frontiers in Earth Science

ORIGINAL RESEARCH
published: 19 May 2021
doi: 10.3389/feart.2021.662053

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Environmental Influences on Human Subsistence Strategies in Southwest China During the Bronze Age: A Case Study at the Jiangxifen Site in Yunnan

*Minxia Lu[1], Xiaorui Li[2], Wenyu Wei[1], Yiwen Lu[1], Lele Ren[3] and Minmin Ma[1]**

[1] Key Laboratory of Western China's Environmental Systems (Ministry of Education), College of Earth and Environmental Sciences, Lanzhou University, Lanzhou, China, [2] Yunnan Provincial Institute of Cultural Relics and Archaeology, Kunming, China, [3] History and Culture School, Lanzhou University, Lanzhou, China

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***Correspondence:**
Minmin Ma
mamm@lzu.edu.cn

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

Received: 31 January 2021
Accepted: 27 April 2021
Published: 19 May 2021

Citation:
Lu M, Li X, Wei W, Lu Y, Ren L and Ma M (2021) Environmental Influences on Human Subsistence Strategies in Southwest China During the Bronze Age: A Case Study at the Jiangxifen Site in Yunnan. Front. Earth Sci. 9:662053. doi: 10.3389/feart.2021.662053

The study of human dietary structures is an effective means of elucidating the subsistence patterns of our prehistoric ancestors and can highlight the processes through which humans interacted with the environment. We conducted stable isotope and archeobotanical analyses of human, animal, and plant remains at the Jiangxifen site, dated to ∼900–400 BC, to explore human paleodiets and determine the environmental adaptation strategies adopted by humans in the middle valley of the Jinshajiang River in Yunnan Province. Humans predominantly consumed C_4 foods (e.g., millet) and C_4 food-fed animal protein sources, with smaller contributions from C_3 food plants (e.g., rice) and C_3 food-fed animal protein sources. We argued that the local dry-hot environment was the reason for the accessibility of C_4 plants in the studied area. A comparison of our results with previously published archeobotanical data and isotopic evidence from human bones in other Bronze Age sites in Yunnan Province revealed high spatial variability in diets of human and subsistence strategies during this period. These differences were caused by the highly varying living environment of each region, which was related to fragmentation resulting from the geomorphological features of Yunnan Province.

Keywords: living environment, Bronze Age, subsistence strategy, human-land relationship, Jinshajiang River Valley

INTRODUCTION

In Eurasia, major changes in subsistence took place during the transition from the Neolithic to the Bronze Age (Dong et al., 2017; Hanks et al., 2018), changes that were profoundly impacted by the emergence and intensification of early trans-Eurasian exchanges (Svyatko et al., 2013; Dong et al., 2020). In East Asia, the transformation of human subsistence strategies was asynchronous during the Bronze Age. Exotic crops (wheat and barley) and livestock (sheep, cattle, etc.) encompassed the dominant forms of human subsistence in northwest China during the second millennium BC (Chen et al., 2015; Zhou et al., 2016; Dong et al., 2021), whereas indigenous millet cultivation dominated in the Central Plains of North China until the late first millennium BC (Li et al., 2020). However, the spatial pattern of means of human livelihood in Yunnan Province in Southwest China, another important region for transcontinental exchange during the Bronze Age (Gao et al., 2020), remains unclear.

Archeobotanical, zooarcheological, and stable isotope analyses are effective methods for studying human subsistence strategies during prehistoric periods (d'Alpoim Guedes et al., 2014; Ma et al., 2016; Ren et al., 2020). Archeobotany and zooarcheology encompass systematic studies aimed at elucidating animal and plant exploitation strategies (Isaakidou and Halstead, 2018). However, the acidic soils in Yunnan Province are unsuitable for macro-fossil preservation, and the animals buried in tombs might not be representative of the prevalent fauna (Yuan, 2015; Hou et al., 2019); this prevents the study of prehistoric subsistence strategies in this area. Stable isotope analysis can be used to reconstruct the diet structure of humans and animals (Kohn, 1999; Richards, 2015), but it only yields C_3/C_4 signals, rather than elucidating specific food types. Therefore, it is necessary to combine a variety of methods to comprehensively reconstruct human subsistence strategies in prehistoric times. Archeobotanical and stable isotope analyses for Bronze Age sites in Yunnan are particularly scarce, with only limited evidence from a small number of sites, such as Dayingzhuang (Dal Martello et al., 2021), Haimenkou (Xue, 2010), Shilinggang (Li et al., 2016; Ren et al., 2017), Jinlianshan–Xueshan (Zhang, 2011; Wang, 2014), and Mayutian (Zhang et al., 2014). Therefore, our current understanding of subsistence during the Bronze Age in this region is limited. Yunnan province is geographically highly diverse and is characterized by the presence of large mountain chains and deeply cut rivers in the eastern margin of the Tibetan Plateau. Deep river valleys which include the valleys of the Lancangjiang, Nujiang, and Jinshajiang Rivers, and large lakes characterize this landscape.

In the present study, we analyzed the stable carbon (C) and nitrogen (N) isotopes of human and animal bones and identified plant remains from the Jiangxifen Bronze Age site, which is located in the Jinshajiang River Valley. We also conducted radiocarbon dating at the site to reconstruct the diets of ancient locals. These results were also compared with previously published data from contemporaneous sites in Yunnan Province to explore the spatial patterning in ancient human diets and their relationship with the local environment. Our study findings contribute to our understanding of past human-land relationships in Southwest China during the Bronze Age before the region was controlled by a unified regime.

STUDY AREA

Yunnan province is located in the low latitude plateau, and it is mainly dominated by the Indian summer monsoon and East Asian summer monsoon (Cao et al., 2012). The temperature in January is about 9–11°C, and in July is about 22°C. The annual mean precipitation is 1,100–1,600 mm (Shi and Chen, 2018). However, the local climate in Yunnan is diverse owing to the presence of many rivers and high mountains. In different valleys, rain shadows can lead to drier and hotter conditions.

The Jiangxifen site (26.18°N and 102.23°E) is located in Jiyi town, Wuding County, Yunnan Province (**Figure 1**). The site is in the Jinshajiang River Valley with dry and mega-thermal climate, the annual average temperature and the $\geq$ 10°C accumulated temperature are 21.5°C and 7,400°C, respectively, and the annual precipitation is $\leq$ 630 mm (Yang, 2006). Shrubs and the Savanna shrubs dominate below 1,700 m in this valley (Jin and Ou, 2000; Zhang et al., 2005), and the coniferous forest is mainly distributed above 1,700 m. The Jinshajiang River flows through the study area from southwest to northeast, and the site is located on the second fluvial terrace at the south bank of the Jinshajiang River with an altitude of 900 m. The terrain of the region is complex and highly fragmented due to geomorphic uplift and erosion (Nie et al., 2008). High mountains flank the east and west sides of the river. Red sandstone is exposed and geological disasters occur frequently. Modern plant vegetation surveys (Cao and Jin, 1989; Ou, 1994; Jin, 1999; Li et al., 2009) have indicated that a large amount of C_4 vegetation is distributed in the dry-hot valley of the Jinshajiang River. Analyses of pollen assemblages (Xiao et al., 2014, 2018, 2020; Zheng et al., 2014) and the stable C isotopes (δ^{13}C) of long-chain *n*-alkanes from sediments (Cui et al., 2015, 2019) indicated the existence of a forest in Yunnan Province during the late Holocene (after 3,300 BP).

In total, 530 tombs were identified during the excavation of the Jiangxifen site in the period from November 2018 to April 2019. The characteristics of the unearthed cultural relics and funeral objects from the site are indicative of the Bronze Age (Yunnan Institute of Cultural Relics and Archaeology, 2019).

MATERIALS AND METHODS

Collagen Preparation and Isotope Analysis

In total, 74 human and 35 animal bone samples were collected from the Jiangxifen site. Of these, 68 human and three animal bone collagen samples were extracted (**Supplementary Table 1**).

Bone collagen was extracted at the Key Laboratory of Western China's Environmental Systems (MOE), Lanzhou University, Gansu Province, China. Based on the method described by Richards and Hedges (1999), we placed 0.5–1.5 g of bones in 0.5 mol/L HCl and 0.125 mol/L NaOH to remove inorganic matter and humic acids, respectively. The bones were then placed in a weakly acidic solution (pH = 3) for acidification and subsequently filtered and freeze-dried to obtain collagen.

The C and N percentages in the five collagen samples were measured using the Elementar Vario EL Cube elemental analyzer (Elementar Analysensysteme GmbH, Germany) at the State Key Laboratory of Applied Organic Chemistry, Lanzhou University. Isotope analysis was conducted using the Thermo Fisher Flash EA1112–MAT253 mass spectrometer (Thermo Fisher Scientific, Germany) at the Key Laboratory of Western China's Environmental Systems (MOE), Lanzhou University. Sixty-six collagen samples were examined using an IsoPrime-100 IRMS mass spectrometer combined with a vario PYRO cube elemental analyzer (Elementar, Germany) at the archaeological stable isotope laboratory, the University of Chinese Academy of Sciences. The C and N isotope ratios were expressed as δ^{13}C and δ^{15}N, relative to the international standards V-PDB and AIR, respectively. The isotopic analytical precision was 0.2‰.

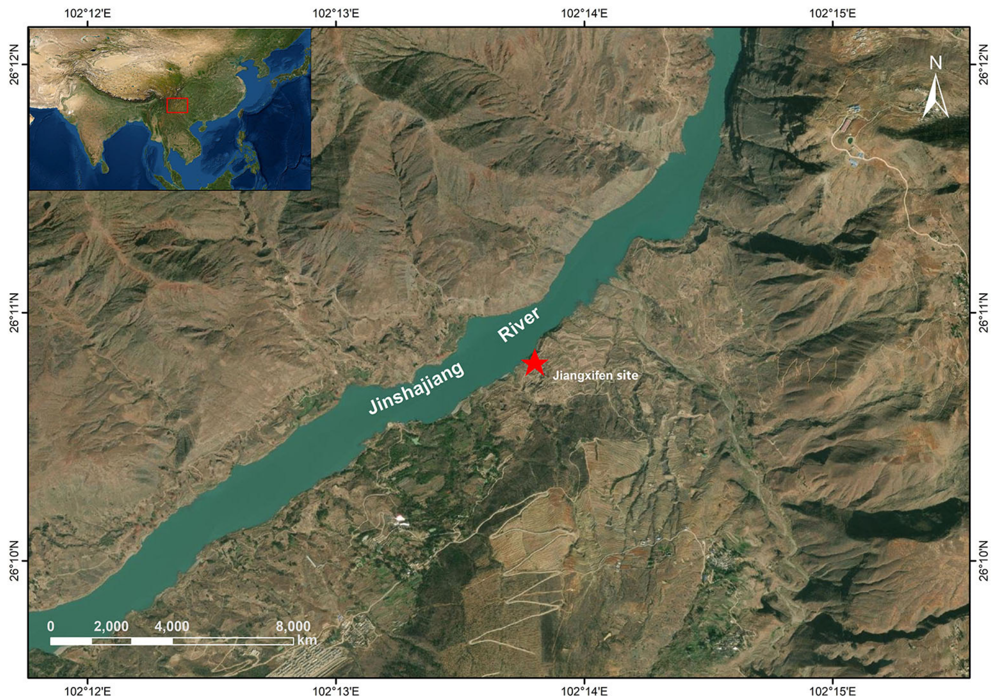

FIGURE 1 | Location of the Jiangxifen site.

TABLE 1 | Radiocarbon dates at the Jiangxifen site.

Lab no.	Context	Sample no.	Species	^{14}C date BP	Calibrated age BC/AD (95.4% prob.)
Beta-547362	2018YnJM205-1	R-15	Human bone	2,660 ± 30	899 cal BC ∼ 790 cal BC
Beta-544140	2018YnJM230	R-34	Human bone	2,560 ± 30	805 cal BC ∼ 563 cal BC
LZU19287	2018YnJM199	R-12	Human bone	2,560 ± 30	805 cal BC ∼ 563 cal BC
Beta-544139	2018YnJM207	R-17	Human bone	2,550 ± 30	801 cal BC ∼ 550 cal BC
Beta-544141	2018YnJM270	R-62	Human bone	2,540 ± 30	796 cal BC ∼ 547 cal BC
LZU19288	2018YnJM204-1	R-13	Human bone	2,530 ± 30	794 cal BC ∼ 544 cal BC
Beta-547363	2018YnJM249	R-45	Human bone	2,520 ± 30	789 cal BC ∼ 544 cal BC
Beta-544137	2018YnJM217	D-37	Bovid bone	2,480 ± 30	772 cal BC ∼ 476 cal BC
LZU19289	T3503⑦	D-27	Pig bone	2,470 ± 30	766 cal BC ∼ 422 cal BC

Radiocarbon Dating

Seven human and two animal collagen samples were selected for accelerated mass spectrometry radiocarbon dating at Peking University, Beijing; and at Beta Analytic Inc., Florida, United States (**Table 1**). The ^{14}C dates were calibrated using Oxcal version 4.4.2 (Ramsey, 2017) with the IntCal20 curve (Reimer et al., 2020) and reported as "cal BC."

Plant Remains

About 17 samples of plant remains were collected *via* flotation sampling from soil (a total of 194 L). Three flotation samples were collected from the ash pits, and 14 flotation samples were collected from the cultural layers. Plant identification was carried out at the key laboratory of Western China's environmental systems (MOE), Lanzhou University.

RESULTS

Chronology

The radiocarbon dating results are presented in **Table 1**. The Jiangxifen site was dated to 899–422 cal BC, with a range of 95.4%. This period covers the middle Western Zhou Dynasty (1,046–771 BCE) to the early Warring States Period (475–221 BC) in the Central Plains.

Isotope Analysis

The isotope data for human and animal bone collagen are presented in **Supplementary Table 1**, **Table 2**, **Figure 2**. The collagen of C:N ratios ranged from 3.1 to 5.7, with yields of 0.1–4.7%. Three human collagen samples were poorly preserved and excluded from further analyses, as their C:N ratios were outside the range of 2.9–3.6

TABLE 2 | Summary of results of C and N isotopes for humans and animals at the Jiangxifen site.

Species	Number	δ^{13}C (‰)			δ^{15}N (‰)		
		Mean	SD	Range	Mean	SD	Range
Human	65	−14.2	1.6	−18.6 ~ −9.4	9.8	1.0	5.9 ~ 12.4
Pig	2	−19.5	2.3	−21.1~ −17.8	6.2	1.6	5.1 ~ 7.3
Bovid	1	−8.1	–	−8.1	4.6	–	4.6

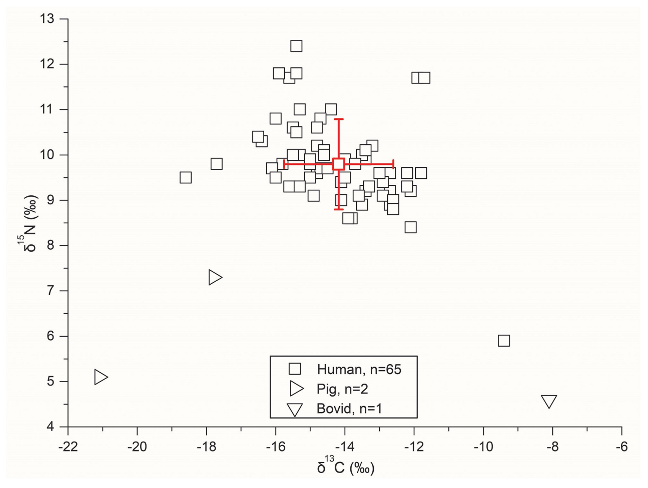

FIGURE 2 | Scatter diagram of carbon (C) and nitrogen (N) isotopes values for human and animal bone collagen.

(DeNiro, 1985; Ambrose, 1990). In addition, samples with a yield <1% and with C:N ratios between 2.9 and 3.6 were considered to be well-preserved and conformed to the analytic standard.

The δ^{13}C and δ^{15}N values of human collagen (n = 65) ranged from −18.6 to −9.4‰ (mean = −14.2 ± 1.6‰) and from 5.9 to 12.4‰ (mean = 9.8 ± 1.0‰), respectively. The δ^{13}C and δ^{15}N values of pig collagen (n = 2) ranged from −21.1 to −17.8‰ (mean = −19.5 ± 2.3‰) and from 5.1 to 7.3‰ (mean = 6.2 ± 1.6‰), respectively. Only one bovid bone collagen was extracted, and its δ^{13}C and δ^{15}N values were −8.1‰ and 4.6‰, respectively (**Table 2**).

Plant Remains

Although we collected a total of 17 flotation samples, only a few plant macrofossils were identified from the ash pits. In total, 203 charred plant seeds were identified. The identified crop remains included eight caryopses of foxtail millet (*Setaria italica*), three caryopses of common millets (*Panicum miliaceum*), 83 whole rice seeds (*Oryza sativa*), and 107 broken rice seeds, as shown in **Table 3**, **Figure 3**. We also identified the remains of two wild plant species: the three-horned bedstraw (*Galium tricornutum*) and lambsquarters (*Chenopodium album* L.).

DISCUSSION

Human Diets and Subsistence at the Jiangxifen Site During the Period ~900–400 BC

Natural vegetation surveys (Cao and Jin, 1989; Ou, 1994; Jin, 1999; Ward et al., 1999; Nelson et al., 2004; Li et al., 2009) and analyses of δ^{13}C values in the Holocene sediments (Cui et al., 2015, 2019) indicated that C_4 plants have an advantage in the hot and dry climate of the Jinshajiang River Valley in both modern times and throughout the Holocene. In contrast, C_3 vegetation dominates the higher altitude. Therefore, we urge caution in the interpretation of the C_4 signal in humans and animals in this region, even though in North China, C_3 food resources in human diets are typically associated with wheat and rice, whereas C_4 resources are typically associated with millet (Zhang et al., 2015; Zhou and Garvie-Lok, 2015; Ma et al., 2016; Cheung et al., 2019). Evidence from charred plants at the Baiyangcun site revealed that the earliest rice and foxtail millet remains in Yunnan were dated between 2,624–2,475 cal BC and 2,868–2,573 cal BC, respectively (Dal Martello et al., 2018). In Yunnan, wheat was cultivated later, with the earliest occurrence dated to 3,125 ± 30 BP, as determined in the second phase of the Haimenkou site (Xue, 2010). However, both rice and millet accounted for a certain proportion of plant food sources in the dry-hot valley of the Jinshajiang River during the prehistoric period; this is supported by evidence from unearthed plant remains from the Dadunzi and Baiyangcun sites (Jin et al., 2014; Dal Martello et al., 2018), as well as those from the Jiangxifen site in the present study (**Figure 3**).

Animal isotope data are typically used to explain human isotope values for the reconstruction of human diets. In the present study, the average δ^{13}C value for the two pigs (−19.5 ± 2.3‰) indicated a predominately C_3 food-based diet, which suggested either that the pigs foraged or were captured in the high-altitude forests or that humans fed them C_3 food (e.g., C_3 plants, rice by-products etc.; **Table 2**, **Figure 2**). The δ^{13}C value for single bovid (−8.1‰) indicated a C_4 plant-based diet, which suggested that the bovid might have been fed C_4 plants by humans, as the natural vegetation in the dry-hot valley included both C_3 and C_4 vegetation (**Table 2**, **Figure 2**).

The δ^{13}C and δ^{15}N values for humans (n = 65) ranged from −18.6 to −9.4‰ (mean = −14.2 ± 1.6‰) and from 5.9 to 12.4‰ (mean = 9.8 ± 1.0‰), respectively, indicating a range of C_4, mixed C_3/C_4, and mainly C_4 diets (**Table 2**, **Figure 2**). The wide range of human δ^{13}C values implies the use of highly varying food resources. However, the δ^{13}C values

TABLE 3 | Number of identified samples of charred seeds from the flotations at the Jiangxifen site.

Sample No.	Soil flotation quantity(L)	*Setaria italica*	*Panicum miliaceum*	*Oryza sativa* (Whole)	*Oryza sativa* (Broken)	*Galium tricornutum* Dandy	*Chenopodium album L.*
T3101 H12	10	7	3	–	–	1	–
H6	7.3	1	–	83	107	–	–
H4	10	–	–	–	–	–	1
Total	27.3	8	3	83	107	1	1

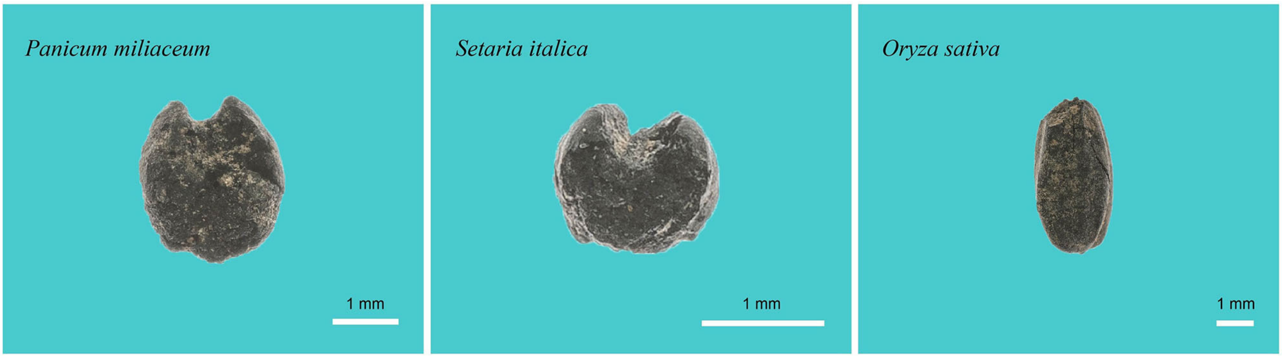

FIGURE 3 | Remains of crops identified at the Jiangxifen site.

for most individuals (60 out of 65) demonstrated mixed C_3/C_4 diets, implying the predominant consumption of both C_3 and C_4 foods. Furthermore, the average human δ^{13}C value (−14.2 ± 1.6‰) indicated a preference for C_4 foods; however, a single individual consumed a significant amount of C_3 foods. Moreover, the δ^{13}C values for four individuals indicated a predominance of C_4 foods. As the plant remains from this and other sites in the region indicated that millet and rice were the staple plant foods during the Bronze Age, we assumed that the C_3-consuming humans mainly relied on rice and C_3 food-fed animal protein, and so on, whereas the C_4-consuming humans mainly relied on millet and C_4 food-fed animal protein, and so on. Consumers of both C_3 and C_4 foods likely relied on both C_3 (rice, C_3 food-fed animal protein, etc.) and C_4 (millet, C_4 food-fed animal protein, etc.) foods. Undoubtedly, all humans likely foraged for both C_3 and C_4 plant foods in the wild, but wild plant consumption was probably limited owing to the prevalence of mixed millet and rice agriculture in Jiangxifen. Overall, humans at the Jiangxifen site might have preferred to consume C_4 foods, implying the predominance of millet agriculture.

The occurrence of mixed millet and rice agriculture in the region suggested the potential adaptation of humans to the specific environment of the dry-hot valley. The river valley is suitable for rice agriculture because this crop requires considerable amounts of water. In contrast, the hillside far away from the river is suitable for millet agriculture, as dry conditions are preferable for the cultivation of this crop. Furthermore, ancient humans likely relied on millet agriculture because the Jinshajiang River Valley was predominantly hot and dry, with only a limited area on the waterfront suitable for rice production.

Nitrogen isotopes are typically used to measure protein consumption (Hu et al., 2008; Ma et al., 2015; Cheung et al., 2017). The δ^{15}N value for humans at the Jiangxifen site ranged from 5.9 to 12.4‰, indicating diverse protein sources. The shift of 5.2‰ in the mean δ^{15}N value between humans and herbivores suggested that humans may have consumed a large amount of animal protein, including fish from the Jinshajiang River. However, only one bovid collagen sample was available to assess the human consumption of animal protein in the present study; therefore, future studies should also assess herbivore δ^{15}N values to confirm our findings.

Spatial Pattern of Human Subsistence Strategies and Influencing Factors Thereof in Yunnan Province During the Bronze Age

To study the spatial pattern of human subsistence strategies in different environments of Yunnan, we compared the isotopic evidence at the Shilinggang, Jinlianshan, and Jiangxifen sites, all of which have similar chronologies (Zhang, 2011; Liu, 2016; Ren et al., 2017). The average δ^{13}C value for human bones at the Shilinggang site (−18.7 ± 0.9‰) was significantly more negative than that at the Jiangxifen site (p = 0.000, **Table 4**), indicating a higher consumption of C_3 foods. According to the archeobotanical studies carried out at Shilinggang (Li et al., 2016; Zhang et al., 2017), humans cultivated both rice and millets, as well as some plants with underground storage organs, such as tubers, roots, and rhizomes. The annual average temperature and precipitation at the Shilinggang site are ∼21°C and 1,100–1,200 mm, respectively (Li et al., 2016); thus, the climate of this

TABLE 4 | Comparison of results of the human bone collagen isotope from archaeological sites in Yunnan.

Site	Age	Number	δ^{13}C (‰)		δ^{15}N (‰)		References
			Average	Range	Average	Range	
Jiangxifen	~900~400 BC	65	−14.2 ± 1.6‰	−18.6‰ ~ −9.4‰	9.8 ± 1.0‰	5.9‰ ~ 12.4‰	This study
Shilinggang	~950~350 BC	48	−18.7 ± 0.9‰	−20.0‰ ~ −14.9‰	9.7 ± 1.5‰	3.9‰ ~ 11.9‰	Li et al., 2016; Liu, 2016; Ren et al., 2017
Jinlianshan	~500 BC~220 AD	9	−18.8 ± 0.4‰	−19.3‰ ~ −18.2‰	9.8 ± 0.9‰	8.8‰ ~ 11.4‰	Zhang, 2011

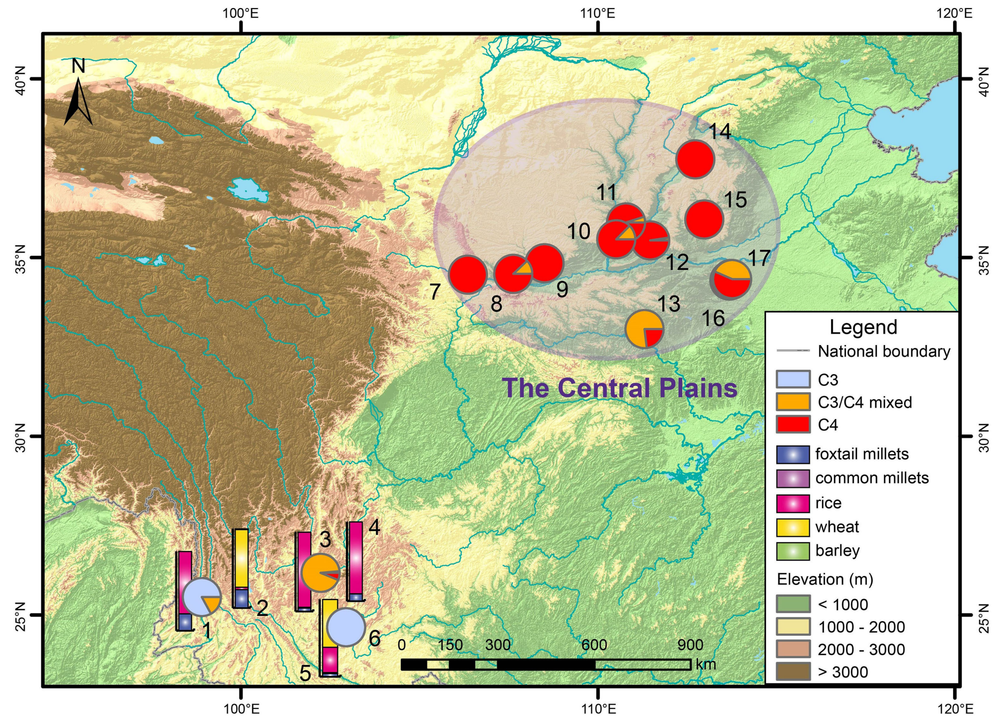

FIGURE 4 | Comparison of human C isotope values and frequency index of the crop remains at the Jiangxifen site and other contemporaneous sites in Yunnan (Xue, 2010; Zhang, 2011; Wang, 2014; Yao et al., 2015; Li and Liu, 2016; Li et al., 2016; Liu, 2016; Yang, 2016; Ren et al., 2017; Dal Martello et al., 2021) and the Central Plains (Pei et al., 2008; Ling et al., 2010a,b; Chen, 2012; Hou et al., 2012; Dong et al., 2017; Lan, 2017; Zhou et al., 2017; Tang et al., 2018; Sun, 2019; Li et al., 2020): (1) Shilinggang; (2) Haimenkou; (3) Jiangxifen; (4) Yubeidi; (5) sites around Dian and Fuxianhu Lake (including Dayingzhuang, Hebosuo, Anjiang, Xiaogucheng, Guangfentou, and Xueshan); (6) Jinlianshan; (7) Jianhe; (8) Sunjianantou; (9) Zaoshugounao; (10) Liangdaicun; (11) Neiyangyuan; (12) Hengshui; (13) Shenmingpu; (14) Xiaonanzhuang; (15) Xinancheng; (16) Changxinyuan; and (17) Xiyasi.

site is wetter and cooler than that of Jiangxifen. Accordingly, humans mainly consumed C_3 foods, with a little supplement from C_4 foods (likely millets). The age of the Jinlianshan site overlaps with that of the Jiangxifen site (Jiang and Wu, 2011). The δ^{13}C value for the human bone collagen at the Jinlianshan site was found to range from −19.3 to 18.2‰, suggesting that humans mainly consumed C_3 foods. This finding is significantly different from the findings at the Jiangxifen site ($p = 0.000$, **Table 4**). Unearthed plant remains from the Xueshan site (which is located near the Jinlianshan site and has a similar chronology) indicated that humans cultivated wheat, rice, barley, and millets in that area (Wang, 2014). Wheat and rice were the main crops at the Jinlianshan site. The δ^{13}C values obtained from enamel samples at the Shamaoshan site, a contemporaneous site near the Jinlianshan site, also suggested that humans mainly consumed C_3 foods in this area (Wu et al., 2019). In contrast to the hot-dry valley of the Jinshajiang River, the Jinlianshan and Shamaoshan sites are located in lake basins and are therefore more humid, indicating that there were sufficient water sources for wheat and rice cultivation.

Previous archeobotanical research has revealed differences in agricultural practices among various regions of Yunnan (**Figure 4**). The number of wheat seeds identified during the third phase of the Haimenkou site accounted for 73% of the total number of seeds from unearthed crops (Xue, 2010). In contrast, no wheat seeds were unearthed at the Jiangxifen, Shilinggang, and Yubeidi sites during the same period. Rivers and lakes with abundant water were convenient for imported wheat agriculture (Xue, 2010). Moreover, the high mountains and deep valleys in Yunnan may have hindered human migration and cultural exchanges among different regions during the Bronze Age. This may have been the main reason for the lack of wheat remains at the Jiangxifen and Shilinggang sites. Wheat and rice were the main crops in the sites around Dian and Fuxian lakes (**Figure 4**). The terrain around Dian and Fuxian lakes is flat, and the water resources are sufficient for wheat and rice cultivation.

Furthermore, tomb types and artifact assemblages unearthed from the Bronze Age sites in different regions of Yunnan Province exhibited different characteristics (Fan, 2007). These characteristics can be used to divide Yunnan into multiple cultural regions (He, 2003; Ao, 2015), further highlighting the effect of the fragmented landscape on cultural evolution (including dietary patterns) of humans during the Bronze Age. Casting processes, vessel types, and patterns of bronze ware differed among cultural regions (Fan, 2007). For example, the bronze wares unearthed in the sites around Dian Lake have complex casting techniques and diverse patterns, whereas the bronze wares from the Erhai Lake have simple casting techniques and fewer patterns. The bronze wares unearthed in northwest Yunnan have a considerable relationship with North China (Fan, 2007). In addition, the tomb type at the Wanjiaba site, which is a site near Dian Lake, is completely different from the tomb type in northwest Yunnan (He, 2003).

In contrast to the spatial heterogeneity of human livelihoods in Yunnan, the Zhou Dynasty sites in the Central Plains (∼1,046–256 BC) are revealed by isotopic evidence to have homogenous spatial characteristics in terms of human diet and subsistence (**Figure 4**). Millet crops were generally the dominant food source, whereas other crops, including wheat, rice, and soybean, were complementary food sources (Zhao, 2014; Zhou et al., 2017; Tao et al., 2020). As shown in **Figure 4**, the C isotopes of human bones from Zhou Dynasty sites in the Central Plains indicated that most individuals consumed C_4 foods (likely millets and their by-products), with only a small number of individuals consuming mixed C_4 and C_3 foods. The differences in human dietary patterns between Yunnan and the Central Plains might have been caused by the diversity of geomorphological features. Yunnan is located on the Yunnan–Guizhou Plateau; this terrain is high in the northwestern part and low in the southeastern part, with great undulations. The presence of large rivers, alternating mountains, and valleys is the reason for the high terrain fragmentation in Yunnan (Nie et al., 2008). Geomorphological features in the Central Plains are significantly different from those in Yunnan Province. Although the landform types in the Central Plains are complex, with high mountains and large plains, archeological sites are mostly distributed in the flat river valley areas (**Figure 4**). Stream networks in the middle reaches of the Yellow River facilitated human migration and cultural communication among different geographical units, and the area was controlled by a nominally unified regime (the Zhou Imperial Court). For this reason, human subsistence practice was based primarily on millet cultivation. The same social phenomenon did not occur in Yunnan until more recent historical periods; however, it is unclear whether the spatial pattern of subsistence also transformed synchronously. Therefore, this topic should be investigated further in future studies.

CONCLUSIONS

Based on C and N isotopic results and archeobotanical evidence, we concluded that humans in the Jiangxifen site consumed both C_3-based (rice and C_3 food-fed animal protein) and C_4-based food (millet and C_4 food-fed animal protein) during the period of ∼900–400 BC, with a preference for C_4-based food. The local environment in the dry-hot valley of the Jinshajiang River provided favorable conditions for millet and rice growth, which was the primary factor influencing food choice in this valley. When we compared our results with previously published isotopic data and archeobotanical evidence in contemporaneous sites of Yunnan Province, we were able to identify notable spatial discrepancies in human livelihoods in the Bronze Age in Yunnan. In this period, various crops and livestock were introduced to Yunnan Province; however, the highly fragmented geomorphological setting of the region significantly hindered trans-regional exchange. Therefore, prior to the development of a strong transportation network, local environmental settings (especially hydrothermal conditions) had a significant impact on local human diets and livelihoods in different parts of Yunnan Province.

DATA AVAILABILITY STATEMENT

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

AUTHOR CONTRIBUTIONS

MM and ML: formal analysis and writing and editing. MM: funding acquisition and supervision. XL: resources. WW, YL, and LR: sample collection. ML, WW, YL, and LR: methodology. All authors contributed to the article and approved the submitted version.

FUNDING

This research was supported by the Strategic Priority Research Program of Chinese Academy of Sciences, the Pan-Third Pole, the Environment Study for a Green Silk Road (Pan-TPE) (Grant No. XDA20040101), the Major Program of the National Natural Science Foundation of China (Grant No. 41991251), and the National Natural Science Foundation of China (Grant No. 41871076).

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feart.2021.662053/full#supplementary-material

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

The handling editor declared a past co-authorship with one of the authors LR and MM.