wu, W.X.; Liu, D.S. 5500 a BP climatic event and its implications for the emergence of civilizations in Egypt and Mesopotamia and Neolithic cultural development in China. *Earth Sci. Front.* **2002**, *9*, 155–162. (In Chinese)
39. Institute of Archaeology, Chinese Academy of Social Sciences, Sino-Australian-American Collaborative Archaeological Team of the Yiluo River Valley. *Pre-Qin Period Sites in the East and Central Luoyang Basin: The Systematic Regional Archaeological Survey Report (1997–2007)*; Science Press: Beijing, China, 2019; pp. 1129–1146. (In Chinese)
40. Wu, W.X.; Fang, Q.; Ge, Q.S. Climate change during the Longshan period (5.0–4.0 ka BP). *Mar. Geol. Quat. Geol.* **2013**, *33*, 129–137. [CrossRef]
41. Wang, Y.J.; Cheng, H.; Edwards, R.L.; He, Y.Q.; Kong, X.G.; An, Z.S.; Wu, J.Y.; Kelly, M.J.; Dykoski, C.A.; Li, X.D. The Holocene Asian monsoon: Links to solar changes and North Atlantic climate. *Science* **2005**, *308*, 854–857. [CrossRef]
42. Cosford, J.; Qing, H.R.; Eglington, B.; Mattey, D.; Yuan, D.X.; Zhang, M.L.; Cheng, H. East Asian monsoon variability since the Mid-Holocene recorded in a high-resolution, absolute-dated aragonite speleothem from eastern China. *Earth Planet. Sci. Lett.* **2008**, *275*, 296–307. [CrossRef]
43. Dong, Y.C.; Zheng, D.S. *Crops and Their Wild Relatives in China (Food Crops)*; China Agriculture Press: Beijing, China, 2006; p. 605. (In Chinese)
44. Chai, Y.; Feng, B.L. Present situation and developing strategies of minor grain crops in China. *Agric. Res. Arid. Areas* **2003**, *5*, 145–151. (In Chinese)
45. Yang, W.Z.; Yu, C.Z. *Regional Governance and Evaluation of the Loess Plateau*; Science Press: Beijing, China, 1992; pp. 73–124. (In Chinese)
46. Wang, X.Y. *Chinese Millets*; China Agriculture Press: Beijing, China, 1996; p. 155. (In Chinese)
47. Yang, J.S.; Zhang, D.J.; Xiaoyan, Y.; Wang, W.W.; Perry, L.; Fuller, D.Q.; Li, H.M.; Wang, J.; Ren, L.L.; Xia, H.; et al. Sustainable intensification of millet–pig agriculture in Neolithic North China. *Nat. Sustain.* **2022**, *5*, 780–786. [CrossRef]
48. Wang, X.; Fuller, B.T.; Zhang, P.C.; Hu, S.M.; Hu, Y.W.; Shang, X. Millet manuring as a driving force for the Late Neolithic agricultural expansion of north China. *Sci. Rep.* **2018**, *8*, 5552. [CrossRef] [PubMed]
49. He, H.Z.; Hui, F.P. *The History of Millet Cultivation in Ancient China*; China Agricultural Science and Technology Press: Beijing, China, 2015; p. 157. (In Chinese)

50. Fuller, D.; Rowlands, M. Ingestion and Food Technologies: Maintaining Differences over the Long-term in West, South and East Asia. In *Interweaving Worlds: Systemic Interactions in Eurasia, 7th to 1st Millennia BC.*; Wilkinson, T.C., Sherratt, S., Bennet, J., Eds.; Oxbow Books: Oxford, UK, 2011; pp. 37–60.
51. Liu, X.Y.; Lister, D.L.; Zhao, Z.J.; Staff, R.A.; Jones, P.J.; Zhou, L.P.; Pokharia, A.K.; Petrie, C.A.; Pathak, A.; Lu, H.L.; et al. The virtues of small grain size: Potential pathways to a distinguishing feature of Asian wheats. *Quat. Int.* **2016**, *426*, 107–119. [CrossRef]
52. Liu, X.Y.; Reid, R.E. The prehistoric roots of Chinese cuisines: Mapping staple food systems of China 6000 BC–220 AD. *PLoS ONE* **2020**, *15*, e0240930. [CrossRef] [PubMed]
53. Zhao, Z.J. Origin of Agriculture and Archaeobotanical Works in China. *Agric. Hist. China* **2020**, *39*, 3–13. (In Chinese)
54. Liu, C.J.; Kong, Z.C.; Lang, S.D. The study of the plant remains and environment in Dadiwan site. *Cult. Relics Cent. China* **2004**, *4*, 26–30. (In Chinese)
55. Guo, W.T. Origins of soybean cultivation in China. *J. Nanjing Agric. Univ.* **2004**, *1*, 60–69. (In Chinese)
56. He, K.Y.; Yu, X.S.; Shen, C.M.; Lu, H.Y. Coupled and decoupled legumes and cereals in prehistoric northern and southern China. *Front. Plant Sci.* **2022**, *13*, 1013480. [CrossRef]
57. Zhao, Z.J. New archaeobotanic data for the study of the origins of agriculture in China. *Current Anthropology* **2011**, *52*, S295–S306. [CrossRef]
58. He, K.Y.; Lu, H.Y.; Zhang, J.P.; Wang, C.; Huan, X.J. Prehistoric evolution of the dualistic structure mixed rice and millet farming in China. *Holocene* **2017**, *27*, 1885–1898. [CrossRef]
59. Zhang, J.P.; Lu, H.Y.; Wu, N.Q.; Li, F.J.; Yang, X.Y.; Wang, W.L.; Ma, M.Z.; Zhang, X.H. Phytolith evidence for rice cultivation and spread in Mid-Late Neolithic archaeological sites in central North China. *Boreas* **2010**, *39*, 592–602. [CrossRef]
60. Chinese-American Collabborative Team. *Liangchengzhen:1998–2001 Excavation Report*; Cultural Relics Press: Beijing, China, 2017; pp. 1072–1122. (In Chinese)
61. Zhong, H. The tentative research of the spreading of rice in the Central Plain during prehistoric period. School of Cultural Heritage, Northwest University (Ed.). *Archaeol. West. China* **2018**, *15*, 211–223. (In Chinese)
62. Zhong, H.; Zhao, Z.J. The Preliminary Study of Agricultural Production Mode of the Central Plain during the Late Yangshao Period. *Agric. Hist. China* **2023**, *42*, 52–61. (In Chinese)
63. Zhang, J.N.; Xia, Z.K.; Zhang, X.H. Research on charred plant remains from the Neolithic to the Bronze Age in Luoyang Basin. *Chin. Sci. Bull.* **2014**, *59*, 3388–3397. [CrossRef]
64. Li, Y.P.; Zhang, J.N. The influence of landscape evolution on rice planting in the middle-late Neolithic period to Xia-Shang dynasties in Luoyang Basin. *Quat. Sci.* **2020**, *40*, 499–511.
65. Yuan, J. A Zooarchaeological study on the origins of animal domestication in ancient China. *Chin. Ann. Hist. Sci. Technol.* **2021**, *5*, 1–26.
66. Hu, S.M. A Restricted View on the Development of Animal Husbandry from Archaeology in Yulin Area—Based on the Animal Archaeology and the Latest Dating Data of Yulin Area from 5000 to 4000 Years. *China Social Science News*, 14 September 2021; 2251. (In Chinese)
67. Brunson, K. A case study on the change of animal utilization in the late Neolithic Age in China—An animal study of Taosi site in the late Longshan age in Shanxi Province. *Archaeol. Three Dynast.* **2011**, 129–182. (In Chinese)
68. Chen, X.L.; Yuan, J.; Hu, Y.W.; He, N.; Wang, C.S. Investigating into livestock husbandry strategies at Taosi site through stable carbon and nitrogen isotope analysis. *Archaeology* **2012**, *9*, 75–82. (In Chinese)
69. Ma, Z.K.; Liu, S.; Song, J.C.; Zhang, H.; Zhai, L.L.; Huan, X.J. Early Millet Use and Its Environmental Impact Factors in Northern Shaanxi, Northwest China. *Agronomy* **2023**, *13*, 1272. [CrossRef]
70. Li, H.M.; Cui, Y.F.; James, N.; Ritchey, M.; Liu, F.W.; Zhang, J.N.; Ma, M.M.; Dong, G.H. Spatiotemporal variation of agricultural patterns in different geomorphologic and climatic environments in the eastern Loess Plateau, north-central China during the late Neolithic and Bronze Ages. *Sci. China Earth Sci.* **2022**, *65*, 934–948. [CrossRef]
71. Bao, Y.G.; Li, X.Q.; Liu, H.B.; Zhao, K.L.; John, D.; Shen, H.; Zhang, G.L.; Wang, J.; Zhou, X.Y. Evolution and bioenvironmental adaptation of Neolithic and Bronze age agriculture in the North Chinese Loess Plateau. *Acta Anthropol. Sin.* **2020**, *39*, 461–472.