People and Plants in Ancient Southwest China
3,000 Years of Agriculture in Yunnan from the First Villages
to the Han Conquest
Rita Dal Martello

5 A Story of Outside Influence and Local Adaptation

5.1 The Beginning of Mixed Rice-Millet Systems and the Spread of Agriculture

After the domestication of rice and millets in their respective centres of origin (see Ch. 2), the two crops dispersed in the surrounding regions and came together to form the first mixed rice-millet agricultural systems **[fig. 29]** **[Appendix 5]**. It is important to note, however, that although it was traditionally thought that native wild millet and rice distribution divided at the boundary of the Qingling Mt. Range, recent archaeological research has shown they overlapped in the area between the Yellow and Yangzi Rivers, for example in the Huai River Basin (e.g., Yang et al. 2016). Such a northerly distribution of wild rice was possible due to higher precipitation and temperatures during the mid-Holocene (estimated to be 2-4°C degrees higher than today; Ge et al. 2007; Wang, Gong 2000; Dykoski et al. 2005). This had caused the expansion of tropical landscapes and environments much further north that attested today (see Ch. 3). A recent survey of over 800 archaeological sites in China dating between the seventh and first millennia BCE (He et al. 2017) individuated 155 sites with attested presence of both rice and either foxtail or broomcorn millet. This survey showed how both crops are present at some sites in the Shandong Peninsula and the Central Plains already during

DOI 10.30687/978-88-6969-935-1/006

the sixth millennium BCE [fig. 29];[1] however, grains are present in overall very low quantities for which is difficult to argue local cultivation, not least because these finds often lack direct chronological dating (Stevens, Fuller 2017). Low numbers of rice grains in a millet dominant assemblage have been reported from Zhuzhai B in Henan (ca. 5700 BCE; Bestel et al. 2018) and from Beiliu, near Xi'an (ca. 5700-5400 BCE; Zhou, Wang, Zhao 2024). Conversely, low numbers of millet grains with high quantities of rice remains have been reported from Baligang in southern Henan (ca. 6700-6500 BCE, Deng et al. 2015), a site representative of the southern expansion of the Yangshao Culture (ca. 5000-3000 BCE). At Balingang, while only 1 grain of broomcorn millet has been reported from the seventh millennium BCE strata, hundreds of foxtail and broomcorn millet grains have been found in flotation samples dating to the late fifth millennium BCE (Deng et al. 2015). Directly dated rice and millet grains are present at Nanjiaokou, in western Henan (north from Baligang), dating to 4000-3800 BCE (Qin, Fuller 2009). While in the successive millennia in the Shandong Peninsula and the Central Plains rice progressively declines in favour of millet, mixed farming is attested from sites dating from the late fourth millennium BCE onward in regions progressively farther away from their domestication centres (He et al. 2017; Stevens, Fuller 2017). For example, both crops are attested at Chengtoushan in the middle Yangzi River Basin at 4300-4000 BCE (Nasu et al. 2012), where previously documented cultivation systems were rice dominant. Mixed farming systems appear widespread in Southwest China (see Ch. 4). Scholars argue that the integration of rice and millet cultivation in a mixed farming system reflects the outward spread of millet agriculturalists, rather than rice (and especially wet rice) cultivators. This is because carrying capacity per unit of land for millet is lower than that for rice. It is thus hypothesesed that intensification of millet production is achieved through continuously incorporating new land into cultivation, which result in outward migrations (Stevens, Fuller 2017; Qin, Fuller 2019; Stevens, Zhuang, Fuller 2024). Despite claims of directly dated broomcorn and foxtail millet grains from 3800 BCE at Anle 安乐, in the Lower Yangzi Basin in northern Zhejiang (Tang, Marston, Fang 2022), upon examination of published photos of the seeds, they appear to be *Echinochloa* sp. (a species also present in the assemblage),[2] rather than either broomcorn of foxtail millet (as proposed by Tang, Marston, Fang 2022).[3] Mixed farming systems in the regions are attested almost a millennia later [fig. 29].

1 For example, Yuezhuang 月庄, in Shandong, has reported 91 grains of broomcorn millet, 9 grains of foxtail millet, and 28 grains of rice (Crawford 2016), however the status of rice as wild or domesticated is unclear. Xihe 西河, another site in Shandong, has 72 reported grains of rice and two of foxtail millet (Jin et al. 2013); but as for Yuezhuang, local rice cultivation has not been conclusively determined. See Appendix 5 for full list of sites.

2 *Echinochloa* seeds often present a flat back, while *Setaria italica* and *Panicum miliaceum* seeds puff and become particularly round when charring. The seeds' hilum also presents substantial differences (author's own observations and C.J. Stevens pers. comm. 2024).

3 The millet seeds are also present in negligible quantities compared to rice (16 of foxtail millet grains and only two of broomcorn millet, compared to 12,719 remains of rice, including grains and spikelet bases), which raises further doubts about any potential local cultivation.

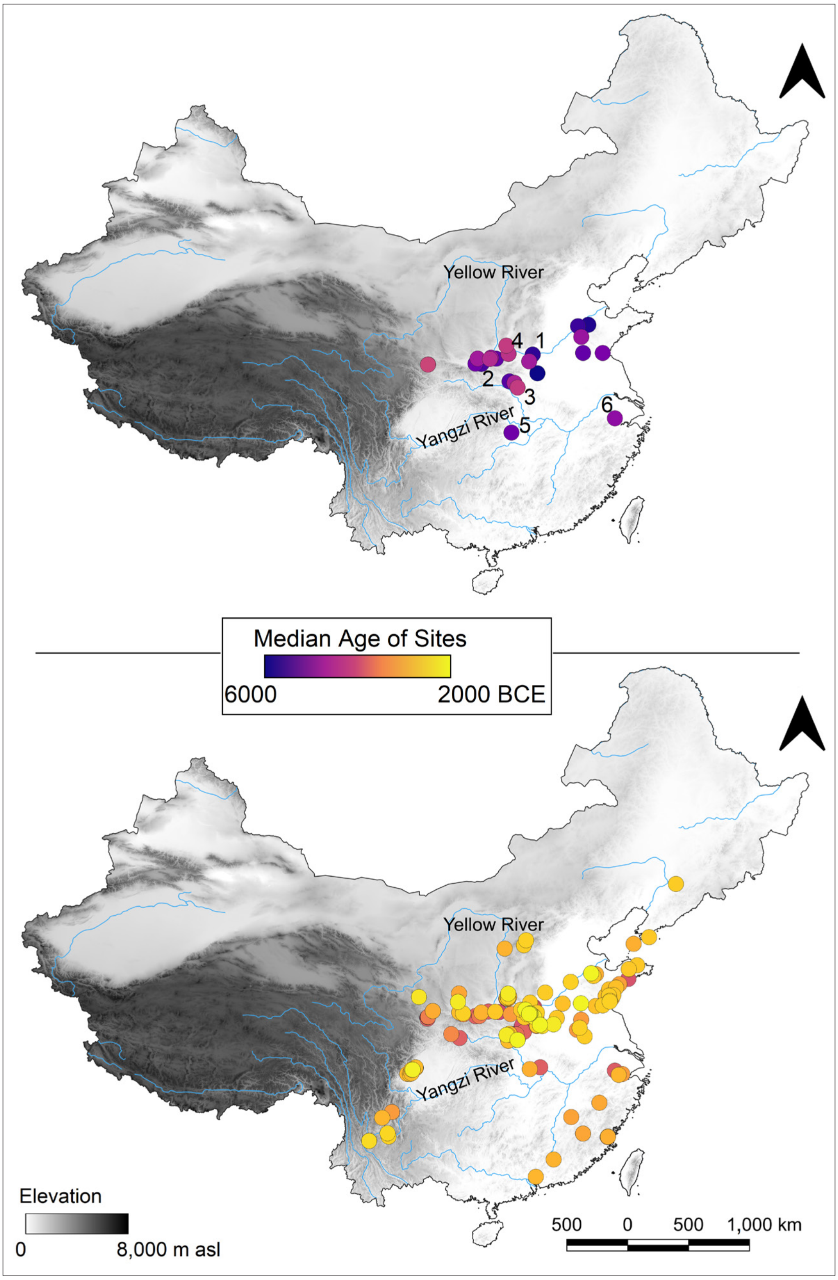

Figure 29 Sites with reported seeds of either foxtail or broomcorn millet and rice, dating between the sixth and third millennia BCE, plotted chronologically based on median age of occupation (see Appendix 5). Sites mentioned in text: 1. Zhuzhai B; 2. Beiliu; 3. Baligang; 4. Nanjiaokou; 5. Chengtoushan; 6. Anle (here, millet presence is disputed). Made by the Author with QGIS 3.28.5-Firenze, Natural Earth and EROS Digital Elevation basemap, U.S. Geological Survey

Scholars argue that the apparent lack of millet at sites with evidence for intensive rice cultivation in the Lower Yangzi (for example those connected with the Liangzhu Culture; see § 2.3.1.2), substantiate the view that it was expanding millet farmers that uptook rice cultivation during their spread (Qin, Fuller 2019; Stevens, Zhuang, Fuller 2024).

5.2 Comparison of Crop Systems and Chronological Crop Dispersal Trajectories in Broader Southwest China

Archaeobotanical data from regions surrounding Yunnan is quite uneven. For broader Southwest China, here including the provinces of Sichuan, Tibet, Chongqing and Guizhou, most of the available data derives from recent work on the Tibetan Plateau and Sichuan Province **[fig. 30] [Appendix 6]**.

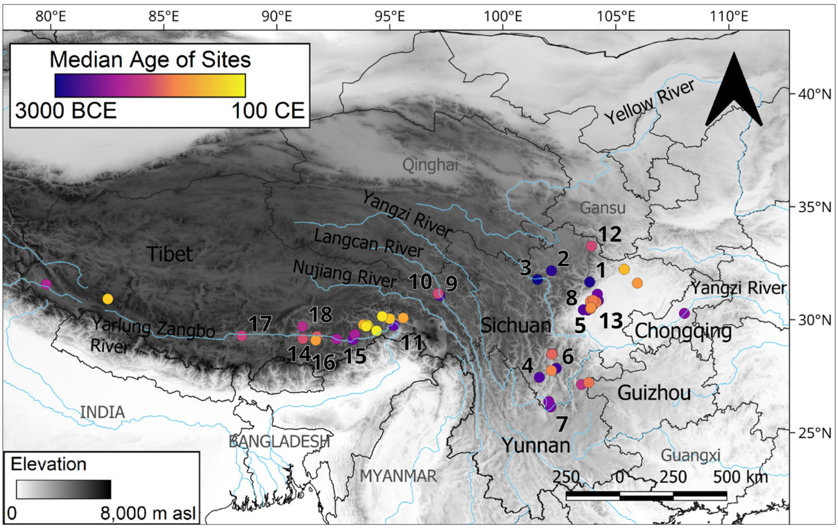

Figure 30 Sites in broader Southwest China with evidence for domesticated crops, plotted chronologically based on median age of occupation (see Appendix 6). Sites mentioned in text. 1. Yingpanshan; 2. Haxiu; 3. Liujiazhai; 4. Guijiabao; 5. Baodun; 6. Henglanshan; 7. Houzidong; 8. Gaoshan; 9. Karuo; 10. Xiaoenda; 11. La Phob; 12. Ashaonao; 13. Zhonghai; 14. Changguogou; 15. Klu lding; 16. Bangga; 17. Kuoxiong; 18. Qugong. Made by author with QGIS 3.28.5-Firenze, Natural Earth and EROS Digital Elevation basemap, U.S. Geological Survey

Chongqing and Guizhou instead are still rather understudied, with only three known sites with archaeobotanical remains.[4] Albeit grouped together, these regions have diverse environments that range from fertile, water-rich basins (such as the Sichuan Basin) to perennial snow mountains and extreme high altitudes on the Tibetan Plateau. This results in a variety of lifestyles and subsistence strategies as well as constraints in feasibility of agricultural production. Sichuan has often been indicated as the source of agricultural spread to Yunnan (e.g., d'Alpoim Guedes 2011), therefore an examination of the agricultural trajectories of broader Southwest China is needed to contextualise the origins of agriculture in Yunnan. In this section I review

4 In Chongqing, rice remains have been reported from Zhongba 中坝 phase I (2470-1700 BCE) and rice, foxtail millet and broomcorn millet have been reported from phase II (1100-200 BCE; Zhao, Flad 2013). Despite the site being located on the Yangzi River, it has been suggested that the vertical topography of the area constrained rice cultivation (d'Alpoim Guedes 2013, 767). In Guizhou, handpicked rice remains have been reported Jigongshan (ca. 1300-800 BCE) and Wujiadaping (ca. 1300 BCE), both sites are dated via cultural association (Zhao 2003a; Guizhou et al. 2006; Zhao, Hung 2010).

archaeobotanical data from sites in broader Southwest China dating from the fourth to the first millennia BCE, with a focus on the earliest documented presence of domesticated crops and the establishment of farming systems. The data presented in this section derives from site-specific archaeobotanical reports published in both Chinese and English academic journals, as well as master's and doctoral theses. These sources provide raw quantitative and qualitative data on the archaeobotanical assemblage composition of each site, along with information on the domestication and exploitation status of plant species recovered. However, since most of the sources consulted did not include detailed sample-by-sample information, the analysis outlined here focuses solely on the overall archaeobotanical assemblage composition to assess the presence (or availability) of species and their inferred role in the local farming system, as suggested by each source primary authors. Previously published archaeobotanical databases have also been consulted and are listed in Appendix 6. Sites from broader Southwest China are mentioned in text and are summarised in Table 13; all sites are illustrated in Figure 30.

Table 13 Summary of sites in broader Southwest China with evidence of agricultural crops mentioned in text. Plants recovery methods are indicated with Latin names for systematic flotation studies, and English common name for handpicked material. Modified from Dal Martello 2020

Site	Chronology	Plant remains	Faunal remains	References
Sichuan				
Yingpanshan 营盘山 Upper Minjiang (northern Sichuan)	3300-2600 BCE	*Setaria italica* *Panicum miliaceum* *Glycine* sp. Fruits	-	Huan et al. 2022c; Zhao, Chen 2011
Haxiu 哈休 Upper Dadunhe (Yellow R.)	3300-2700 BCE	*Panicum miliaceum* *Setaria italica* *Prunus* sp. *Avena* sp. *Zanthoxylum* sp.	Dog Pig Deer Macaca	Wang et al. 2023; d'Alpoim Guedes 2013; Zhao, Chen 2011; Aba et al. 2007; 2008
Liujiazhai 刘家寨 Jinchuan	3300-2700 BCE	*Setaria italica*	-	Chen et al. 2022, 2021
Ashaonao 阿梢垴 eastern Tibetan Plateau (Sichuan)	1400-1000 BCE	*Triticum aestivum* *Hordeum vulgare* *Setaria* cf	Sheep Deer	d'Alpoim et al. 2015
Ashaonao 阿梢垴 eastern Tibetan Plateau (Sichuan)	400-200 BCE	*Triticum aestivum* *Hordeum vulgare* *Chenopodium* sp. *Prunus* sp. *Rubus* sp. *Sambucus* sp. *Potentilla/Fragaria* *Linum usitatissimum*	-	d'Alpoim et al. 2015

Site	Chronology	Plant remains	Faunal remains	References
Guijiabao 皈家堡 Yanyuan county (southern Sichuan)	3300-1700 BCE	*Setaria italica* *Panicum miliaceum* *Oryza sativa* (rice from 3000-2800 BCE)	-	Hao et al. 2022
Henglanshan 横欄山 Xichang county (southern Sichuan)	2500-2200 BCE	*Setaria italica* *Panicum miliaceum* *Glycine max* *Vigna* sp.	-	Liu, Hao 2007 ; Jiang et al. 2016a; 2016b
Houzidong 猴子洞 Huili county (southern Sichuan)	2200-1900 BCE	*Setaria italica* *Oryza sativa* *Vigna* sp. *Ziziphus jujuba* var. *spinosa* *Zanthoxylum bungeatum* *Physalis alkekengi* *Chenopodium* sp.	-	Wang et al. 2023; Wang 2021
Baodun 宝墩 Sichuan Basin (Chengdu)	2700-2000 BCE	*Oryza sativa* *Setaria italica* *Coix lacryma-jobi* *Vicia* sp. *Vigna* sp. *Chenopodium* sp.	-	d'Alpoim Guedes 2013; d'Alpoim Guedes et al. 2013
Gaoshan 高山 Sichuan Basin (Chengdu)	2500-2000 BCE	*Setaria italica* *Oryza sativa*	-	Lee et al. 2019
Zhonghai 中海 Sichuan Basin (Chengdu)	1400 BCE	*Oryza sativa* *Triticum aestivum* *Setaria italica* *Panicum miliaceum* *Chenopodium* sp.	-	Chengdu 2012; Yan, Zhou, Jiang 2014
Zhonghai 中海 Sichuan Basin (Chengdu)	1400 BCE	*Oryza sativa* *Triticum aestivum* *Setaria italica* *Panicum miliaceum* *Chenopodium* sp.	-	Chengdu 2012; Yan, Zhou, Jiang 2014
Tibet				
Chamdo Karuo/ Qamdo Karuo/ Mkhar-ro 昌都卡若 Upper Langcan/ Mekong (Eastern Tibet)	2800- 2300 BCE	*Setaria italica* *Panicum miliaceum* *Fragaria/potentilla* sp. *Rubus* sp. *Chenopodium* sp.	Pig Unspecified large and small game; fish	d'Alpoim Guedes et al. 2013; Song et al. 2021
Xiaoenda/ Gshorngul-mda 小恩达 Eastern Tibet	2900-2200 BCE	*Setaria italica* *Panicum miliaceum*	Musk deer Roe deer Goral Blue sheep Pigs?	Zhang et al. 2019; Lu 2023

Site	Chronology	Plant remains	Faunal remains	References
Xiaoenda/ Gshorngul- mda 小恩达 Eastern Tibet	1550-850 BCE	*Setaria italica* *Panicum miliaceum* *Triticum aestivum* *Hordeum vulgare*	-	Zhang et al. 2019; Lu 2023
La Phob 拉颇 Southern Tibet	2800-2100 BCE	*Setaria italica* *Panicum miliaceum* *Hippophae rhamnoides* *Chenopodium* sp. *Sambucus* sp. Rosaceae fruits Nuts	Pigs Herbivores	Wang et al. 2024
La Phob 拉颇 Southern Tibet	700-300 BCE	*Setaria italica* *Panicum miliaceum* *Triticum aestivum* *Hordeum vulgare*	-	Wang et al. 2024
Changguogou 昌果沟 Southern Tibet	1420-800 BCE	Wheat Barley Foxtail millet (Avena; Rye) Pea *Potentilla*	-	Fu 2001
Klu liding 立定 Southern Tibet	1600-1400 BCE	*Setaria italica* *Panicum miliaceum* *Triticum aestivum* *Hordeum vulgare* *Chenopodium* sp.	-	Wang et al. 2024
Banga 邦嘎 Western Tibet	1000-210 BCE	*Hordeum vulgare*	Wild animal species	Tang et al. 2021
Qugong 曲贡 Central Tibet	1500-1250 BCE	*Setaria italica* *Panicum miliaceum* *Triticum aestivum* *Hordeum vulgare* *Fagopyrum tataricum*	Deer Yak Sheep	Gao et al. 2021
Chongqing				
Zhongba 中坝 Three Gorges (Yangzi)	2470-1700 BCE 1100-200 BCE	*Oryza sativa* *Oryza sativa* *Setaria italica* *Panicum miliaceum*	*Sus scrofa* *Nycterteutes procyonides* *Rhizomys sinensis* *Canis familiaris* *Bos* p. *Bubalus* sp. *Cervus* spp. *Vulpes* sp. *Macaca* sp. High quantity of fish remains including: Cypriniformes Siluriformes Perciformes and some giant salamander Snakes Turtles	Flad 2011; d'Alpoim Guedes 2013; Zhao, Flad 2013

Site	Chronology	Plant remains	Faunal remains	References
Guizhou				
Jinggongshan Lower Jinsha (Yangzi)	1300-800 BCE	Rice	-	Zhao 2003a Zhang, Hung 2010
Wujiadaping Lower Jinsha (Yangzi)	1300 BCE	Rice	-	Guizhou et al. 2006; Zhao 2003a

5.2.1 Fourth to Third Millennium BCE Sites and Archaeobotanical Evidence for the Spread of Agriculture to Sichuan and the Tibetan Plateau

The first agricultural systems in broader Southwest China have been attested on the margins of the eastern Tibetan Plateau in western Sichuan **[fig. 30]**. Here, charred millet grains dating to the end of the fourth millennium BCE have been reported from Yingpanshan 营盘山, Haxiu 哈休, and Liujiazhai 刘家寨 (albeit at Liujiazhai seeds are dated by cultural association) **[tab. 13]**.[5] A few centuries later, domesticated crops (mostly millets) have been reported from Guijiabao 皈家堡 in southern Sichuan (3300-1700 BCE); at this site rice appears a few centuries later than millet (ca. 3000-2800 BCE; Hao et al. 2022). Slightly later, the first mixed agricultural systems based on foxtail millet and rice appear on the Chengdu Plain, at Baodun 宝墩 (2700-1700 BCE; d'Alpoim Guedes 2013).

At Yingpanshan, located in modern Sichuan on the western edge of the Tibetan Plateau, broomcorn millet, foxtail millet, and soybean have been retrieved through flotation (Zhao, Chen 2011). Despite the lack of rice grains from flotation samples, isotopes on two skeletons from Yingpanshan showed a mixed C_3/C_4 signature, with a C_3 predominance (Lee et al. 2019, 2020). Some authors argued that the lack of rice macro-remains from Yingpanshan may derive from insufficient sampling (Huan et al. 2022c); however, according to the same study, animal protein intake for these two individuals derived from terrestrial herbivores (deer and cattle; Lee et al. 2019). This is in sharp contrast with inferences of a millet-pig based economy, as attested by the predominant presence of millets and pigs, and isotope analyses showed pigs fed on C_4 plants, presumably millet. The differences in diet for these two individuals may derive from them being non-locals, rather than indicating a possible rice presence at Yingpanshan (Lee et. 2019). At Haxiu, flotation results attested the presence of both broomcorn and foxtail millets and some fruit species, as well as seeds of possible Sichuan pepper (d'Alpoim Guedes 2013).

At Guijiabao, foxtail and broomcorn millet seeds retrieved through flotation have been directly dated to ca. 3300-2900 BCE. Rice grains, which were also retrieved through flotation, dated to a few centuries later (ca. 3000-2800 BCE; Hao et al. 2022). The site is located in southern Sichuan on the western section of the Yalong River before it joins the Jinsha River **[fig. 30]**. Guijiabao shows strong cultural affinities with Neolithic Cultures in northwest Yunnan, especially those in the middle of Jinsha River Basin,

5 Huan et al. 2022c; Chen et al. 2021; 2022; d'Alpoim Guedes 2013; Zhao, Chen 2011; Aba et al. 2007; 2008.

including Baiyangcun, which is about 200 km south from Guijiabao. At Guijiabao, graves are vertical earthen shaft pits with the deceased mostly placed in flexed supine position (like those found at Baiyangcun). Ceramic vessels from 2500-1700 BCE (indicated as phase II in the report) are characterised by coarse, grey pottery with incised/impressed decoration (Hao et al. 2022), which is also the main ceramic tradition at Baiyangcun. Perforated knives and other agricultural tools have been found from cultural layers belonging to phase II, which support an agricultural subsistence. Slightly later than Guijiabao at less than 100 km east from it, archaeobotanical flotation from Henglanshan 横欄山 has found seeds of broomcorn and foxtail millet, as well as soybean and *Vigna* sp. beans, but no rice (2500-2200 BCE; Jiang et al. 2016a, 2016b; Liu, Hao 2007), but some authors argue that the archaeobotanical remains from Henglanshan are not sufficiently representative to make meaningful inferences on the agricultural system of the site (Huan et al. 2022). At the end of the third millennium BCE, mixed rice-millet systems have been reported from Houzidong 猴子洞 (2100-1900 BCE). The site is located south from Guijiabao and Henglanshan, close to the Yunnan border **[fig. 30]**. Here millet is the predominant crop, and flotation undertaken in 2017-18 attested the presence of soybean, *Vigna* sp., jujube (*Ziziphus jujuba* var. *spinosa*), Sichuan pepper, *Physalis alkekengi*, and *Chenopodium* sp., which the authors suggest may have been cultivated/consumed (Wang B. et al. 2023).

On the Chengdu Plain, farming systems are documented from ca. 2700 BCE at Baodun and at a few several other sites in the Sichuan Basin (d'Alpoim Guedes 2013) **[Appendix 6]**. Archaeobotanical assemblages from these sites include both rice and millets. For example, at Baodun rice accounts for ca. 30% of the archaeobotanical assemblage. By being on the Chengdu Plain, people at Baodun would have had plenty of water resources which would have allowed a rich rice production. Archaeological seeds of typical wetland rice cultivation species such as *Fimbristylis* sp. and *Scirpus* sp. indicate that rice at Baodun was grown in a wet regime (d'Alpoim Guedes 2013; d'Alpoim Guedes et al. 2013b). Beyond rice, archaeobotanical remains included seeds of Job's tear (*Coix lacryma-jobi*), *Vigna* sp., *Perilla* sp., *Crataegus* sp., *Sambucus* sp., and peach stones. A slightly later site on the Chengdu Plain with good evidence for agriculture is Gaoshan 高山 (2500-2000 BCE), where also both rice and millet were retrieved through flotation. Isotope studies on human skeletons from the site (n=27) showed a predominant C_3 signature, presumably derived from rice intake (Lee et al. 2019). Genetic analyses were conducted on five individuals buried at Gaoshan; the results indicated they had genetic affinity with Late Neolithic populations from the upper Yellow River Basin (Tao et al. 2023, 4996). Scholars have inferred that people at Gaoshan (and presumably at Baodun too but this is not substantiated by direct genetic evidence from Baodun) were migrant millet farmers adopting rice, rather than being migrating rice farmers (Tao et al. 2023, 4999). Previous hypotheses on the origin of Baodun included an upward spread of rice farmers from the middle Yangzi River Basin, where Daxi 大溪 and Qujialing 屈家嶺 Culture sites (5000-3300 BCE, and 3400-2500 BCE, respectively) have wall enclosures and large architectural structures similar to the one documented at Baodun (Flad, Chen 2006; Fuller, Qin 2009; Zhang, Hung 2010). Other scholars attributed the origin of Baodun to the southward Majiayao expansion, based on ceramic similarities (Huang, Zhao 2004; Jiang, Wang, Zhang 2001). While this is the most favoured hypothesis for the origins of agricultural spread to Southwest China (see below), and it has been confirmed by some genetic data at Gaoshan, Tao and colleagues clarify that further sampling is needed to understand the formation of mixed farming in the area (Tao et al. 2023, 4999).

In Tibet, domesticated crops are reported from the early third millennium BCE at Chamdo Karuo/Qamdo Karuo/Mkhar-ro 昌都卡若 and Gshorngul-mda/Xiaoenda 小恩达, in the upper Langcan (Mekong) River in eastern Tibet, and from La Phob 拉颇 in southern Tibet **[fig. 30] [tab. 13]**.[6] Karuo is located at 3,100 m asl; charred foxtail and broomcorn millet seeds have been retrieved through floration and directly dated to 2800-2100 BCE (d'Alpoim Guedes et al. 2013a; Song et al. 2021). At Karuo foxtail millet is more predominant than broomcorn millet, and the cereals are present throughout the whole occupation of the site (including a second period after a temporary abandonment between 1600-700 BCE, see below). Given the location of the site at an altitude higher than the assumed altitudinal limit for millet cultivation (2,400 m asl),[7] past scholarship suggested that ancient Karuo people were foragers which obtained cultivated crops via trade (e.g., d'Alpoim Guedes, Manning, Bocinsky 2016; d'Alpoim Guedes 2018). However, palaeoclimate studies have evidenced that at the time of Karuo's occupation, the weather was warmer and wetter and therefore could have provided suitable conditions for the cultivation of millets.[8] Other plants retrieved include *Chenopodium* sp. seeds, and *Rubus*, *Artemisia*, and *Potentilla/Fragaria/Duchesnea* species seeds (Song et al. 2021). Fish bones were also reported, and the authors of the study suggest people at Karuo were practicing a broad-spectrum subsistence strategy, which included a wide variety of both floral and faunal resources (Song et al. 2021). Foxtail and broomcorn millet seeds have been retrieved through flotation at Xiaoenda, a site not far from Karuo, located at 3,140 m asl and dated to 2900-2200 BCE on mammalian bones (Zhang et al. 2019; Lu 2023). Here, the large faunal assemblage included mostly wild animals (e.g., musk deer, roe deer, goral, and blue sheep) and possibly domesticated pigs (Zhang et al. 2019). Current genetic and linguistic evidence both indicate that farming on the Tibetan Plateau likely ultimately originates from demic expansion of Yellow River millet farmers (see Jacques, Stevens 2024 for a recent summary of the research on this topic).

At La Phob, located at 2,788 m asl on the Bodui Zangbo River Basin, directly dated foxtail and broomcorn millet grains indicate the contemporaneous presence of the crops as at Karuo, and high quantities of *Chenopodium* seeds have also been reported, suggesting it was most likely exploited as food resource (Yang et al. 2024a). Domesticated pig bones have also been unearthed at the site and directly dated to 2800-2100 BCE, indicating that pigs were possibly raised at the site at the same time as millet was cultivated

6 d'Alpoim Guedes et al. 2013a; Song et al. 2021; Zhang et al. 2019; Lu 2023; Wang Y.R. et al. 2024.

7 This was also empirically inferred from a large survey conducted on the northeastern Tibetan Plateau (in modern Qinghai Province) when flotation samples from test pits were collected during surveys (Chen et al. 2015). The results showed that sites located at elevations lower than 2,527 m asl almost exclusively contained seeds of broomcorn millet, while later sites (especially those dating to after 1600 BCE) were barley dominant and these sites were located at higher elevations than millet sites (as high as 3,000 m asl; Chen et al. 2015). The authors of the study suggest this reflects environmental constraints in millet cultivation; however, recent research from Karuo and La Phob challenge this interpretation, at least for the southern Tibetan Plateau.

8 Today cultivated crops in the area include barley, wheat, turnips and rapeseed (Song et al. 2021).

(Yang et al. 2024a). Stable isotope analyses were conducted on both pigs and other herbivore species found at the site. The results indicated that pigs consumed a C_4 diet ($\delta^{13}C$ average value –8.4‰ ±0.5‰; n=11) in contrast to herbivores, which showed a C_3 based diet (in line with the reconstructed background vegetation make-up; $\delta^{13}C$ average value –19.0‰ ±0.7‰; Yang et al. 2024a). Authors of the study suggested that pig manure was utilised to fertilise millet fields (and before this time the status of pigs as wild boar or domesticated animal is unknown; Yang et al. 2024a). This kind of intensive millet-pig economy has been attested since the fourth millennium BCE in the Yellow River Basin in North China (Yang J.S. et al. 2022; Wang X. et al. 2018)[9] but before the discovery of La Phob, this kind of system was thought to not reach the high altitudes of Tibet. Agricultural crops were thought to spread to the Tibetan Plateau in the absence of domesticated animals, with wild animal hunting maintaining an important role in the early agricultural communities established on the Plateau.

The southward Majiayao expansion, originating in Gansu and moving along the eastern edge of the Tibetan Plateau, is widely regarded as the likely origin of agriculture in Southwest China. This expansion is believed to have stemmed from the earlier Yangshao expansion from the Yellow River Basin during the late Yangshao period.[10] The Majiayao dispersal to Sichuan is supported by similarities in painted ceramic types and chemical composition analyses on ceramic paint, for example documented at Yingpanshan (Hung 2011). Some authors have suggested that the chronological discrepancy in the arrival of millet and rice in Sichuan, as seen at Guijiabao (at present the earliest attested evidence for mixed rice-millet systems in Sichuan), indicates a separate dispersal for the cereals, possibly two successive waves (or routes) of spread. The lack or later appearance of rice in millet predominant systems outside of the Chengdu Plain suggests that the emergence of agriculture in Sichuan may indeed derive from migrating millet agriculturalists, which adopted rice farming. The lack of documented cultural connections and interactions between the Yangzi region and Sichuan in these centuries (Hao et al. 2022), along with the recent genetic evidence from Gaoshan (Tao et al. 2023) substantiate this view, but wider sampling from more sites in Sichuan (including Baodun) is needed to fully confirm this hypotheses.

5.2.2 Second to First Millennium BCE Sites and the Arrival of Wheat and Barley

The agricultural systems of Southwest China expand in the second millennium BCE, following the arrival of wheat and barley (see § 2.5.2). Directly dated wheat grains (1600-1400 BCE; d'Alpoim Guedes et al. 2015) have been reported from Ashaonao 阿梢垴, located in the Jiuzhaigou National Park on the eastern margin of the Tibetan Plateau in Sichuan Province **[fig. 30]**. At the site, the archaeobotanical assemblage is wheat dominant, and

9 Although conclusive proof of millet manuring is still lacking, scholars suggest that this may be the driver behind the expansion of millet agriculture in the millennia previous (Yang et al. 2024b; Wang X. et al. 2018).

10 The literature on this topic is vast, see for example Jiang 2004; Zhao, Chen 2011; d'Alpoim Guedes 2013; d'Alpoim Guedes, Butler 2014; d'Alpoim Guedes et al. 2013a, 2015; Chen et al. 2015; He 2015; d'Alpoim Guedes, Hein 2018; Song et al. 2021.

other potential edible resources include seeds of elderberry (*Sambucus* sp.), *Rubus* sp., and *Potentilla/Fragaria* sp. Hexaploid barley and flax (*Linum usitatissimum*) seeds have been reported from samples dating to the late first millennium BCE, at present among the earliest attested evidence for flax in East Asia (d'Alpoim Guedes et al. 2015). Albeit dated via cultural association, wheat grains have also been reported from Zhonghai 中海, on the Chengdu Plain, by the mid-second millennium BCE (Chengdu 2012; Yan, Zhou, Jiang 2014).

Wheat and barley grains have been reported from sites in Tibet from the mid-second millennium BCE, where they appear to be initially cultivated in mixed systems alongside millets **[tab. 13]**. Two grains of wheat and one of possible barley have been retrieved from Karuo and the wheat directly dated to ca. 1500 BCE (Liu et al. 2016; Lu 2016), although these are intrusive to their layer of provenance (with millet grains from the same contexts dating to few centuries earlier; Song et al. 2021). Wheat and barley grains have been reported from Changguogou/'Phreng-po-lung 昌果沟, on the southern Tibetan Plateau, about 580 km southwest of Karuo **[fig. 30]**. Here, archaeobotanical remains also include seeds of foxtail millet and possible pea and oat (ca. 1500-1200 BCE; Fu 2001; d'Alpoim Guedes et al. 2013a; Gao et al. 2020b). Wheat and barley grains, in association to foxtail and broomcorn millet grains, have been directly dated to ca. 1500 BCE at Liding/Klu Lding 立定, in southern Tibet (Wang Y.R. et al. 2024). At Klu Lding, *Chenopodium* seeds are also present, along with several other dryland cultivation species which support the local cultivation of millet (Wang Y.R. et al. 2024). Another important site where wheat and barley have been attested is Qugong 曲贡, located north from Changguogou. Here, flotation samples included seeds of wheat, barley, broomcorn and foxtail millets (directly dated to ca. 1400 BCE), tartary/bitter buckwheat (*Fagopyrum tataricum),* and possible pea. More than half of the archaeobotanical assemblage is constituted by wild seeds, among which *Chenopodium* grains are particularly dominant (Gao et al. 2021). Tartary buckwheat seeds from Qugong represent the earliest archaeological find of this species in China today. At the site, animal remains derived from wild deer and domesticated yak and sheep, possibly indicating the development of agro-pastoral subsistence strategies.

Around the end of the second millennium BCE, a barley dominant subsistence became well established especially at sites located at high altitutes (>2,500 m asl). A barley dominant archaeobotanical assemblage has been reported from Bangga 邦嘎, a site on the southern Tibetan Plateau located at ca. 3,700 m asl (1055-210 BCE; Tang et al. 2021). Barley seeds at Bangga have been directly dated to 1055-899 BCE (Tang et al. 2021). Other species at Bangga include wheat (although wheat grains have been directly dated to a few centuries later than barley; ca. 820-595 BCE), low quantities of buckwheat (identified as *Fagopyrum* sp.), and high quantities of *Chenopodium* seeds, which the authors of the study infer deriving from animal dung burning, rather than human consumption. One flotation sample from Bangtangbu 邦唐布 (ca. 1263-1056 BCE), a site located 10km from Bangga, contained seeds of naked barley, wheat, broomcorn millets and numerous wild species remains, including *Chenopodium* sp. (Tang et al. 2021). Naked barley has been reported from Kuoxiong 廓雄, located at 4,000 m asl further west upstream on the Yarlung Zangbo River **[fig. 30]**, but the archaeobotanical data is ambiguous (Tang et al. 2021). A positive correlation between barley presence and increases in altitudes had been previously attested during a large survey of the northeastern Tibetan Plateau (in modern Qinghai Province; Chen et al. 2015). The survey showed that millet dominant sites are present below >2,500 m asl, while barley dominant sites are found at elevations as high as 3,000 m asl (Chen et al. 2015).[11] Compared to millet, barley is much more tolerant to night frosts; survives well to drought and is known to mature even with short daylight during growing period, which would make it particularly well adapted to high altitudes, and this may be among the reasons for the development of a barley dominant economy in southern Tibet from the end of the second millennium BCE onward.[12]

5.2.3 Summary

When comparing Yunnan with the other southwestern Chinese provinces, the first attested agricultural trajectories in different areas appear quite different. Environmental constraints played a crucial role in directing the individual pathway of each of the diverse regions of Southwest China, but Majiayao millet farmers expansion had an important role in the initial spread of millet to the region. The first attested agricultural systems in Sichuan were based on millet cultivation, with rice appearing a few centuries later than the first appearance of millet regimes. Mixed farming systems based on rice and millet are reported from at least 3000 BCE in southern Sichuan, as attested at Guijiabao, a site close to Yunnan's border. Although the precise origin for rice spread to Guijiabao is unclarified, rice and millet may have formed a package in this area of Sichuan, and from there entered Yunnan. Rice dominant systems, instead, became established in the water-rich Sichuan Basin. While in Sichuan rice predominant systems are confined to water-rich lowlands (such as the Chengdu Plain), within Yunnan, the first documented agricultural systems are mixed regimes based on both rice and millets, with various levels of predominance of either one of these crops in different areas of Yunnan (see Ch. 4) **[fig. 29]**. On the Tibetan Plateau, agriculture initially developed thanks to millet dispersal, which contrary to previous hypotheses, became established even at high elevations, such as at Karuo and La Phob (2,788 m asl). Here, an intensive millet-pig economy has been attested by both macro botanical remains and isotope studies. From the mid-second millennium BCE, the spread of wheat and barley to the region caused a shift to barley predominant systems, especially at high altitudes. Here, the faunal data suggest the development of an agro-pastoral subsistence, based on the cultivation of cereals (barley), the raising of sheep/goat (and possibly yak), and occasionally hunting wild species. While wheat and barley are much better suited than millet to the Tibetan Plateau high altitudes environmental constraints, they have broadly similar ecological and growing requirements, with barley having slightly lower water needs than wheat **[tab. 9]**. Barley's lower water requirement may have led to its

11 Barley has also been reported in western Tibet at the sites of Piyang 皮央 and Jiweng 吉翁 at elevations above 4,000 m asl (both sites have been directly dated on barley grains to ca. 390-210 BCE, see Tang et al. 2022). The authors of the study suggest that barley was cultivated at both sites.

12 Jamieson, Beck 2010; d'Alpoim Guedes et al. 2015; d'Alpoim Guedes, Manning, Bocinsky 2016; Tang et al. 2021, 2022 predominance over wheat, however, other reasons (such as taste preferences and other social factors) cannot be excluded, as already highlighted by other scholars (Tang et al. 2021). Seasonally differentiated harvesting times for cultivated crops are recorded in Chinese written texts from the late first millennium BCE (Liu et al. 2017). Scholars have argued that spring, wheat and barley varieties developed after the dispersal of the two species to the Tibetan Plateau. Based on the available data, spring varieties may have originated around the end of the second millennium BCE. The retrieval of pea seeds at Karuo and Changguogou may indicate the development of connections and spread of crops from India, where peas have been reported from Neolithic and Harappan sites along the southern Himalayas at least a millennium earlier than those reported at Karuo and Changguogou.[13]

5.3 Beyond Southwest China: Ancient Migrations and the Role of Plants

Southern China, but especially Yunnan, has been postulated to be the source for the dispersal of agriculture to mainland Southeast Asia, in part based on linguistic reconstructions for early Austroasiatic languages (see § 2.2.1.1) and in part based on similarities in material culture production and innovations. Recent archaeological research has demonstrated that short and long-range networks for metal sourcing existed across Yunnan and Southeast Asia from at least the late second millennium BCE.[14] While the emergence of metallurgy in Yunnan from the late second millennium BCE was the result of earlier cultural connections, and possibly migrations, from Northwest China (e.g., Ciarla 2013; Min 2009a; 2009b), scholars argue that in mainland Southeast Asia, this technological innovation was the result of cultural connections established with southern China, possibly Yunnan, from the mid-third millennium BCE (based on similarities in ceramic decorations, see below).[15] The spread of metallurgy is attested by the widespread presence of copper alloy deep-socketed axes produced through bivalve casting moulds (a technique ultimately originating in the Steppe; Pigott, Ciarla 2007). Deep-socketed metal axes and bivalve moulds have been found, for example at Haimenkou (1400-400 BCE), in Yunnan, Oakaie and Nyaung'gan in Myanmar (end of second millennium BCE), Thanh Den in Vietnam, Non Pa Wai (1000-700 BCE), Ban Non Wat and Ban Chiang in Thailand (1050-420 BCE; see Higham 2021 for a recent synthesis on the topic). The presence of incised/impressed ceramic remains at late third to second millennium BCE sites in Yunnan and mainland Southeast Asia have been argued to represent those earlier cultural connections and interactions across the regions, which were conducive for the later emergence of metallurgy in Southeast Asia (e.g., Rispoli 2007; Rispoli, Ciarla, Pigott 2013;

13 For examples, pea is reported in northern India from Masudpur VII (ca. 2870-2470 BCE; Bates 2024; Bates, Petrie, Singh 2017); Hetapatti (ca. 2500- 2250 BCE; Pokharia et al. 2016), Senuwar (ca. 2500- 2000 BCE; Saraswat 2004a), Ojiyana (ca. 2450-1500 BCE; Liu et al. 2017), and Kanispur in Kashmir (ca. 2700-2000 BCE; Pokharia et al. 2017). See also Ch. 4 fn. 33, 38.

14 Pryce et al. 2023; 2022; 2021; Higham 2021; Yun, Scott 2020; Chiou-Peng 2018; Ciarla 2013.

15 Although a possible route via Lingnan has also been proposed. For the Yunnan route see Yun, Scott 2020; Chiou-Peng 2018; Ciarla 2013; Rispoli, Ciarla, Pigott 2013; White, Hamilton 2009; for the Lingnan route see Ciarla 2013; 2007; Pigott, Ciarla 2007; Higham 1996b.

Ciarla 2013). In northwest Yunnan, incised/impressed ceramic remains have been reported from Baiyangcun, Xinguang, Dadunzi, Mopandi, Haimenkou, and Shifodong as well as the majority of known Neolithic sites in Yunnan (which have not been discussed in Ch. 4 for lack of archaeobotanical remains). Sites with this ceramic tradition cluster along the upper Langcan (Mekong), middle Nujiang (Salween), Jinsha (Yangzi), and Yalong rivers. At Karuo, in the upper Langcan River in eastern Tibet **[fig. 30]**, incised/impressed zigzags and diamond-shaped designs have been reported. Similarly decorated ceramic remains have recently been reported from Guijiabao, in the Jinsha River Basin in southern Sichuan, dated to 2500-1700 BCE (Hao et al. 2022). From the second half of the third millennium BCE onward, incised/impressed ceramics "appear suddenly at sites distributed in the major river plains" of mainland Southeast Asia (Rispoli 2007, 238; Rispoli, Ciarla, Pigott 2013).[16] This includes sites in Thailand (Higham 2021), Vietnam (such as An Son and Loc Giang; Sarjeant 2014), and north-central Myanmar (Hudson, Lwin 2012; Pautreau, Coupey, Kyaw 2010; Pryce et al. 2024). According to Rispoli and colleagues, two designs are the most recognizable and representative of these cultural connections: the 'meander' and 'double-S' designs **[fig. 31]**. Examples of such designs are known in Yunnan at Dadunzi,[17] Mopandi, Xinguang, and Shifodong (listed here are only the already discussed sites in Ch. 4). Although, upon close examination of the relative proportions of each design presence, this is quite low. For example, at Mopandi the meander design accounts for only 0.6% out of the 8% incised/impressed ceramic remains retrieved at the site (Yunnan 2003); at Xinguang, the double-S design accounts for 5% out of the 30-50% incised/impressed ceramic remains from Xinguang; moreover, the design decreases through time (Yunnan 2002). Unfortunately, no information is provided about the relative proportions of these designs from Dadunzi, where the incised/impressed decorations account for 30% of the overall ceramic assemblage. In mainland Southeast Asia the two designs have been reported from Non Pa Wai, Tha Kae, Khok Phanom Di and Ban Chiang among other sites with incised/impressed decorations (Rispoli, Ciarla, Pigott 2013) **[fig. 31]**.

16 Here incised/impressed ceramics are often associated with small, polished stone tools, stone or shell bracelets and necklace beads.

17 The ceramic sherd illustrated in in Rispoli, Ciarla, Pigott 2013, 120 fig. 12 is mistakenly attributed to Baiyangcun; it comes instead from Dadunzi (illustrated in the 1997 excavation report published in *Kaogu Xuebao* 1, 66 fig. 16-5). Although incised/impressed ceramics constitute most of the ceramic remains reported from the first excavation season of Baiyangcun, this design has not been individuated in the currently published report (Yunnan 1981), but its presence cannot be excluded since material unearthed from the second excavation season is yet unpublished.

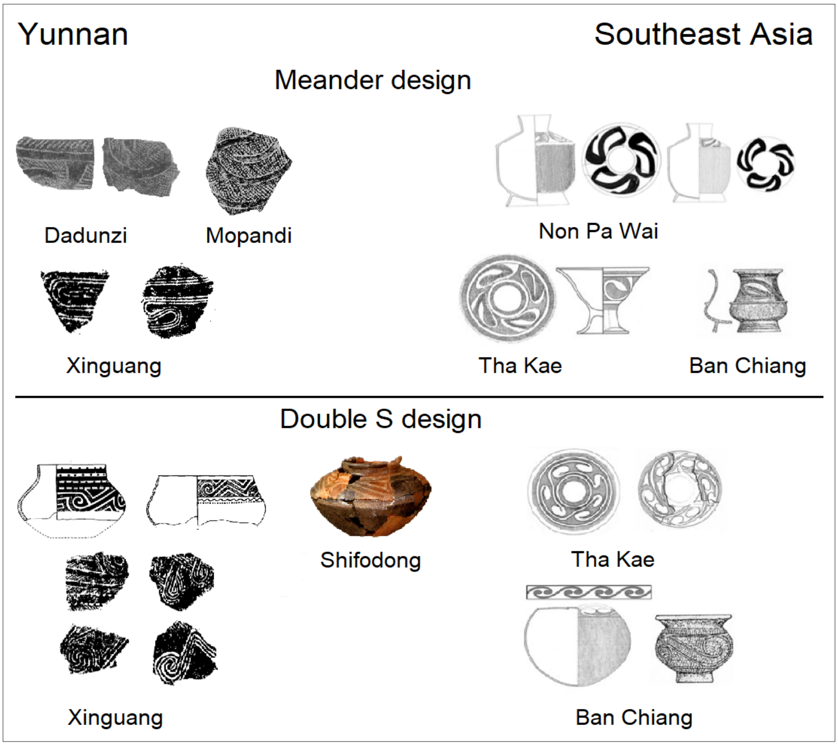

Figure 31 Illustrations of meander and double-S designs in incised/impressed pottery traditions with examples sites in Yunnan and mainland Southeast Asia that hold relevance for the dispersal of agricultural crops mentioned in text. From Dal Martello 2020, fig. 8-13. Redrawn and adapted from Yunnan 1997; 2002; 2003; Rispoli, Ciarla, Pigott 2013

Although such similarities in ceramic decorations from sites dating to the third millennium BCE onward suggest possible cultural contacts between Southwest China and mainland Southeast Asia, it remains unresolved whether these similarities derive from direct dispersal (migration of populations from Yunnan) or from multi-directional trade and exchange. Some scholars highlighted how the meander and double-S designs are absent from the incised/impressed ceramic remains at those sites located north from the middle Jinsha Basin (such as Karuo) and have inferred that this cultural trait originates in the Jinsha Basin before dispersing south, based on the later dates of sites in mainland Southeast Asia (Hao et al. 2022). One limiting factor in fully understanding the nature of these connections is the lack of equivalent shared typewares and systematic chaîne opératoire studies, which would allow the evaluation of homologies in pottery assemblages from the regions (Pryce et al. 2023, 174), but most importantly, as already noted by numerous scholars, incised/impressed ceramics sites from Yunnan and mainland Southeast Asia share rather close chronologies,[18] which further complicates reconstructing the nature and directions of these cultural connections. In this section I review evidence of agricultural practices in mainland Southeast Asia on the basis of archaeobotanical material, so to

18 For recent syntheses on chronologies based on radiocarbon dating from the region see for example Higham, Douka, Higham 2015; Dal Martello 2022; Pryce et al. 2018; 2024; Yao A. et al. 2020.

evaluate the possible role of Yunnan early agricultural communities in the emergence of the first agricultural systems in mainland Southeast Asia.

Many of the known archaeological sites in mainland Southeast Asia dating to between the third and first millennia BCE have been excavated before the introduction of flotation, which results in a limited number of sites with reported archaeobotanical remains **[tab. 14]**. Rice grain impressions and grains and husk inclusions are instead reported from numerous sites. For example, in Laos, where no flotation studies are known, rice inclusions have been reported from Lao Pako, along the Mekong Basin, which however is dated to 300-600 CE (Kallen 2004) **[fig. 32]**.[19]

Table 14 Summary of the main early sites in mainland Southeast Asia; chronological date; recovery methods of archaeobotanical materials; main archaeobotanical cultigens present at the sites; animal resources present if known/zooarchaeological analysis present. Adapted from Dal Martello 2020

Site	Chronology	Plant collection method	Plant remains	Faunal remains	References
Thailand					
Non Pa Wai	2470-2200 BCE/ 1000-700 BCE	Flotation	*Setaria italica*/ Second phase: *Setaria italica* *Oryza sativa* *Panicum* sp. *Coix lacryma-jobi*	*Sus scrofa* *Canis familiaris* *Cervus* spp. *Bos* sp. *Bubalus bubalis* *Bos frontalis* (gaur) *Bos indicus* Catfish-*Mystis* sp. Birds (mostly fowl) Turtles snakes & lizards	Weber et al. 2010; Pigott et al. 2006
Khok Phanom Di	2000-1400 BCE	Flotation	*Oryza sativa** *Coix* sp. *Paspalum* sp. *Eragrostis* sp. *Amaranthus* sp. *Eleocharis* sp. *Cyperus sp.* *(rice cultivation regime unclear: decrue?)	*Sus scrofa* *Macaca* sp. *Cervus* sp. *Canis* sp. *Muntiacus muntjak* *Bos* sp. *Bubalus bubalis* Birds Reptiles (including crocodile) Turtles Fish & mollusks	Thompson 1996
Non Mak La	2100-1450 BCE/ 1450-700 BCE	Flotation	*Setaria italica*/ Second phase: *Setaria italica* *Oryza sativa*	-	Weber et al. 2010
Ban Non Wat	Neolithic: 1750-1050 BCE Bronze Age: 1050-420 BCE Iron Age: 420 BCE- 500 CE	Flotation	*Oryza sativa* (initially associated with dryland weed species; later shift from dryland to wetland weeds)	Pig	Castillo 2013; Higham 2004; Higham, Higham 2009; Castillo et al. 2018a
Tha Kae	1700-1100 BCE	Chaff- pottery impressions	Rice	-	Rispoli, Ciarla, Pigott 2013

19 According to the report, rice material inclusions in pottery temper from Lao Pako are sometimes in such a high density that vessels seem unsuitable to be used as containers (Kallen 2004, 204).

Site	Chronology	Plant collection method	Plant remains	Faunal remains	References
Ban Chiang	1650-1050 BCE/ 1050-400 BCE	Flotation	*Oryza sativa*	*Bos* sp *Cervus* sp. *Sus scrofa* *Canis familiaris* *Bubalus bubalis*	Yen 1982; White 1982; Thompson 1996
Nil Kham Haeng	1350-800 BCE/ 800-500 BCE	Flotation	*Setaria italica* Second phase: *Setaria italica* *Oryza sativa*	Turtle	Weber et al. 2010
Ban Na Di	900-500 BCE	Hand-picked	Rice	Cattle Pig Dog Fish Turtle Crocodile Frog	Castillo 2013; Higham et al. 2015
Khao Sam Kaeo	400-100 BCE	Flotation	*Oryza sativa* *Setaria italica* *Vigna umbellata* *Vigna* spp. *Macrotyloma uniflorum* *Citrus* sp. *Gossypium* sp. *Sesamum indicum*		Castillo 2013; Castillo, Fuller 2010; Castillo et al. 2016
Noen U-Loke	450 BCE- 500 CE	Flotation	*Oryza sativa** *(shift from dryland to wetland weeds)		Castillo et al. 2018a
Khao Sek	400-100 BCE	Flotation	*Oryza sativa*		Castillo 2018
Phu Kao Thong	200 BCE- 20 CE	Flotation	*Oryza sativa* *Setaria italica* *Vigna umbellata* *Vigna spp.* *Macrotyloma uniflorum* *Citrus* sp. *Gossypium* sp. *Sesamum indicum*		Castillo 2013; Castillo et al. 2016
Phromtin Thai	500 BCE- 900 CE	Flotation	*Oryza sativa* *Setaria italica* *Vigna* sp. Fabaceae		d'Alpoim Guedes et al. 2018; 2020
Vietnam					
An Son	2300-1200 BCE (wood charcoal, human teeth, food residue)	Pottery impression* (microCT), Phytoliths *from 1800 BCE	*Oryza sativa japonica* chaff (Gene coding)	Mammals: Pig Dog Reptiles: Fish Turtles	Bellwood et al. 2011; Barron et al. 2017
Loc Giang	2000-1300 BCE	Pottery impressions (microCT)	Rice		Barron et al. 2017
Trang Kenh	2000-1000 BCE (wood charcoal, plant fragments)	Starches	Foxtail millet? Rice?		Wang W. et al. 2022
Dong Dau	1400-800 BCE	Pottery impressions/ Flotation	*Oryza sativa*		Nguyen 2002; 2013; 2017
Thanh Den	1700-600 BCE	Pottery impressions/ Flotation	*Oryza sativa*		Nguyen 2017

Site	Chronology	Plant collection method	Plant remains	Faunal remains	References
Rach Nui	1845-1385 BCE	Flotation	*Oryza sativa* *Setaria italica* Both crops imported Large quantities of roots, tubers, and sedges (exploited)	Shellfish and fish: *Geloina coaxans* *Cerithidea obtusa* *Neritina violacea* *Ellobium* sp. Freshwater fish Reptiles: *Batagur* sp. Turtles: *Cuora* sp. *Cyclemys* sp. *Crocodylus porosus* *Varanus* sp. *Macaca* sp. *Sus scrofa* *Canis familiaris* (exploited for meat) Indet. birds *Cervus* sp. Pig Dog	Oxenham et al. 2015; Castillo et al. 2018b
Lo Gach	1100-700 BCE	Flotation (unpubl.)	*Oryza sativa*		C. Castillo, pers. comm., 2018

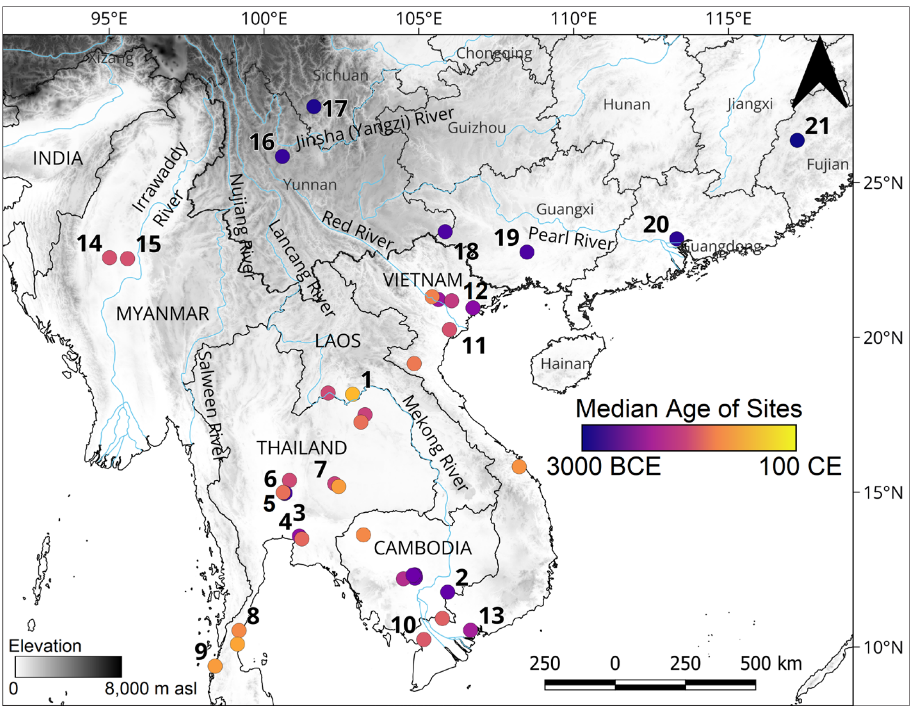

Figure 32 Sites in mainland Southeast Asia and southern China with evidence for domesticated crops, plotted chronologically based on median age of occupation (see Appendix 6). Site mentioned in text. 1. Lao Pako; 2. Krek 52/62 sites; 3. Non Pa Wai; 4. Khok Phanom Di; 5. Non Mak La; 6. Nil Kham Haeng; 7. Ban Non Wat; 8. Khao Sam Kheo; 9. Phu Khao Thong; 10. An Son; 11. Loc Giang; 12. Trang Kenh; 13. Rach Nui; 14. Oakaie; 15. Nyaung'gan; 16. Baiyangcun; 17. Guijiabao; 18. Gantuoyan; 19. Dingshishan; 20. Gancaoling; 21. Nanshan. Made by the Author with QGIS 3.28.5-Firenze, Natural Earth and EROS Digital Elevation basemap, U.S. Geological Survey

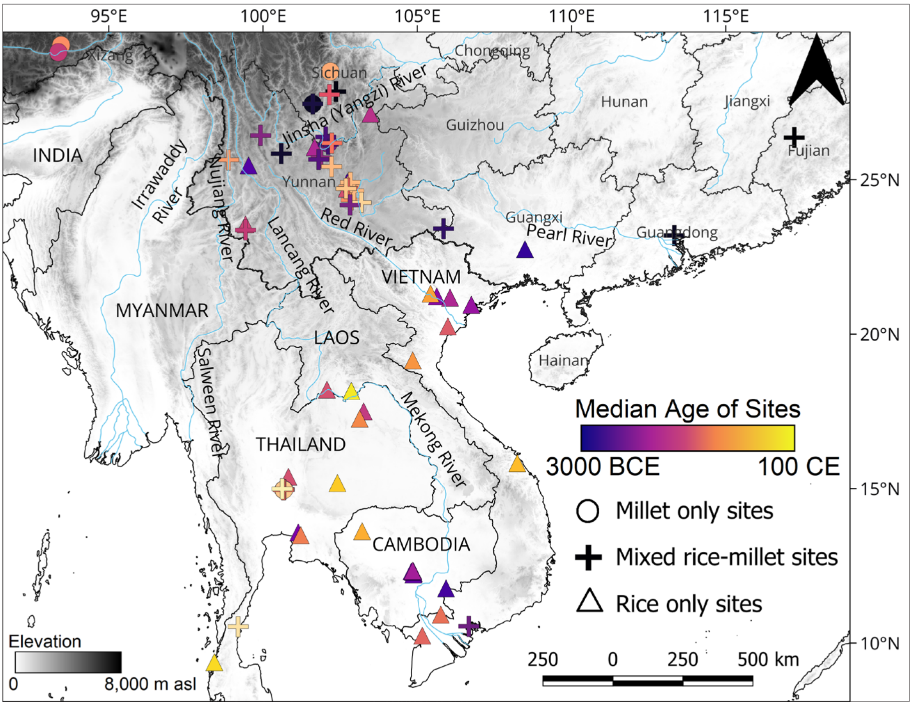

Figure 33 Presence of rice, millet, and mixed farming systems in southern China and mainland Southeast Asia between the late fourth to the first millennium BCE, highlighting potential routes of dispersal of main crop species into and out of Yunnan (sites plotted chronologically based on median age of occupation phase for the first documented appearance of the crops; all sites listed in Appendix 6). Made by the Author with QGIS 3.28.5-Firenze, Natural Earth and EROS Digital Elevation basemap, U.S. Geological Survey

In Cambodia flotation studies from prehistorical sites are lacking, and here, rice chaff inclusions have been reported from circular earthwork sites, including Krek 52/62, Samrong Sen, and Mlu Prei, all located in the Mekong Basin and dating to the second millennium BCE (Vanna 2002) **[fig. 32]**. This kind of rice remains can only indicate the availability of the plant during the occupation of these sites, and do not provide information about its domestication status or role in the economy. Wild rice presence in the area would be expected as mainland Southeast Asia was part of the natural wild rice distribution during these millennia **[fig. 5]**. Recently, microCT (Micro Computed Tomography) scanning has proved to be a useful tool to further investigate this kind of remains, which otherwise do not provide information about the domesticated status of the crop and its role in the overall economy of the site. MicroCT scanning can capture and re-create a 3D microscale morphology of the remains included in the pottery sherds, such as rice husks and spikelets, and allows the researchers to determing whether the rice plants were domesticated or not. However, this type of analysis has been applied only to two sites so far (An Son and Loc Giang in Vietnam; Barron et al. 2017; see below). For these reasons, sites with rice inclusions are not further discussed below.

At present the earliest securely dated evidence for domesticated crops in mainland Southeast Asia comes from Non Pa Wai, in central Thailand, where hundreds of foxtail millet grains have been recovered, and direct radiocarbon dating on one foxtail millet grain furnished a date of 2470-2200 BCE

(Weber et al. 2010). At Non Pa Wai, rice grains are present in much lower quantities than millet and appear at the site only in the first millennium BCE (Weber et al. 2010, tab. 14). The early date of this find is not universally accepted, with some scholars questioning the reliability of the small sample size (only one grain) and more generally pointing to the high level of disturbance at the site (Rispoli, Ciarla, Pigott 2013). However, given the short life cycle of herbaceous Poaceae plants like foxtail millet (within one year), direct dates on charred seeds from these plants provide strong reliability for their chronology, regardless of the sample size.[20] The identification of the seed with *Setaria italica* can also be confirmed through examination of photos and descriptions provided in Weber et al. 2010, thus excluding confusion with local species.

The earliest report of rice grains and domesticated-type spikelet bases is attested from Khok Phanom Di, a site dating to dating to the early second millennium BCE (2000-1400 BCE) and located close to the Gulf of Thailand (Thompson 1996; Higham, Thosarat 2012) **[fig. 32]**. Here, rice is present in the absence of millet. Isotope analyses on human bones have demonstrated that a number of female individuals buried at Khok Phanom Di were not born locally. Based on this, scholars investigating the sites hypothesesed that rice was imported to the region with the arrival of these female individuals (rice farmers?), and it was further suggested that rice was cultivated in seasonally flooded fields located in swamps. However, this hypotheses cannot be substantiated due to the lack of any kind of weedy flora from the plant remains retrieved at the site (see below; Castillo 2017; Thompson 1996).

After ca. 2000 BCE, rice and foxtail millet grains have been found at Non Mak La (2100-700 BCE) and Nil Kham Haeng in central Thailand (1350-800 BCE; Weber et al 2010) **[fig. 32]**. At the two sites, rice quantities from samples dating to the mid-second millennium BCE are initially quite low. Higher quantities of rice remains are reported only from the first millennium BCE (Weber et al. 2010). The soil types of the area are characterised by limestone derived clay, clay loam and silty clay, which are unsuitable for wetland rice cultivation (Pigott et al. 2006). For this reason, scholars suggested that either rice was not locally cultivated or that if it was, people adopted opportunistic cultivation strategies and cultivated rice in a dryland regime, much the same way as foxtail millet, also present at the sites, was cultivated (Castillo 2017, 344). This kind of dryland rice regime has been attested in the late first millennium BCE from Ban Non Wat, in central Thailand, and Khao Sam Kaeo and Phu Kao Thong, in southern Thailand **[fig. 32] [tab. 14]**.[21] At all three sites, rice is associated with seeds of *Acmella paniculata*, a dryland species that indicates rice was cultivated in a rainfed regime (Castillo et al. 2018a; 2016; Castillo 2013). Present day average annual precipitation in central Thailand is around 1,200-1,300 mm; this high level of precipitation would support rainfed rice agriculture **[tab. 3]**. Scholars have also noted the higher presence of wild animal taxa compared to domesticated ones from the early sites in central Thailand (Mudar, Pigott 2003; Pigott et al. 2006). This, together with the

20 For example, direct dates on charred millet grains from sites in Europe demonstrated that the seeds were intrusive to their layer of provenance, demonstrating the importance of directly dating charred grains (Filipović et al. 2020; Motuzaite-Matuzeviciute et al. 2013).

21 Kealhofer, Piperno 1994; Mudar 1995; Weber et al. 2010; Higham 2014; Wohlfarth et al. 2016; Castillo et al. 2016, 2018a; Castillo 2017, 2018.

archaeobotanical data, suggests a low intensity hunting and gathering subsistence supplemented by rainfed farming for the second and early first millennium BCE. Some scholars argue this indicates a persistence of local foragers subsistence traditions (d'Alpoim Guedes et al. 2020). This type of dryland agriculture in central mainland Southeast Asia would support linguistic reconstructions postulated by proponents of the 'Southern Riverine Hypotheses' according to which early Austroasiatic terminology included terms for upland (dry) cultivation, rather than lowland (wet) cultivation (Blench 2005; Sidwell, Blench 2011; see § 2.2.1.1). At Phu Kao Thong, in addition to rice, archaeobotanical flotation documented the appearance of pulse species dispersing from India, including mungbean (*Vigna radiata*), horsegram (*Macrotyloma uniflorum*), pigeon pea (*Cajanus cajan*)[22] and cotton (*Gossypium arboreum*; Castillo 2013; Castillo et al. 2016; Fuller, Castillo 2021). This indicates the establishment of maritime connection routes with India by the early first millennium BCE (Castillo, Fuller 2021).

At Ban Non Wat, dryland weed species decrease through time and wetland weed species, fox example *Diplacrum caricinum,* a typical rice paddy field weed, become predominant only from 100 BCE onward. This indicates that in this region wetland rice cultivation developed in the early first millennium CE (Castillo et al. 2018a; Fuller, Castillo 2021; Miller 2014). Water management practices in this time period have also been inferred from the presence of moats and water reservoirs structures at Noen U-Loke (450 BCE-500 CE) and Non Ban Jak, two sites not far from Ban Non Wat (King et al. 2014). At Noen U-Loke rice has also been reported (Castillo et al. 2018a).

Archaeobotanical remains from Vietnam are scarce. There are numerous reports of rice inclusions in pottery temper from sites in northern Vietnam dating to the second millennium BCE onward (Bellwood et al. 2011), and the transition from gathering to cultivation has been inferred based on the apparent decline in grinding stones at sites in Vietnam after the second millennium BCE. Domesticated rice has been identified at An Son and Loc Giang, in northern Vietnam **[fig. 32]**, through microCT scanning of rice inclusions in pottery temper (Barron et al. 2017). The site is dated to 2000-1300 BCE and at present is among the earliest conclusive evidence for domesticated rice in the region, although it has not been substantiated by direct dating. Recently, a study on starch residues from stone tools has indicated people may have been processing rice and possibly millet at Trang Kenh, in the Red River Basin in northern Vietnam, already in the late third millennium BCE (Wang W. et al. 2022), but this is not substantiated with macro-botanical remains, and the domesticated status of rice cannot be determined from starch grains. Rice and foxtail millet have been found at the site of Rach Nui, in southern Vietnam (1845-1385 BCE). Here, however, the crops are considered traded from inland rather than locally cultivated, in part due to the lack of rice inclusions in the locally produced pottery assemblage as well as the lack of suitable environmental growing conditions for either cereal (Castillo et al. 2018b).

In Myanmar, flotation was conducted at Halin located in the Irrawaddy River Basin in north Myanmar, close to the Yunnan's border (Neolithic occupation ca. 2500 BCE; Bronze Age transition ca. 1100 BCE; see Pryce et al. 2024); however, rice and millet seeds retrieved from the samples were

22 Pigeon pea may predate the arrival of the other species as *Cajanus* seeds have been reported from Non Pa Wai around 1100- 500 BCE (d'Alpoim Guedes et al. 2020).

later intrusions and no seed dated to either the Neolithic or Bronze Age period (D.Q. Fuller, pers. comm. 2025). Some preliminary information on the diet of ancient populations in Myanmar is available from a stable isotope study undertaken at the sites of Oakaie and Nyaung'gan, south from Halin, on the Chindwin River Basin, a tributary of the Irrawaddy. The two sites were occupied from the end of the second to the early first millennium BCE (Willis et al. 2022). Eighteen individuals were sampled from each site and the authors of the study interpreted the results as showing that people had a mixed C_3/C_4 diet ($\delta^{13}C$ values on dental calculus for Oakaie range from –8.6‰ to –4.9‰; Nyaung'gan –7.7‰ to –5.9‰), with some individuals being pure C_3 consumers and some being pure C_4 consumers (Willis et al. 2022, 12). It should be noted that for bone isotopic analyses such a range would indicate a predominately C_4 diet (see for example Liu et al. 2020 for China), but for dental enamel/apatite data such values are seen to be elevated (e.g., Tykot, Merwe, Hammond 1996). Given that as Willis et al. (2022, 11) state "Southeast Asia is largely a C_3 biome", the C_4 element of this diet is likely based on millet species. The authors further state in the conclusion that the sites are located in "the rainshadow of the Rakhine Mountains which is currently mostly not suitable for growing rice" (Willis et al. 2022, 12). Isotopes on pigs and bovids from the site show that pigs had a (according to the authors, mixed) diet similar to that of humans, and thus most likely consumed left over foods, while bovids had a largely C_4 based diet, consistent with grazing local grasslands. Locally available C_4 plants would include local wild Poaceae, job's tear (*Coix lachrymal-jobi*), and potentially foxtail or broomcorn millet if we presume a dispersal from China, possibly Yunnan, where foxtail and millet grains have been attested at Baiyangcun, ca. 2650 BCE, at least one millennium before the occupation of Oakaie and Nyaung'an. This hypothesis, however, cannot be confirmed, due to the lack of macro-botanical remains from Oakaie and Nyaung'gan (Willis et al. 2022).

5.4 Summary

The development of agriculture in Southeast Asia has been described as a "rapid and multi-directional" phenomenon (Oxenham et al. 2015, 310), which arose thanks to the 'greater Mekong' sphere, a network of interactions linking Vietnam, Thailand and Cambodia from at least the 2500 BCE (Bellwood et al. 2011). Archaeobotanical studies in mainland Southeast Asia are scarce and scattered; most of the available data coming from Thailand and dating to after ca. 2000 BCE. Here, the earliest documented agricultural systems were based on the dryland cultivation of foxtail millet. Rice spread to the area is attested later than that of millet, but itself was initially cultivated in a dryland regime, as demonstrated by the examination of the weedy flora associated to rice retrieved at Ban Non Wat, Khao Sam Kaeo and Phu Kao Thong. The most cited hypotheses in relation to the beginning of agriculture in mainland Southeast Asia was a spread from Yunnan in the context of the Austroasiatic languages dispersal (see § 2.2.1.1). The first documented agricultural systems in Thailand contrasts with farming systems attested archaeobotanically from Yunnan, where mixed rice-millet farming was present since the earliest stages of agricultural development.

At Baiyangcun, rice was most likely cultivated in a wetland regime, opposed to the dryland regimes attested in Thailand.

As opposed to a terrestrial route via Yunnan (itself traced back to Sichuan via Gansu, evidence by mixed farming at Guijiabao) **[figs 32-33]**, others have inferred that rainfed rice spread to mainland Southeast Asia through a coastal route via Guangdong/Guangxi (e.g., Castillo 2017; Castillo, Fuller 2010; Fuller et al. 2010). In Guangxi, rice and millet grains have been reported from Gantuoyan 感驮岩 (ca. 3500-1000 BCE; Lu 2009), but according to direct dates on seeds provided in the excavation report, these appear only in the second phase of occupation of the site (2000-800 BCE; Guangxi 2003, 55). Possible broomcorn millet (*Panicum miliaceum*) starch grains have been reported from Dingshishan site, dating to possibly as early as 5000-4000 BCE (Zhang et al. 2022a), but the identification of this find is disputed, and the antiquity of the material cannot be substantiated by direct dating. In Guangdong, recent archaeobotanical studies from the region have found evidence for mixed farming dating back the early third millennium BCE, for example at the site of Gancaoling (Deng et al. 2022a). Here, charred seeds of rice and foxtail millet have been directly dated to 2600 BCE, although the overall archaeobotanical assemblage is dominated by rice and only seven mature and eight immature foxtail millet grains have been retrieved (Deng et al. 2022a). In addition to cereals, other plant species at Gancaoling include *Canarium* sp., *Sambucus* sp., which may have been consumed, and wild weedy taxa indicative of a wetland landscape. The find of a *Canarium* endocarp, a tree nut that has been found at earliest sites in the region, shows a gradual transition to agricultural production rather than an abrupt change (Deng et al. 2019; 2022a). Although the origin for the spread of agriculture in the area is attributed to migrant rice farmers from the Yangzi Valley (via the Jiangxi Mountains), recent ancient DNA studies evidenced a mixture of local groups with Yangzi derived groups, indicating that farmers did not replace local hunter-gatherers but mixed with them (Matsumura et al. 2019; Yang M.A. et al. 2020; Wang et al. 2021). Further east on the Chinese coast, the earliest attested rice and foxtail millet grains have been documented at Nanshan 南山 (Yang et al. 2018; Carson, Hung 2018) from layers dated between 3300-2400 BCE, albeit the chronology was established on radiocarbon dating of charcoal and rice seeds, not millet seeds **[figs 32-33]**. If those millet seeds are not intrusive to their layers of provenance, this would place the spread of millet to this region from at least the mid-third millennium BCE, if not earlier. Other sites with archaeobotanical remains have also been reported in southern China dating to the early second millennium BCE (e.g., Deng et al. 2018; Yang et al. 2017, 2018). Scholars argued that the hilly landscape of Fujian may have been conducive to the development of dryland rice cultivation (Deng et al. 2018); however, this hypotheses has not yet been corroborated by either archaeobotanical weedy flora or phytoliths studies. Further archaeobotanical research might clarify this issue and at present the origin of the development of rainfed rice cultivation is still unanswered. The arrival of millet and later arrival of rice in mainland Southeast Asia indicate successive waves of dispersals or even separate routes of introductions for the two species **[fig. 33]**. Evidence of Indian legumes at Phu Kao Thong after the initial emergence of agriculture in the region indicates continued interactions and multiple waves of dispersal through the millennia. The emergence of metallurgy later than the initial spread of agricultural crops further demonstrates continued connections (Ciarla 2013, 221). Therefore, the history of cultural, agricultural and possibly demographic diffusion from China into mainland Southeast Asia does not appear to have been a single, clearly defined southward dispersal in terms of chronology and geographical direction. Instead, increasing evidence highlights a complex series of overlays that may have followed terrestrial, riverine and coastal routes across several millennia, through which agricultural and technological innovations emerged.