land

MDPI

Article

Agricultural Economic Transformations and Their Impacting Factors around 4000 BP in the Hexi Corridor, Northwest China

Haiming Li [1], Nathaniel James [2], Junwei Chen [3], Shanjia Zhang [4], Linyao Du [4], Yishi Yang [5], Guoke Chen [5,*], Minmin Ma [4] and Xin Jia [3,*]

[1] College of Humanities & Social Development, Institute of Chinese Agricultural Civilization, Agricultural Archaeology Research Center, Nanjing Agricultural University, Nanjing 210095, China
[2] Department of Anthropology, University of California, San Diego, CA 92093, USA
[3] School of Geography, Institute of Environmental Archaeology, Nanjing Normal University, Nanjing 210023, China
[4] Key Laboratory of Western China's Environmental Systems (Ministry of Education), College of Earth and Environmental Sciences, Lanzhou University, Lanzhou 730013, China
[5] Gansu Provincial Institute of Cultural Relics and Archaeology, Lanzhou 730015, China
* Correspondence: chenguoke1980@sina.com (G.C.); jiaxin@njnu.edu.cn (X.J.)

Abstract: By 4000 BP, trans-Eurasian agricultural exchanges increased across the Hexi Corridor. However, the nature and timing of many early prehistoric agricultural exchanges remain unclear. We present systematically collected archaeobotanical data from the ancient Haizang site (3899–3601 cal a BP) within the Hexi Corridor. Adding to previous archaeobotanical studies of the Hexi Corridor, we find that agricultural production transformed from purely millet-based agriculture during the Machang Period (4300–4000) to predominantly millet-based agriculture increasingly supplemented with wheat and barley during the Xichengyi and Qijia periods (4000–3600 BP). These transformations are likely due to adaption to a cooler and drier climate through cultural exchange. A warm and humid climate during 4300–4000 BP likely promoted millet agriculture, Machang cultural expansion westward, and occupation across the Hexi corridor. However, after the "4.2 ka BP cold event" people adopted wheat and barley from the West to make up for declining millet agricultural productivity. This adoption began first with the Xichengyi culture, and soon spread further eastward within the Hexi Corridor to the Qijia culture.

Keywords: archaeobotanical; Haizang site; Qijia culture; millet-based agriculture; cooler drier climate

Citation: Li, H.; James, N.; Chen, J.; Zhang, S.; Du, L.; Yang, Y.; Chen, G.; Ma, M.; Jia, X. Agricultural Economic Transformations and Their Impacting Factors around 4000 BP in the Hexi Corridor, Northwest China. *Land* **2023**, *12*, 425. https://doi.org/10.3390/land12020425

Academic Editor: Deodato Tapete

Received: 12 December 2022
Revised: 1 February 2023
Accepted: 3 February 2023
Published: 6 February 2023

1. Introduction

Prehistoric transcontinental cultural exchanges and their impacts on agricultural economic systems are key topics of scientific research and concern. A central issue is the spread of "Neolithic founder crops" eastward from the Fertile Crescent, and of domesticated millets expanding westward from China [1–11]. These processes, known as "Prehistoric food globalization", represent early worldwide transformations in agriculture and culture [12–14]. Archaeobotanical evidence indicates that East Asian millets and West Asian wheat and barley converged in eastern Central Asia around 4500 BP [4,15,16]. The spread of wheat and barley eastward to the Gansu-Qinghai region created dramatic impacts on the agricultural activities and ecological opportunities for cultures in northwest China [7,9,17–23]. Archaeobotanical and stable isotope evidence suggests that wheat and barley were introduced into the Hexi Corridor and northeastern Qinghai-Tibet Plateau in 4000 BP [9,12,17,18,20,21,24], rapidly replacing millets as primary staple crops after 3700 BP [20–22]. The Hexi Corridor is an ideal location to understand changing agricultural practices and crop exchanges. Our study site, Haizang, was occupied at a time of increasing prehistoric transcontinental exchange and climatic variability. It represents a useful case study to understand the timing and nature of these changing practices in land use, particularly when these exchanges occur during times of both beneficial and detrimental climatic changes.

Located in northwest China, the Hexi Corridor is a key section of the Ancient Silk Road, and a hub of past cultural exchange across Eurasia [9,25–27]. Earlier excavations indicate large-scale human habitation in the Hexi Corridor around 4800 BP, originating from north China, and marked by millet agriculture and painted pottery [9]. Only one archaeological site named Xichengyi from around 4000 BP was excavated, and a few wheat crops were identified. However, sporadic studies on profile sampling implied that wheat crops occupied a certain proportion around 4000 BP [9,17,18,28]. Therefore, it is necessary to evaluate and refine arguments of large-scale changes in land use and agricultural production with new evidence based on systemic archaeobotanical research and archaeological excavation.

Notably, for our arguments about agricultural production, an extreme cold and dry climate event named "Holocene Event 3" impacted world climate conditions around 4000 BP [29–34]. As the strongest climate event in the last 5000 years, the "4.2 ka BP cold event" has been argued to lead to the demise of some ancient states, such as the Akkad Empire and the Harappa civilization [35–38]. This event is also argued to have led to significant cultural transformations and changes in subsistence strategies in China [20,34,39–42]. During this time, the Hexi corridor area experienced a dramatic climate shift around 4000 BP, and the temperature and humidity decreased significantly compared with the Holocene's climatically suitable period [31,43–46]. However, due to the lack of systematic interdisciplinary research, the relationships between the "4.2 ka BP cold event" and the cultural, agricultural, and economic dynamics around 4000 BP in the Hexi Corridor remain unclear.

In this paper, we integrate new data from the Haizang site with existing published data to better understand the changes in cultural and agricultural practices in the ancient Hexi Corridor. To do so, we begin by comparing our results with existing archaeobotanical data and radiocarbon dates. We then compare these processes with paleoclimate and geomorphological data to better understand the driving factors behind cultural and agricultural change in the Hexi Corridor around 4000 BP. This work deepens our understanding of the complexities surrounding prehistoric transcontinental cultural exchange.

2. Study Area and Site Description

The Hexi Corridor (92°21′ E–104°45′ E, 37°15′ N–41°30′ N) is a narrow corridor located in northwest China (Figure 1). It spans from the Wushaoling Mountains in the east, to the Yumen Pass in the west and is oriented along a southeast-northwest axis between the Qilian Mountains to the south, and the Mongolian plateau and Gobi to the north. The region is relatively flat and lies approximately 1500 m a.s.l. The climate of the Hexi Corridor belongs to the temperate semi-arid and temperate arid climate [47], with a mean annual temperature of 5–9 °C and mean annual precipitation around 200 mm (http://data.cma.cn/site/index.html, accessed on 30 November 2021). The vegetation consists of the Stipa steppe in the east, with the west dominated by desert shrubs such as Chenopodiaceae, Ephedra, Tamarix, Hippophae, and Nitraria. Three main river systems, the Shiyang, Hei, and Shule, flow northward from the Qilian Mountains to the desert. They are fed with mountain snowmelt from the Qilian Mountains and generate three oases in their respective fluvial plains: from east to west, the Wuwei Oasis, the Zhangye Oasis, and the Jiuquan Oasis. The Hexi Corridor's water access, low elevation, and intersection between mountains and deserts has made it the key route connecting central China with Xinjiang and Central Asia.

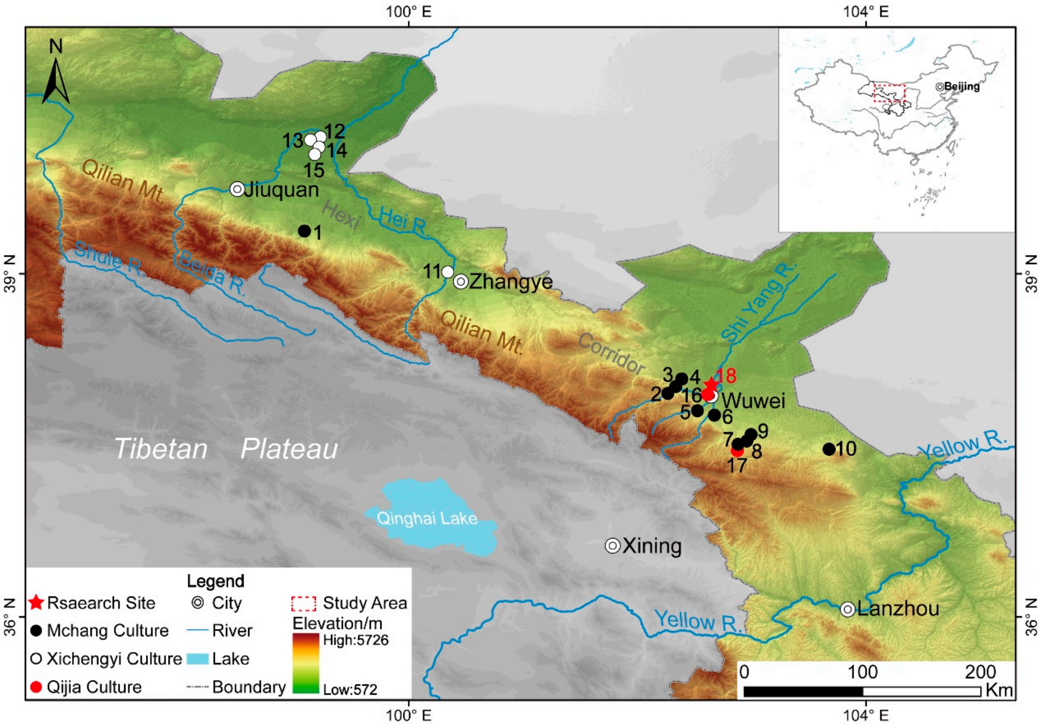

Figure 1. Location of Machang culture, Xichengyi culture, and Qijia culture sites in the Hexi Corridor, Northwest China. Machang culture sites (4300–4000 BP): 1. Xihetan; 2. Qipanshan; 3. Xinzhai; 4. Guojiashan; 5. Maolinshan; 6. Mozuizi; 7. Xitai; 8. Shuikou; 9. Duojialiang; 10. Guandi. Xichengyi culture sites (4000–3600 BP): 11. Xichengyi; 12. Huoshiliang; 13. Ganggangwa; 14. Yigediwonan; 15. Yigediwonan2. Qijia culture sites (4000–3600 BP): 16. Huangniangniangtai; 17. Lijiageleng; 18. Haizang.

The Haizang site (102.64° E, 37.96° N) is located in the eastern half of the Hexi Corridor in the Liangzhou District, Wuwei City (Figure 1). To the west, 2.5 km away, lies Wuwei City, and 2.2 km to the southwest is the Huangniangniangtai site. The Haizang site covers an area of nearly 30,000 m^2 with a mean altitude of 2403 m a.s.l. There are no trees at the site today due to extreme aridity (mean annual precipitation of 100 mm and mean annual temperature of 7.7 °C), and the area's surface is heavily eroded by wind. In cooperation with ongoing ecological restoration and construction projects at Haizang lake, the Gansu Provincial Institute of Cultural Relics and Archaeology conducted archaeological excavations at the Haizang site from 2018 to 2019. Across an area of 1100 m^2, eighteen cultural layers were excavated and stratigraphically delineated by context. The uppermost layer belongs to modern contexts, the second to third layers date to the Warring States period (2476–2221 BP), and the fourth to eighteenth layers date to the Qijia culture (4000–3600 cal BP). Twenty-six discrete contexts were documented as belonging to the Qijia: these include tombs, house sites, ash pits, etc. From these contexts, large numbers of artifacts were unearthed: including pottery, stone artifacts, jade artifacts, bronzes, bone artifacts, etc. Simultaneously, a large number of carbonized plant seeds, human remains, and faunal material was excavated.

To date, more than two hundred Neolithic-Bronze Age sites have been found in the Hexi Corridor [48]. From archaeological data and radiocarbon dating at these sites, the regional Neolithic to Bronze Age chronological framework has been established [28,49–53]. The Neolithic of the Hexi Corridor is related to three Majiayao cultures: the Majiayao (4800–4450 BP), Banshan (4450–4250 BP), and Machang (4200–4000 BP). Bronze Age cultures include the Qijia (4000–3600 BP), Xichengyi (4000–3600 BP), Siba (3700–3300 BP), Dongjiatai (3200–3000), Shajing (2900–2100 BP), and Shanma (2700–2100 BP).

3. Materials and Methods

From the excavation of eleven 11 m × 10 m trenches, 122 soil samples with a volume of 970 L were collected from the fourth to eighteenth cultural layers, thirteen ash pits (H1–H13), and one house site (F1). All samples were floated with manual bucket flotation, and in order to collect the light fraction and carbonized plant remains a sieve with #80 mesh (aperture size of 0.2 mm) was used [54]. After drying, all seeds were sorted and identified under a 40× stereo microscope. The preliminary identification of carbonized plant remains was carried out in the Laboratory of Agricultural Archaeology Research Center, Nanjing Agricultural University, and further refined at the Paleoethnobotany Laboratory, Institute of Archaeology, Chinese Academy of Social Sciences.

Nine samples, including seven carbonized wheat seed and two foxtail millet seed samples, were selected for radiocarbon dating by accelerator mass spectrometry (AMS). All samples were prepared with the standard pretreatment (acid-alkali-acid) at the MOE Key Laboratory of Western China's Environmental Systems at the Lanzhou University, and then measured by accelerator mass spectrometry (AMS) at Peking University. The IntCal20 curve [55] and the Libby half-life of 5568 years were used to calculate all dates, with calibration performed using the OxCal 4.4 program (https://c14.arch.ox.ac.uk/oxcal.html, accessed on 20 November 2021). All ages reported are relative to AD 1950 (referred to as "cal a BP").

4. Results

4.1. Radiocarbon Dating

Nine calibrated ^{14}C ages from wheat and foxtail millet collected from the Haizang site are listed in Table 1. All nine calibrated ^{14}C ages are within the range of 3899–3601cal a BP and belong to the Qijia culture period.

Table 1. Calibrated ^{14}C data from Haizang site in the Hexi Corridor, Northwest China.

Laboratory no.	Methods	Material	^{14}C Date (BP)	Calibrated Age (cal yr BP)	
				1σ Range	2σ Range
LZU19372	AMS	Wheat	3390 ± 20	3692–3580	3601–3663
LZU19369	AMS	Wheat	3410 ± 20	3703–3591	3630–3692
LZU19371	AMS	Wheat	3430 ± 20	3818–3614	3632–3714
LZU19375	AMS	Wheat	3440 ± 20	3823–3636	3639–3739
LZU19374	AMS	Wheat	3450 ± 20	3825–3640	3651–3759
LZU19377A	AMS	Wheat	3430 ± 20	3818–3614	3632–3714
LZU19370	AMS	Wheat	3480 ± 20	3831–3694	3716–3804
LZU19368	AMS	Foxtail millet	3420 ± 20	3810–3608	3632–3700
LZU19373	AMS	Foxtail millet	3570 ± 20	3959–3830	3839–3899

4.2. Flotation

A total of 4482 carbonized plant remains were identified from all 122 soil samples at the Haizang site (Figure 2 and Table S1). Of these seeds, four types of crop species were identified: 2901 foxtail millet (*Setaria italica*) (Figure 2a and Table S1), 662 broomcorn millet (*Panicum miliaceum*) (Figure 2b and Table S1), 632 wheat (*Triticum aestivum*) (Figure 2c and Table S1), and 36 barley (*Hordeum vulgare* L.) (Figure 2d and Table S1), accounting for 64.73%, 14.77%, 14.10%, and 0.80% of all charred plant seeds, respectively. The ubiquities of charred seeds in the 122 floated samples were 91.80% for foxtail millet, 82.79% for broomcorn millet, 38.52% for barley, and 15.57% for wheat. Twenty types of weed seeds were found (223), cumulatively accounting for 4.97% of all carbonized seeds. These included Green Bristlegrass (*Setaria viridis* (L.) Beauv.) (Figure 2e), Foxtail-Like Sophora (*Sophora alopecuroides* L.), Lambsquarters (*Chenpodium album* L.) (Figure 2f), Erect Milkvetch (*Astragalus adsurgens* Pall.) (Figure 2j), Daghestan Sweetclover (*Melilotus suaveolens* Ledeb.) (Figure 2k), Lespedeza (*Lespedeza bicolor* Turcz.) (Figure 2l), White Thorn (*Nitraria tangutorum* Bobr.) (Figure 2p), *Carex* spp., etc.; among them, the seeds of Lespedeza dominated the weed seed assemblage (38.89%). The absolute counts of all carbonized seeds from all samples are listed in Table S1, with images presented in Figure 2.

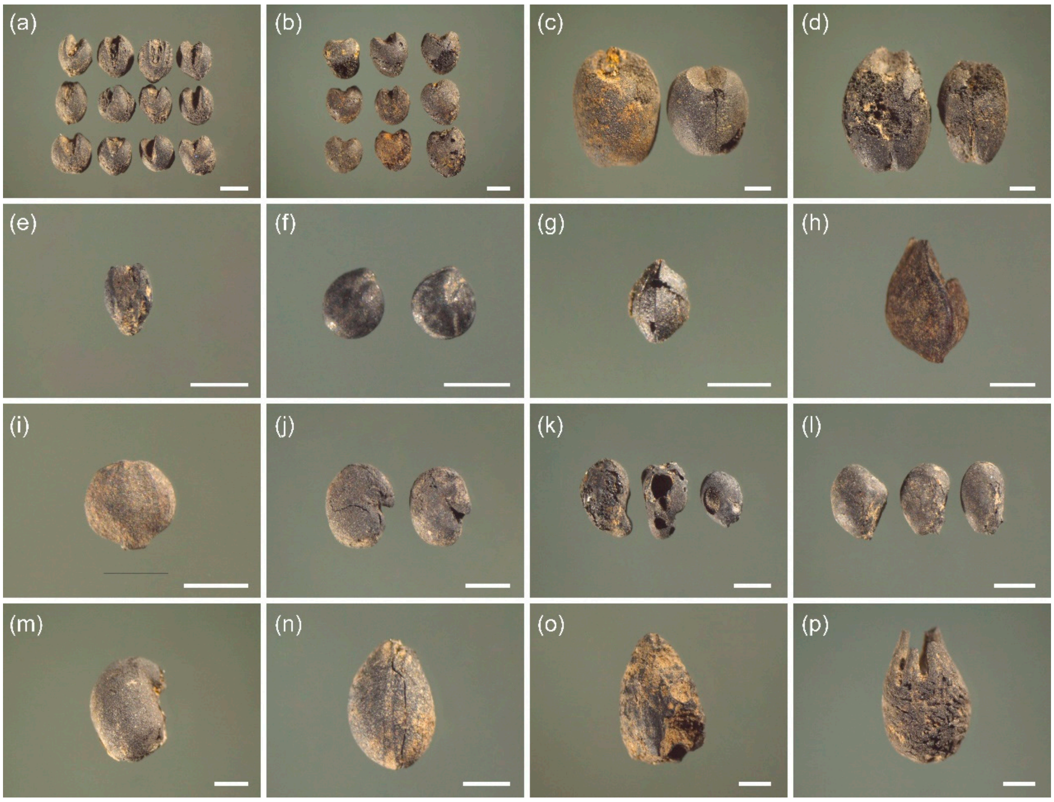

Figure 2. Carbonized plant seeds unearthed from Haizang site in the Hexi Corridor. (**a**) Foxtail millet (*Setaria italica*); (**b**) Broomcorn millet (*Panicum miliaceum*); (**c**) Wheat (*Triticum aestivum*); (**d**) Barley (*Hordeum vulgare* L.); (**e**) Bristlegrass (*Setaria viridis* (L.) Beauv.); (**f**) Lambsquarters (*Chenpodium album* L.); (**g**) Garden Sorrel (*Rumex acetosa* L.); (**h**) Common Knotweed (*Polygonum aviculare* L.); (**i**) Sedge (*Carex* L.); (**j**) Erect Milkvetch (*Astragalus adsurgens* Pall.); (**k**) Daghestan Sweetclover (*Melilotus suaveolens* Ledeb.); (**l**) Lespedeza (*Lespedeza bicolor* Turcz.); (**m**) Foxtail-Like Sophora (*Sophora alopecuroides* L.); (**n**) Sea-Buckthorn (*Hippophae rhamnoides* Linn.); (**o**) Siberian Cockbur (*Xanthium sibiricum* Patrin.); and (**p**) White Thorn (*Nitraria tangutorum* Bobr.); (All scale bar = 1 mm).

5. Discussion

5.1. Agricultural Economic Transformations in the Hexi Corridor around 4000 BP

Through comparisons with previously published carbonized plant seed assemblages, accurate radiocarbon dating, and our new data, we can document agricultural transformations in the ancient Hexi Corridor. Three prehistoric cultures existed in the Hexi Corridor around 4000 BP: the Machang (4300–4000), Xichengyi (4000–3600 BP), and Qijia (4000–3600 BP) [51]. Previous archaeological studies argue that the Machang and Qijia cultures migrated from the east, while the Xicheng culture was the continuation of the earlier Machang [49,56].

The Machang culture (4300–4000 BP) is considered the last Neolithic culture in the ancient Hexi Corridor. Based on the archaeobotanical results of all Machang (4300–4000 BP) cultural sites, the agricultural economy was predominately reliant on millets. Numbers of carbonized millet from Machang sites are recorded as 484 at Duojialiang, 592 at Shuikou, 552 at Xitai, five at Guandi, 2993 at Xinzhai, 2556 at Xihetan, 381 at Mozuizi, 57 at Maolinshan, 599 at Guojiashan, and 208 at Qipanshan, respectively (Figure 3) [21,53]. Although some carbonized wheat seeds were found in Machang archaeological contexts, radiocarbon dating on these seeds indicate these are very likely mixed from later stratum, because the chronologies were 3316–3073 cal a BP, 3697–3485 cal a BP, and 3632–2953 cal a BP, belonging to Mozuizi, Maolinshan, and Guojiashan sites, respectively [18,21,28]. Supporting the reliance on millet, in human and pig remains dating to the Machang period, dietary isotopic evidence (δ^{13}C values) indicates strong C4 (millet) signals [23,28]. This demonstrates that the Machang agricultural economy in the Hexi Corridor was a dry-land farming system dominated by millet cultivation, with little to no cultivation of wheat and barley.

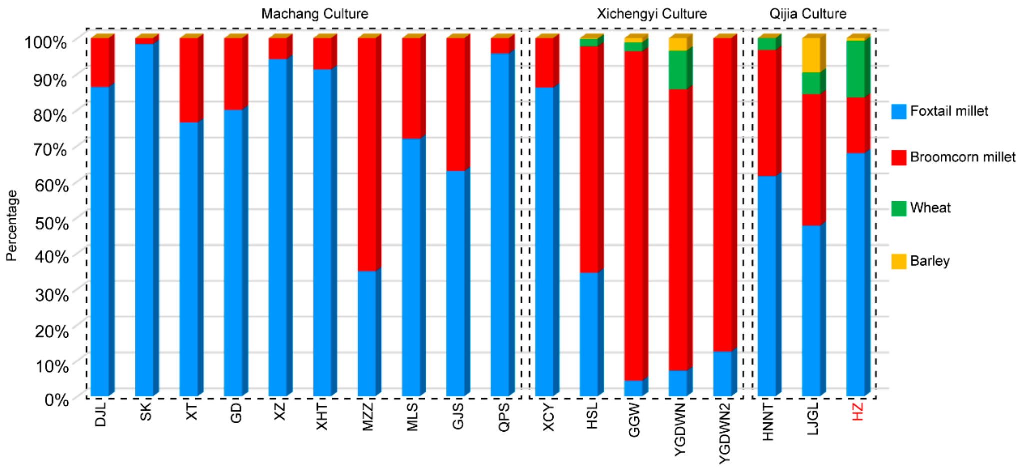

Figure 3. Percentage of charred crop seeds unearthed from Machang culture, Xichengyi culture and Qijia culture sites in the Hexi Corridor. DJL, SK, XT, GD, XZ, XHT, MZZ, MLS, GJS, QPS, XCY, HSL, GGW, YGDWN, YGDWN2, HNNT, LJGL, and HZ represents Duojialiang, Shuikou, Xitai, Guandi, Xinzhai, Xihetan, Mozuizi, Maolinshan, Guojiashan, Qipanshan, Xichengyi, Huoshiliang, Ganggangwa, Yigediwonan, Yigediwonan2, Huangniangniangtai, Lijiageleng, and Haizang.

The Xichengyi culture (4000–3600 BP) represents the continuation of the Machang culture, with some notable differences in the Hexi Corridor. Supplementing millet cultivation, wheat occasionally appears during the Xichengyi period. There are abundant carbonized millet seeds identified at all Xichengyi archaeological sites: 6664 millets representing 100% of crop seeds at Xichengyi, 1211 representing 97.66% at Huoshiliang, 154 representing 96.25% at Ganggangwa1, 24 representing 88.89% at Yigediwanan, 24 representing 100% at Yigediwonan2, 137 representing 93.19% at Ganggangwa, and 14,821 representing 99.32% at Huoshiliang, respectively (Figure 3) [21,53,57]. Diverging from an exclusive focus on millets, sporadic wheat was found at the Huoshiliang, Ganggangwa, and Yigediwonan sites (no wheat was found in the Xichengyi contexts at the Xichengyi site and Yigediwonan2 site) [21,53,57]. These wheat seeds represent less than 3% of archaeobotanical assemblages (three wheat at Huoshiliang, two wheat at Ganggangwa, and one barley at Yigediwonan) [21,53,57]. This may represent the minor economic importance of the newly introduced cereal crops during the Xichengyi period in the Hexi Corridor. Dietary isotopic analysis from the Huoshiliang and Ganggangwa sites also supports the heavy dependence on millet cultivation during the Xichengyi culture [58].

The Qijia culture (4000–3600 BP) originated from the middle and eastern Gansu-Qinghai region, and it spread westward to the eastern Hexi Corridor around 4000 BP [49,51,59–61]. Based on comprehensive sampling at Haizang, our analysis indicates millet-based agriculture remained predominant in the Hexi Corridor during the Qijia period around 3899–3601 cal a BP (Tables 1 and S1; Figures 2 and 3). At the Haizang site, 2901 carbonized foxtail millet seeds and 661 carbonized broomcorn millet seeds were identified from 122 soil samples (Table S1 and Figure 2), comprising 79.47% of all total carbonized plant seeds (Figure 3). This corroborates the previous sampling: the 329 carbonized foxtail millet seeds and 188 carbonized broomcorn millet seeds from the Huangniangniangtai site (90.07% of total carbonized seeds) (Figure 3) [21], and 1435 carbonized foxtail millet seeds and 1103 carbonized broomcorn millet seeds from the Lijiageleng site (83.55% of total carbonized seeds) [53]. Simultaneously, wheat and barley cultivation became less sporadic, and it supplemented Qijia agricultural activities in the Hexi corridor [18,21,22].

At Haizang, from 122 soil samples we document increasing numbers of wheat and barley: 632 carbonized wheat seeds representing 14.33% of the assemblage, and 36 carbonized barley seeds representing 0.82% of the assemblage (Figure 3). This result confirms previous sporadic sampling: 181 carbonized wheat grains (5.96%) and 291 carbonized barley grains (9.58%) found in the Lijiageleng site [28,53], and the 18 carbonized wheat seeds recovered from the Huangniangniangtai site [21]. Animal stable isotopic evidence at Lijiageleng also suggests increasing proportions of C3 plants (probably wheat, barley, and C3 grass) likely came from wheat [28]. Our analysis, in conjunction with prior studies, concludes that the agricultural economies of the Hexi corridor were dominated by millets, increasingly supplemented by wheat and barley during the Qijia period.

The agricultural economies of the Hexi Corridor shifted significantly around 4000 BP, transitioning from the near exclusive cultivation of millets, to one based on the supplementary use of wheat and barley.

5.2. Influencing Factors on the Agricultural Economic Transformations in the Hexi Corridor around 4000 BP

Climate change is often argued as a key driving force of prehistoric agriculture and civilization [31,38,62,63]. Scholars argue that favorable climates promote agricultural activity and experimentation, increasing economic and dietary breadth, leading to flourishing cultures [40,64,65]. Conversely climatic deterioration has been often argued to result in cultural collapse and diminished prehistoric agricultural activity [21,30,31,34,66–68].

Many paleoclimate studies indicate a warm and wet climate in the Hexi Corridor during the Machang period (4300–4000 BP) [69–71]. The favorable climate likely supported the Machang culture's growth in the Hexi Corridor, with settlements expanding significantly during this period. During 4300–4000 BP, Machang groups occupied almost the entirety of the Hexi Corridor, encompassing the alluvial areas and river terraces of the Qilian Mountain piedmont plain [48,53]. These areas were ideally suited for rain-fed millet agriculture. The presence of high proportions of carbonized millet seeds and low proportions of carbonized weed seeds implies that human populations, technology, and knowledge had grown and strengthened between 4300–4000 BP [21,53]. Benefited by the warm and wet climate, the Machang culture expanded from east of Hexi Corridor to the west, simultaneously spreading millet-based agriculture. This agricultural system supported a growth in population during the Machang period.

The warm and wet climate did not last. During the "4.2 ka cold event", the climate in northern China tended toward dry and cold, and the climate deteriorated in the Hexi Corridor [69,71–73]. Due to millet's low frost tolerance, during this time of climate deterioration, millet production likely was seriously affected [74–77]. A frost-tolerant wheat crop was introduced into the Hexi Corridor at this time [18]. The introduction of Eurasian large cereal crops such as wheat and barley likely made up for any impacts on millet agriculture from an increasingly poor climate. In the Hexi Corridor by 4000 BP, wheat and barley effectively supplemented the millet-dominated agricultural economy at Haizang and other Qijia sites. An indications of the climatic impacts is the migration of peoples from the high-altitude piedmont alluvial plains to the low-altitude corridor plains and river platforms after 4000 BP [48,53]. The difficulties from colder and drier climate conditions led people to choose areas with lower altitude and higher temperatures.

Xichengyi culture is a "transitional" Neolithic to Bronze culture in the Hexi Corridor [51,53,78]. In the early stages of the Xichengyi, the scope of activities of Xichengyi were much the same as that of Machang, reaching to the western border of Hexi Corridor (Figure 1). Influenced by the "4.2 ka BP cold event", Xichengyi settlements gradually withdrew to the east of the Hexi corridor, at the junction of Xichengyi and Qijia. With the pressure of climatic deterioration, the Qijia peoples shifted to the Xichengyi practice of wheat and barley planting to supplement millet agriculture. This is supported by the earlier planting of Eurasian large cereals by the Xichengyi. All direct radiocarbon dates from carbonized wheat seeds unearthed from Xichengyi sites predate those of the Qijia in the Hexi Corridor (Tables 1 and S1) [21,28]. Direct radiocarbon dating on carbonized wheat seeds unearthed from Ganggangwa and Huoshiliang sites, belonging to the Xichengyi culture, are 4085–3843 cal a BP and 3979–3702 cal a BP, respectively, which were earlier than 4076–3695 and 3804–3601 cal a BP from the Huangniangniangtai site and Haizang site belonging to the Qijia culture (Tables 1 and S1) [18,21,28]. Therefore, Xichengyi people may be the first people in the Hexi Corridor to adapt to the cold and dry climate by planting wheat and barley crops, and then they spread them to the Qijia people. This earlier adoption of frost-tolerant wheat and barley by the Xichengyi is likely due to their earlier access provided by the areas of the Hexi Corridor they inhabited (Figure 1).

From our findings, we find that during climatic pressures around 4000 BP, these two groups of people supplemented endangered millet agriculture with newly introduced wheat and barley. In addition to this adaptive strategy, Xichengyi and Qijia peoples migrated to areas more suitable for rainfed millet agriculture: the alluvium and river terraces of the piedmont plain of the Qilian Mountains.

6. Conclusions

The warm and wet climate promoted the expansion of the Machang Culture with millet-based agriculture, yet this was not sustainable in times of harsher climatic conditions. At the Haizang site, Qijia peoples relied on millet dominated agriculture, yet in-creased their use of wheat crops from 3899–3601 cal a BP. This agricultural mode, while still relying on millet, represents a key diversification in agricultural strategies from the purely millet-based practices of the earlier Machang period.

The economic transformations of agricultural production likely occured in response to climatic degeneration caused by global cooling from the "Holocene Event 3" around 4000 BP. Xichengyi sites shifted slightly earlier than Qijia people, likely due to receiving wheat crops earlier. At Haizang and other Qijia sites around 4000 BP, people likely increased their use of wheat and barley beyond that of the Xichengyi to mitigate risk and support a diversified agricultural economic system.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/land12020425/s1.

Author Contributions: Conceptualization, H.L. and X.J.; methodology, H.L., S.Z., L.D. and Y.Y.; formal analysis, H.L., N.J., J.C. and X.J.; investigation, H.L., J.C., S.Z., L.D., G.C., Y.Y., M.M. and X.J.; writing—original draft preparation, H.L., N.J., J.C., G.C. and X.J.; writing—review and editing, H.L., N.J., S.Z., L.D., Y.Y., M.M. and X.J. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the National Natural Science Foundation of China (Grant No. 42101152), the National Social Science Foundation of China (Grant No. 21CKG011), the Natural Science Foundation of Jiangsu Province, China (Grant No. BK20221027), the Open Foundation of MOE Key Laboratory of Western China's Environmental System, Lanzhou University and the Fundamental Research Funds for the Central Universities (Grant No. lzujbky-2021-kb01), the Fundamental Research Funds for the Central Universities of China (Grant Nos. SKYC2021011 and KYQN2022026) and the Open Fund Project of the State Key Laboratory of Loess and Quaternary Geology (Grant No. SKLLQG2015).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: We thank Jingang Yang from the Paleoethnobotany Laboratory, Institute of Archaeology, Chinese Academy of Social Sciences, for identifying carbonized plant seeds.

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

References

1. Diamond, J.; Bellwood, P. Farmers and their languages: The first expansions. *Science* **2003**, *300*, 597–603. [CrossRef] [PubMed]
2. Hunt, H.V.; Linden, M.V.; Liu, X.; Motuzaite-Matuzeviciute, G.; Colledge, S.; Jones, M.K. Millets across Eurasia: Chronology and context of early records of the genera Panicum and Setaria from archaeological sites in the Old World. *Veg. Hist. Archaeobotany* **2008**, *17*, S5–S18. [CrossRef] [PubMed]
3. Jones, M.K.; Liu, X.Y. Origins of agriculture in East Asia. *Science* **2009**, *324*, 730–731. [CrossRef] [PubMed]
4. Spengler, R.; Frachetti, M.; Doumani, P.; Rouse, L.; Cerasetti, B.; Bullion, E.; Mar'Yashev, A. Early agriculture and crop transmission among Bronze Age mobile pastoralists of Central Eurasia. *Proc. Biol. Sci.* **2014**, *281*, 20133382. [CrossRef]
5. Liu, X.; Lister, D.L.; Zhao, Z.; Staff, R.A.; Jones, P.J.; Zhou, L.; Pokharia, A.K.; Petrie, C.A.; Pathak, A.; Lu, H.; et al. The virtues of small grain size: Potential pathways to a distinguishing feature of Asian wheats. *Quat. Int.* **2016**, *426*, 107–119. [CrossRef]
6. Liu, X.; Lister, D.L.; Zhao, Z.J.; Petrie, C.A.; Zeng, X.; 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]
7. Liu, X.; Jones, P.J.; Matuzeviciute, G.M.; Hunt, H.V.; Lister, D.L.; An, T.; Przelomska, N.; Kneale, C.J.; Zhao, Z.; Jones, M.K. From ecological opportunism to multi-cropping: Mapping food globalisation in prehistory. *Quat. Sci. Rev.* **2019**, *206*, 21–28. [CrossRef]
8. Stevens, C.J.; Murphy, C.; Roberts, R.; Lucas, L.; Silva, F.; Fuller, D.Q. Between China and South Asia: A middle Asian corridor of crop dispersal and agricultural innovation in the Bronze Age. *Holocene* **2016**, *26*, 1541–1555. [CrossRef]
9. Dong, G.H.; Yang, Y.S.; Liu, X.Y.; Li, H.M.; Cui, Y.F.; Wang, H.; Chen, G.K.; Dodson, J.; Chen, F.H. Prehistoric trans-continental cultural exchange in the Hexi Corridor, northwest China. *Holocene* **2017**, *28*, 621–628. [CrossRef]
10. 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]
11. Li, H.; Sun, Y.; Yang, Y.; Cui, F.; Ren, L.; Li, H.; Chen, G.K.; Petrs, V.; Dong, G.; Liu, X. Water and soil management strategies and the introduction of wheat and barley to northern China: An isotopic analysis of cultivation on the Loess Plateau. *Antiquity* **2022**, *96*, 1478–1494. [CrossRef]
12. Liu, X.Y.; Jones, M.K. Food globalisation in prehistory: Top down or bottom up? *Antiquity* **2014**, *88*, 956–963. [CrossRef]
13. Jones, M.K.; Hunt, H.; Lightfoot, E.; Lister, D.; Liu, X.; Motuzaite-Matuzeviciute, G. Food globalization in prehistory. *World Archaeol.* **2011**, *43*, 665–675. [CrossRef]
14. Jones, M.; Hunt, H.; Kneale, C.; Lightfoot, E.; Lister, D.; Liu, X.; Motuzaite-Matuzeviciute, G. Food globalization in prehistory: The agrarian foundation of an interconnected continent. *J. Br. Acad.* **2016**, *4*, 73–87. [CrossRef]
15. Frachetti, M.D.; Spengler, R.N.; Fritz, G.J.; Mar'Yashev, A.N. Earliest direct evidence for broomcorn millet and wheat in the central Eurasian steppe region. *Antiquity* **2010**, *84*, 993–1010. [CrossRef]
16. Doumani, P.N.; Frachetti, M.D.; Beardmore, R.; Tekla, M.S.; Robert, N.S.; Alexei, N.M. Burial ritual, agriculture, and craft production among Bronze Age pastoralists at Tasbas (Kazakhstan). *Archaeol. Res. Asia* **2015**, *1–2*, 17–32. [CrossRef]
17. Flad, R.; Li, S.C.; Wu, X.H.; Zhao, Z.J. Early wheat in China: Results from new studies at Donghuishan in the Hexi Corridor. *Holocene* **2010**, *20*, 955–965. [CrossRef]
18. Dodson, J.R.; Li, X.Q.; Zhou, X.Y.; Zhao, K.L.; Sun, N.; Atahan, P. Origin and spread of wheat in China. *Quat. Sci. Rev.* **2013**, *72*, 108–111. [CrossRef]
19. Jia, X.; Dong, G.H.; Li, H.; Brunson, K.; Chen, F.H.; Ma, M.M.; Wang, H.; An, C.B.; Zhang, K.R. The development of agriculture and its impact on cultural expansion during the late Neolithic in the Western Loess Plateau, China. *Holocene* **2013**, *23*, 85–92. [CrossRef]
20. Chen, F.H.; Dong, G.H.; Zhang, D.J.; Liu, X.Y.; Jia, X.; An, C.B.; Ma, M.M.; Xie, Y.W.; Barton, L.; Ren, X.Y.; et al. Agriculture facilitated permanent human occupation of the Tibetan Plateau after 3600 B.P. *Science* **2015**, *347*, 248–250. [CrossRef]
21. Zhou, X.Y.; Li, X.Q.; Dodson, J.; Zhao, K.L. Rapid agricultural transformation in the prehistoric Hexi corridor, China. *Quat. Int.* **2016**, *426*, 33–41. [CrossRef]
22. Li, H.M.; Dong, G.H. The adoption of wheat and barley as major staples in northwest China during the early Bronze Age. In: Far from the Hearth Essays in Honour of Martin Jones. *Camb. Univ. Camb.* **2018**, *16*, 189–198. [CrossRef]
23. Liu, X.Y.; Lightfoot, E.; O'Connell, T.C.; Wang, H.; Li, S.C.; Zhou, L.P.; Hu, Y.W.; Motuzaite-Matuzeviciute, G.; Jones, M.K. From necessity to choice: Dietary revolutions in west China in the second millennium BC. *World Archaeol.* **2014**, *46*, 661–680. [CrossRef]
24. Ma, M.M.; Dong, G.H.; Jia, X.; Wang, H.; Cui, Y.F.; Chen, F.H. Dietary shift after 3600 cal yr BP and its influencing factors in northwestern China: Evidence from stable isotopes. *Quat. Sci. Rev.* **2016**, *145*, 57–70. [CrossRef]
25. Frankopan, P. *The Silk Roads: A New History of the World*; Bloomsbury Publishing: London, UK, 2015.
26. Long, T.; Wagner, M.; Demske, D.; Leipe, C.; Tarasov, P.E. Cannabis in Eurasia: Origin of human use and Bronze Age trans-continental connections. *Veg. Hist. Archaeobotany* **2016**, *26*, 245–258. [CrossRef]
27. Barisitz, S. *Central Asia and the Silk Road: Economic Rise and Decline over Several Millennia*; Springer International Publishing: Berlin/Heidelberg, Germany, 2017.
28. Yang, Y.; Ren, L.; Dong, G.H.; Cui, Y.; Liu, R.; Chen, G.; Wang, H.; Wilkin, S.; Chen, F. Economic change in the prehistoric Hexi corridor (4800–2200 bp), north-west China. *Archaeometry* **2019**, *61*, 957–976. [CrossRef]

29. Wick, L.; Lemcke, G.; Sturm, M. Evidence of Lateglacial and Holocene climatic change and human impact in eastern Anatolia: High-resolution pollen, charcoal, isotopic and geochemical records from the laminated sediments of Lake Van, Turkey. *Holocene* **2003**, *13*, 665–675. [CrossRef]
30. An, C.B.; Feng, Z.; Tang, L. Environmental change and cultural response between 8000 and 4000 cal. yr BP in the western Loess Plateau, northwest China. *J. Quat. Sci.* **2004**, *19*, 529–535. [CrossRef]
31. An, C.B.; Tang, L.; Barton, L.; Chen, F.H. Climate change and cultural response around 4000 cal yr BP in the western part of Chinese Loess Plateau. *Quat. Res.* **2005**, *63*, 347–352. [CrossRef]
32. Marchant, R.; Hooghiemstra, H. Rapid environmental change in African and South American tropics around 4000 years before present: A review. *Earth-Sci. Rev.* **2004**, *66*, 217–260. [CrossRef]
33. Neff, H.; Pearsall, D.M.; Jones, J.G.; Bárbara, A.P.; Dorothy, E.F. Climate change and population history in the Pacific lowlands of southern Mesoamerica. *Quat. Res.* **2006**, *65*, 390–400. [CrossRef]
34. Sun, Q.; Liu, Y.; Wünnemann, B.; Peng, Y.; Jiang, X.; Deng, L.; Chen, J.; Li, M.; Chen, Z. Climate as a factor for Neolithic cultural collapses approximately 4000 years BP in China. *Earth-Sci. Rev.* **2019**, *197*, 102915. [CrossRef]
35. Weiss, H.; Courty, M.A.; Wetterstrom, W.; Guichard, F.; Senior, L.; Meadow, R.; Curnow, A. The genesis and collapse of third millennium north Mesopotamian civilization. *Science* **1993**, *261*, 995–1004. [CrossRef]
36. Kerr, R.A. Archaeology: Sea-floor dust shows drought felled Akkadian Empire. *Science* **1998**, *279*, 325–326. [CrossRef]
37. Cullen, H.M.; Hemming, S.; Hemming, G.; Brown, F.H.; Guilderson, T.; Sirocko, F. Climate change and the collapse of the Akkadian empire: Evidence from the deep sea. *Geology* **2000**, *28*, 379–382. [CrossRef]
38. Staubwasser, M.; Sirocko, F.; Grootes, P.M.; Segl, M. Climate change at the 4.2 ka BP termination of the Indus valley civilization and Holocene south Asian monsoon variability. *Geophys. Res. Lett.* **2003**, *30*, 1425. [CrossRef]
39. Wu, W.X.; Liu, D.X. 4000aB.P. event and its implication for the origin of Ancient Chinese civilization. *Quat. Sci.* **2001**, *21*, 443–451. (In Chinese)
40. Jia, X.; Yi, S.; Sun, Y.; Wu, S.; Harry, H.L.; Wang, L.; Lu, H. Spatial and temporal variations in prehistoric human settlement and their influencing factors on the south bank of the Xar Moron River, Northeastern China. *Front. Earth Sci.* **2017**, *11*, 137–147. [CrossRef]
41. Li, H.; Liu, Z.; James, N.; Li, X.; Hu, Z.; Shi, H.; Sun, L.; Lu, Y.; Jia, X. Agricultural Transformations and Their Influential FactorsRevealed by Archaeobotanical Evidence in Holocene Jiangsu Province, Eastern China. *Front. Earth Sci.* **2021**, *9*, 661684. [CrossRef]
42. He, K.; Lu, H.; Jin, G.; Wang, C.; Zhang, H.; Zhang, J.; Xu, D.; Shen, C.; Wu, N.; Guo, Z. Antipodal pattern of millet and rice demography in response to 4.2 ka climate event in China. *Quat. Sci. Rev.* **2022**, *295*, 107786. [CrossRef]
43. Yao, T.D.; Thompson, L.G. Dundee ice core records with temperature changes over the past 5 ka. *Sci. Sin. Terrae* **1992**, *10*, 1089–1093. (In Chinese)
44. Shen, J.; Liu, X.Q.; Matsumoto, R.; Wang, S.; Yang, X. A high-resolution climatic change since the Late Glacial Age inferred from multi-proxy of sediments in Qinghai Lake. *Sci. China Earth Sci.* **2005**, *48*, 742–751. [CrossRef]
45. Zou, S.B.; Cheng, G.D.; Xiao, H.L.; Xu, B.R.; Feng, Z.D. Holocene natural rhythms of vegetation and present potential ecology in the Western Chinese Loess Plateau. *Quat. Int.* **2009**, *194*, 55–67. [CrossRef]
46. Liu, F.; Feng, Z.D. A dramatic climatic transition at ~4000 cal. yr BP and its cultural responses in Chinese cultural domains. *Holocene* **2012**, *22*, 1181–1197. [CrossRef]
47. Chan, D.; Wu, Q.; Jiang, G.; Dai, X. Projected shifts in Köppen climate zones over China and their temporal evolution in CMIP5 multi-model simulations. *Adv. Atmos. Sci.* **2016**, *33*, 283–293. [CrossRef]
48. Bureau of National Cultural Relics. *Atlas of Chinese Cultural Relics-Gansu Province Volume*; Surveying and Mapping Press: Jacksonville, FL, USA, 2011. (In Chinese)
49. Li, S.C. *Prehistoric Culture Evolution in Northwest China*; Cultural Relics Press: Beijing, China, 2009; pp. 200–293. (In Chinese)
50. Li, S.C.; Shui, T.; Wang, H. Report on Prehistoric Archaeological Survey in Hexi Corridor. *Acta Archaeol. Sin.* **2010**, *2*, 229–262. (In Chinese)
51. Wang, H. *The Genealogy and Pattern of Neolithic-Bronze Age Archaeological Cultures in the Ganqing Region*; Archaeological Studies(nine); Cultural Relics Press: Beijing, China, 2012. (In Chinese)
52. Chen, G.K. Metallurgical community of Xichengyi-Qijia culture: Early metal-masking specialists in the Hexi Corridor and related issues. *Archaeol. Cult. Relics* **2017**, *5*, 37–44. (In Chinese)
53. Yang, Y.S. Study on the Transformation of Prehistoric Livelihood Patterns and the Factors Influence in the Hexi Corridor. Doctoral Dissertation, Fudan University, Lanzhou, China, 2017. (In Chinese).
54. Zhao, Z.J. *Poleoethnobotany: Theories, Methods and Practice*; Science Press: Beijing, China, 2010. (In Chinese)
55. Reimer, P.J.; Austin, W.E.N.; Bard, E.; Bayliss, A.; Blackwell, P.; Ramsey, C.; Butzin, M.; Cheng, H.; Edwards, R.; Friedrich, M.; et al. The IntCal20 Northern Hemisphere radiocarbon age calibration curve (0–55 cal kBP). *Radiocarbon* **2022**, *62*, 725–757. [CrossRef]
56. Zhao, H.C.; Wang, H. *Early The Silk Road and Early Qin Culture International Symposium Proceedings*; Cultural Relics Press: Beijing, China, 2014. (In Chinese)
57. Fan, X.J. Analysis of Carbonized Botanic Remains in Xichengyi Site. Master's Dissertation, Shandong University, Jinan, China, 2016. (In Chinese)

58. Atahan, P.; Dodson, J.; Li, X.; Zhou, X.; Hu, S.; Fiona, B.; Sun, N. Subsistence and the isotopic signature of herding in the Bronze Age Hexi Corridor, NW Gansu, China. *J. Archaeol. Sci.* **2011**, *38*, 1747–1753. [CrossRef]
59. Li, S.C. *East by West: The Process of Prehistoric Culture in Northwest China*; Cultural Relics Press: Beijing, China, 2009. (In Chinese)
60. Han, J.Y. *Early China: The Marking Of The Chinese Cultural Sphere*; Shanghai Classics Publishing House: ShangHai, China, 2015. (In Chinese)
61. Han, J.Y. The Evolution of QiJia Culture: Cultural Interaction and Eurasian Context. *Cult. Relics* **2019**, *7*, 60–65. (In Chinese)
62. Dalfes, H.N.; Kukla, G.; Weiss, H. Third millennium BC Climate Change and Old World Collapse. *Springer Sci. Bus. Media* **1997**, *49*, 1–14. [CrossRef]
63. Bawden, G.; Reycraft, R.M. Environmental disaster and the archaeology of human response. *Am. J. Archaeol.* **2002**, *106*, 475–476. [CrossRef]
64. Xu, D.; Lu, H.; Chu, G.; Liu, L.; Shen, C.; Li, F.; Wang, C.; Wu, N. Synchronous 500-year oscillations of monsoon climate and human activity in Northeast Asia. *Nat. Commun.* **2019**, *10*, 4105. [CrossRef]
65. Yamaura, Y.; Narita, A.; Kusumoto, Y.; Nagano, A.J.; Tezuka, A.; Okamoto, T.; Takahara, H.; Nakamura, F.; Isagi, Y.; Lindenmayer, D. Genomic reconstruction of 100 000-year grassland history in a forested country: Population dynamics of specialist forbs. *Biol. Lett.* **2019**, *15*, 20180577. [CrossRef]
66. Polyak, V.J.; Asmerom, Y. Late Holocene climate and cultural changes in the southwestern United States. *Science* **2001**, *294*, 148–151. [CrossRef]
67. Haug, G.H.; Gunther, D.; Peterson, L.C.; Sigman, D.M.; Hughen, K.A.; Aeschlimann, B. Climate and the collapse of Maya civilization. *Science* **2003**, *299*, 1731–1735. [CrossRef]
68. Jia, X.; Sun, Y.G.; Wang, L.; Sun, W.F.; Zhao, Z.J.; Lee, H.F.; Huang, W.B.; Wu, S.Y.; Lu, H.Y. The transition of human subsistence strategies in relation to climate change during the Bronze Age in the West Liao River Basin, Northeast China. *Holocene* **2016**, *26*, 781–789. [CrossRef]
69. Herzschuh, U.; Tarasov, P.; Wünnemann, B.; Heatmann, K. Holocene vegetation and climate of the Alashan Plateau, NW China, reconstructed from pollen data. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* **2004**, *211*, 1–17. [CrossRef]
70. Marcott, S.A.; Shakun, J.D.; Clark, P.U.; Mix, A.C. A reconstruction of regional and global temperature for the past 11,300 years. *Science* **2013**, *339*, 1198–1201. [CrossRef]
71. Wang, D.; Gouhier, T.C.; Menge, B.A.; Ganguly, A.R. Intensification and spatial homogenization of coastal upwelling under climate change. *Nature* **2015**, *518*, 390–394. [CrossRef]
72. Thompson, L.G. Tropical Climate Instability: The Last Glacial Cycle from a Qinghai-Tibetan Ice Core. *Science* **1997**, *276*, 1821–1825. [CrossRef]
73. Ji, S.; Xingqi, L.; Sumin, W.; Matsumoto, R. Palaeoclimatic changes in the Qinghai Lake area during the last 18,000 years. *Quat. Int.* **2005**, *136*, 131–140. [CrossRef]
74. Klepper, B.; Rickman, R.W.; Waldman, S.; Chevalier, P. The physiological life cycle of wheat: Its use in breeding and crop management. *Euphytica* **1998**, *100*, 341–347. [CrossRef]
75. Saseendran, S.A.; Nielsen, D.C.; Lyon, D.J.; Ma, L.; Felter, D.G.; Baltensperger, D.D.; Hoogenboom, G.; Ahuja, L.R. Modeling responses of dryland spring triticale, proso millet and foxtail millet to initial soil water in the High Plains. *Field Crops Res.* **2009**, *113*, 48–63. [CrossRef]
76. Guedes, J.D.; Butler, E.E. Modeling constraints on the spread of agriculture to Southwest China with thermal niche models. *Quat. Int.* **2014**, *349*, 29–41. [CrossRef]
77. D'Alpoim Guedes, J. Rethinking the spread of agriculture to the Tibetan Plateau. *Holocene* **2015**, *25*, 1498–1510. [CrossRef]
78. Han, J.Y. *Natural Environment and Cultural Development in the Pre-Qin Period of Northwest China*; Cultural Relics Press: Beijing, China, 2008. (In Chinese)