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Post-Neolithic broadening of agriculture in Yunnan, China: Archaeobotanical evidence from Haimenkou

Yining Xue* [1], Rita Dal Martello *[2,6], Ling Qin [3 4], Chris J. Stevens [4], Rui Min [5] & Dorian Q Fuller[6,7,1]

1 Institute of Archaeological Science, Fudan University, 200433 Shanghai, China
2 Max Planck Institute for the Science of Human History, Kahlaische Str. 10, 07745 Jena, Germany
3 Center for the Study of Chinese Archaeology, Yiheyuan Rd. 5, Haidian District, Peking University, 10087 Beijing, China
4 School of Archaeology and Museology, Peking University, Yiheyuan Rd. 5, Haidian District, 10087 Beijing, China
5 Yunnan Province Institute for Cultural Relics and Archaeology, 650118 Kunming, China
6 Institute of Archaeology, University College London, Gordon Sq. 31-34, WC1H 0PY London, UK
7 School of Cultural Heritage, Northwest University, 710127 Xi'an, Shaanxi, China

Corresponding author: dalmartello@shh.mpg.de ORCID: 0000-0001-8367-1309

*these authors contributed equally to this work

Abstract: We report archaeobotanical results from systematic flotation obtained during the 2008 excavation of the site of Haimenkou, in Northwest Yunnan, dated to c. 1600-400 BC. Haimenkou is thus far the earliest site with evidence for wheat and barley in Yunnan and provides essential evidence for tracing the spread of the two crops into Yunnan, as well as for the understanding the agricultural production development in the province from the second millennium BC onward. People at Haimenkou were practicing a mixed-crop farming strategy based first on rice and millet, and with the addition of wheat from c. 1400 BC. Between c. 800-400 BC archaeobotanical remains attests to a general decrease of millet and rice production in favour of wheat, possibly linked with climate deterioration. Other important cultivars present include large quantities of *Chenopodium* (associated with other cereal crops remains such as rice and millets), *Perilla* (Shisoo) seeds, and few grains of buckwheat, all possibly utilized as crop. Additionally, *Cannabis* seeds have also been retrieved, but at present it is unclear whether this species was exploited for oil or to obtain textile fiber, or for other uses. Several fruits species have also been retrieved, including peaches (*Prunus persica*), apricots (*Prunus armeniaca*), raspberries (*Rubus* sp.), grape (*Vitis* sp.), melon (*Cucumis melo*), and jujube (*Ziziphus jujubas)*, although these are present in minor quantity in relation to crops and might indicate that wild resources collection had a secondary role to crop cultivation.

Keywords: Paleoethnobotany, Wheat, Buckwheat, Bronze Age, Domestication, Yunnan

Word count: ~9,000

1. Introduction

Yunnan province in Southwest China lies on the crossroads of the Yangtze basin, the rivers of mainland Southeast Asia (the Salween and the Mekong), the Tibetan Plateau, and mountain tracts leading to the Indian subcontinent. It has been seen as a pivotal region in the spread of cultural traditions, including perhaps agriculture and likely bronze working into mainland Southeast Asia (i.e. Higham 1996; Yao et al. 2020), as well as providing potential routeways for the spread of crops moving in both directions. Yunnan may be involved with several south/west dispersal events, including rice between China to India (cf. Van Driem 2017; Silva et al. 2018), a later diffusion of glutinous rice varieties found in the Himalayan zone in India and associated with areas with Tibetan-Burman minority languages (Fuller et al. 2016b), and likely buckwheat and barley varieties associated with Tibetan and Bodic speakers (Hyslop and D'Alpoim Guedes 2020). In terms of west to east movements into Yunnan, there is discussion of cereals such as wheat and barley from India into East Asia (Lister et al. 2018; Liu et al. 2017), sorghum (Fuller and Stevens 2018), Indian sawa millet (*Echinochloa frumentacea*) and finger millet (*Eleusine coracana*) (Blench 2016), and pulses of Indian origin such as *Vigna radiata* or *Cajanus cajan,* the latter now being feral throughout the tropical south of China (Fuller et al. 2019). The topographic variability contributes to high biodiversity (Qian et al. 2020; Li and Yue 2020), and the region is also an ethnolinguistic diversity hotspot (Chirkova 2017). Until recently, however, archaeobotanical evidence for early farming in the region has been limited. With the increasing deployment of flotation during archaeological excavations in China, it is increasingly possible to assess when various crops were introduced to the region, including those originating elsewhere within China (such as rice, millets, soybean or hemp), those that originated outside China, such as wheat, barley or Indian crops like mungbean (*Vigna radiata*) or sawa millet (*Echinochloa frumentacea*), and potentially locally domesticated taxa (indigenous to Yunnan or adjacent areas), such as buckwheat (*Fagopyrum esculentum*), *Chenopodium album* or even soybean. The present paper reports on the rich archaeobotanical record from the site of Haimenkou, which spans the mid-second to the first millennium B.C, corresponding to the Late Neolithic through the Bronze Age of the province, and provides an up to date discussion of these issues.

2. Haimenkou site and excavations

Haimenkou is located in the Dali Bai Autonomous Prefecture in Jianchuan county, Northwest Yunnan (26.466914 N, 99.919778 E; Fig. 1). Jianchuan county is located in the wider Jinsha River Basin, a tributary of the Yangtze River, presenting a mountainous landscape, with elevations reaching between 3600-1000 m asl; the site of Haimenkou itself lies at 2190m asl (Min 2013). The influence of the subtropical monsoon produces distinct rainy and dry seasons, occurring respectively between May-October and November-April. Annual precipitation in this area is about 1000-1200ml, with only 5% of it occurring during the dry season (Zhang 1994). Annual average temperature is about 12-15 °C (Li and Walker 1986). The site was occupied at a time of general monsoon activity deterioration, with overall environmental conditions cooler and drier than the previous millennium and a climatic event associated with a sharp drop in the monsoon intensity taking place at c. 1500 BC and bringing climatic conditions in the region close to those of present day (i.e. Dearing et al. 2008; Shen et al. 2006; Shen et al. 2005; Dykoski et al. 2005).

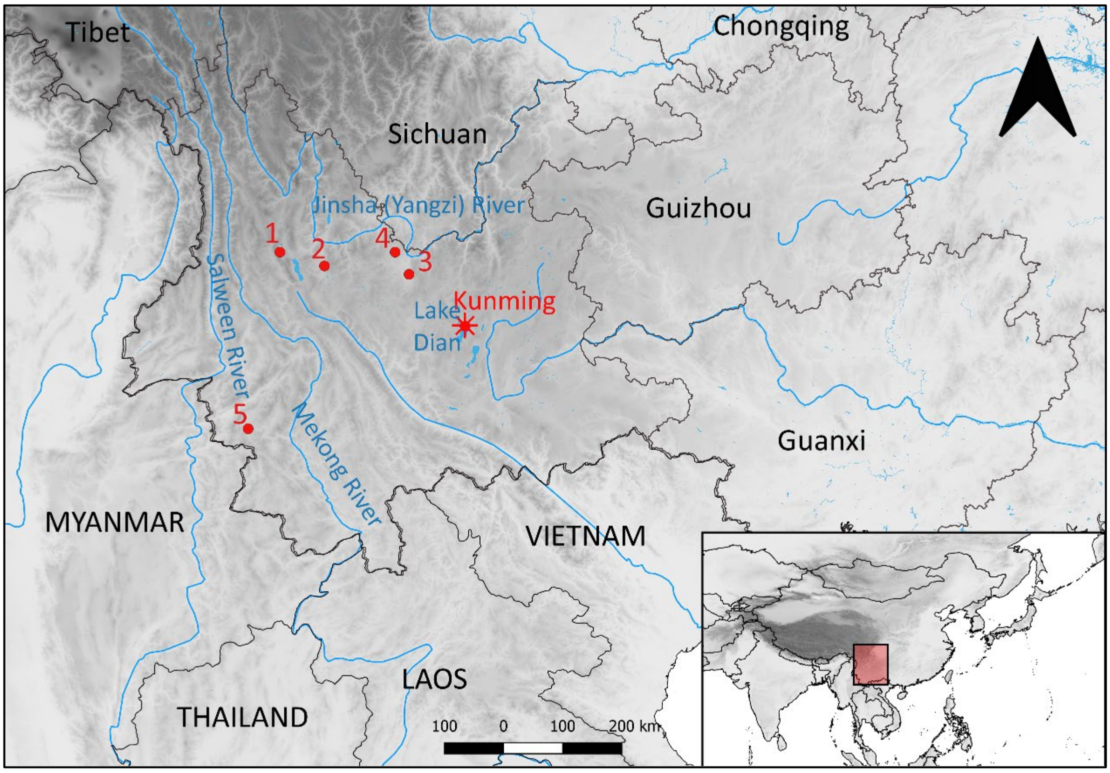

Figure 1. Map showing location of study area and sites mentioned in text: 1. Haimenkou; 2. Baiyangcun; 3. Dadunzi; 4. Mopandi; 5. Shifodong. Made with QGIS

Haimenkou was first discovered in 1957, and subsequently underwent several seasons of excavation; the first in March-April 1957 (YPM 1958); the second in April 1978 (Xiao 1991;

(Xiao 1995), and the third one in January-May 2008 (YIPCRA et al. 2009). Further excavations are currently being undertaken by Sichuan University, which has been leading annual campaigns at the site since 2016. The site extends over ~5 ha, and is regarded as the largest Neolithic site in Yunnan (Yao 2010) built in or adjacent to wetland on the Heihui river as it flows into Jianhu lake. The site features mostly represent rectilinear pile dwellings, with the bases of posts mostly of pine preserved by waterlogging, (Yao 2010; Gao et al. 2014). One especially large wooden structure may have been as large as 2 ha, the largest structure attributed to the Chinese Neolithic to date (Yao 2010). Finds of bronze objects at the site prompted decades-long debates surrounding the nature and the chronology of Haimenkou. Charred wood samples were taken in 1972 dating the site to 3115±90 BP/ 1150±90 BC (CASS 1972), with further samples were taken in 1990 providing dates of 2595±75 BP/ 645±75 BC and 2520±75 BP / 570±75 BC for the later levels (CASS 1990).

In order to clarify the chronology of the site, in 2008 the Yunnan Provincial Institute of Archaeology launched a new excavation campaign. On this occasion, a total area of 1395 m^2 divided in 27 trenches of 5*10m size was excavated (Fig. 2). Ten cultural layers were individuated throughout the site. More than 3000 objects were unearthed, including ceramic remains, lithic and bone tools, wooden tools, bronze and iron objects. In regards to metal objects, none were found in the earliest deposits (layers 10-8), bronze objects were found from layers 6 to 4, and in layer 3 iron objects were found (see Li and Min 2014 for an analysis on the composition of metal objects from Haimenkou, and a discussion on early metal production in Yunnan). Over the 2008 season of excavation flotation was carried out and archaeobotanical samples were taken from trenches T1003, T1004, and T1005 (Fig. 2). This allowed for a more precise chronology to be obtained through the selection of charred annual plant remains, which were submitted for AMS radiocarbon dating, establishing the following chronology (from Xue 2010):

1. Phase I (Neolithic) 1600- 1400 cal BC layers 10-9-8;
2. Phase II (Neolithic/Bronze Age Transition) 1400-1100 cal BC layer 7-6;
3. Phase III (Bronze Age) 800-400 cal BC layers 5-4-3.

Detailed excavation reports for any excavation campaign have yet to be published. We report here on archaeobotanical evidence, incorporating initial sorting carried out by QL & DF to obtain dating samples, work by Xue (2010), and further work by Dal Martello (2020). A previous archaeobotanical assessment of Haimenkou was completed by Jin (2013) who studied additional subsamples from trenches DT1003, DT1004, DT1005 (see Supplementary Material S1); those data counted waterlogged and charred seeds together. As our analysis focused on the charred dataset, we have excluded these from assessments of relative frequency, but we include them in overall assessment of ubiquity (Fig. 3). In general, those data reproduce the patterns found by Xue (2010). Finally, large charred and waterlogged plant remains were hand-picked during excavation (See Supplementary File S4); these are not included in the quantitative analysis here but pictures are provided as supplementary material.

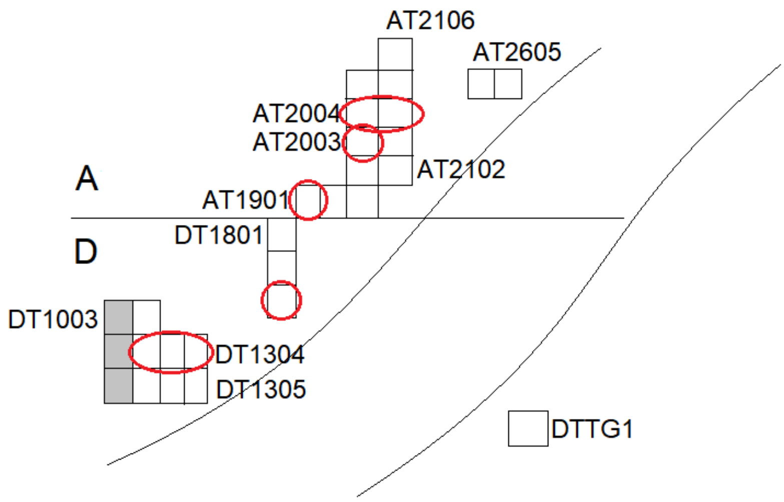

Figure 2. Excavation area and provenance of archaeobotanical samples from Haimenkou; systematically collected samples from trenches DT1003, DT1004, DT1005 shown in filled light grey; trench location of hand-picked samples indicated in red circles. Map redrawn from YPICRA (2009).

Haimenkou has been important for the documentation of faunal remains. A study on the animal bones retrieved during the 2008 excavation has revealed the presence of both domestic and wild animals, including pig (*Sus domesticus*), the most prevalent taxa through the occupation of the site, sheep/goat (*Ovis/Capra* sp.), dog (*Canis familiaris*), and gaur (*Bos gaurus*). Sheep/goat remains, although present since the initial occupation of the site as well as at Baiyangcun (YPM 1981), a nearby site dated to between 2650- 1690 cal BC (Dal Martello et al. 2018), show an increase trend from c. 1400 BC onward, corresponding to the second and third phases of occupation and in conjunction with the appearance of wheat and barley at the site (Wang 2018); nevertheless the introduction of domesticated caprines prior to the start of Haimenkou implies that these livestock were introduced before wheat and barley. Gaur remains constitute the most prevalent taxa among the "wild" mammals, and Wang (2018) hypothesized it was under human management. Today, gaur presence is limited to

Southern Yunnan and nearby areas; gaur is also the wild progenitor of modern gayal (*Bos frontalis*), which herded today only sporadically amongst minority people across Northeast India and Myanmar (Simoons and Simoons 1968; Shaller 1967; Larson and Fuller 2014; Murphy and Fuller 2018: fig. 8). The find of gaur remains from second millennium BC northwest Yunnan could imply that initial gayal herding might have taken place further north in the past, and only later pushed southward from there to those regions where it is documented historically. Previous hypotheses on its domestication proposed that might have been domesticated around 2000 years ago (Larson and Fuller, 2014). Notably, no true cattle (*Bos taurus/ B. indicus*) nor water buffalo (*Bubalus bubalis*) remains have been found from Haimenkou. Finds of *B. taurus* are recorded in Central China from c. 2000 BC (Yuan 2010; Fuller et al. 2011; Huang et al. 2010; Peng et al. 2017), while domesticated water buffalo were not introduced to central China before the Bronze Age (Yang et al. 2008).

3. Materials and Methods

Over the course of the 2008 excavation season, flotation was carried out and archaeobotanical samples were systematically taken covering a complete stratigraphic sequence from layer 3 to layer 10 from the bulks of trenches DT1003, DT1004, and DT1005; additional hand-picked samples were also taken from selected contexts in the rest of the excavation area. The samples from trenches DT1003, DT1004, DT1005 on the western side are from a sample column in the section taken after the stratigraphy was defined for the purposes of chronological modelling. The additional hand-picked samples were taken where the excavators encountered contexts rich in plant remains across the entire site. Of these, 9 were selected as a subset of the richest/largest samples with the aim of obtaining higher taxa diversity through the sequence and come from trenches DT1104, DT1204, DT1304, DT1803, AT1901, AT2003, AT2004, AT2104 (Fig. 2, Supplementary Materials S1 and S2). This paper presents the results from 58 samples, from 36 individual archaeological contexts, including both systematically collected (subsamples from trenches DT1003/1004/1005, se Fig. 2) and 9 selected hand-picked samples (from contexts DT1104, DT1204, DT1304, DT1803, AT1901, AT2003, AT2004, see Fig. 2); systematically collected samples were 5L on average (Table 1, Xue 2010). Floats were collected using a 0.3mm mesh, dried naturally and then sieved to obtain fractions of 2mm; 0.9mm; 0,45mm; and a fine fraction of >0.3mm. The samples presented in this paper were sorted at the Archaeobotanical Laboratory at Peking University, Beijing, and at the Archaeobotany Laboratory at the UCL Institute of Archaeology, London. Macro-botanical remains were extracted from each fraction, and analyzed under a low power stereo binocular microscope, with magnification up to 40x. Identifications were recorded following the nomenclature of revised *Flora of China* (Wu et al 2013; www.efloras.org). Selected specimens were photographed or imaged by scanning electron microscope. While all studied samples are listed in Table S1, quantified data reported here (seed counts, relative frequency) include those studied by Xue (2010), Dal Martello (2020) and some additional hand-picked samples (Tables 1 and 2), as those reported in Jin (2013) did not differentiate charred and waterlogged specimens; presence/absence and ubiquity data regarding waterlogged remains can be found in Supplementary Material S1.

4. Results:

4.1. General features of the assemblage and key economic taxa

A total of 117,857charred identifiable remains from about 20 families and over 30 species were recovered from the analysis of the Haimenkou samples, of which 23,242 from systematically collected samples and 94,609 from hand-picked samples (Tables 1, 2, and 3). Identifiable remains were divided in the following categories: crops, seeds of field weeds and other wild weedy species, pulses, wild fruits, and other possibly utilized economic plants (Supplementary Material Table S1; Fig. 8-9). In addition, many samples included uncharred, waterlogged taxa. Many of these are likely to have been deposited secondarily from natural wetland taxa due to water level rises in prehistory. Waterlogged taxa have been quantified and reported separately (see Supplementary Material S1, Table S1B and Fig. S1A).

	No. of analyzed contexts	Total ID remains	Density (items/L)	Sampling Strategy
Period 1	9	13,144	202.2	Systematically collected
	1	4	n/a	Hand-picked
Period 2	6	7794	103.9	Systematically collected
	7	84,263	n/a	Hand-picked
Period 3	7	2304	25.6	Systematically collected
	3	10,342	n/a	Hand-picked

Table 1. Summary of Haimenkou charred archaeobotanical assemblages.

Phase	1 1600- 1400 cal. BC	2 1400-1100 cal. BC	3 800-400 cal. BC
Volume floated (liters)	c. 65 L	c. 75 L	c. 90 L
No. of contexts	9	6	7
Field crops			
Oryza sativa (grains+fragments+spikelet bases)	2155	1464	35
Triticum aestivum (grains+fragments+rachises)	*11*[1]	267	752
Hordeum vulgare	--	6	7
Setaria italica	2990	735	216
Panicum miliaceum	46	12	1
Indet. millets	21	2	--
Fagopyrum cf. *esculentum*	1	1	2
Other inferred crops			
Cannabis sativum	16	31	--
Chenopodium cf. *album*	6330	1754	7
Perilla sp.	--	--	--
Pulses			
Glycine cf. max	7	66	19
Fruits and nuts			
Prunus sp.	4	2	1
Prunus persica	--	--	--
Prunus armeniaca	--	--	--
Rubus sp.	3	34	21
Vitis sp.	--	2	--
Cucurbitaceae	--	--	--
Cucumis melo	--	--	--
Acorn indet.	--	--	--
Nut shells	1	--	--
Euryale ferox	--	--	--
Grasses			
Setaria viridis	108	54	3
Setaria cf *verticillata*	--	18	--
Echinochloa sp.	--	38	--
Digitaria sp.	30	140	4
Avena cf	--	--	--
Other wild weedy species			
Indet. Poaceae, wild	34	46	3
Verbena officinalis	20	205	11
Galeopsis sp.	2	56	1
Leonurus sp.	--	48	--
Stellaria sp.	2	16	--
Oxalis sp.	4	2	--
Torilis japonica	--	--	--
Sedges and other wetlands			
Cyperus sp.	48	105	7
Juncellus sp.	21	116	3
Juncaceae	--	--	--
Carex sp.	425	698	109
Polygonum sp. (sensu stricto)	70	101	87
Persicaria sp.	5	55	57

[1] Eleven wheat grains recovered from layer 8 have been excluded in the quantitative analyses as direct radiocarbon dating revealed they were intrusive from later periods (see section 4.2.3 in text).

Scirpus sp. Type A	48	362	237
Scirpus sp. Type B	4	--	40
Scirpus juncoides	9	14	1
Scirpus triangulatus	--	11	--
Indet. sedge	442	624	41
Najas sp.	--	--	2
Butomus sp.	3	--	--
Mosla sp.	23	88	--
Brassicaceae	--	--	168
Other wild species			
Bombax sp.	--	22	--
Hibiscus sp.	--	--	--
Apiaceae	2	12	14
Asteraceae	22	34	14
Convolvulaceae	94	87	20
Fabaceae	--	--	--
Lamiaceae	9	33	13
Unidentified remains	134	433	408
Total charred macro-remains	**13,144**	**7794**	**2304**

Table 2. Summary of charred remains from Systematically collected flotation samples from trenches DT1003/1004/1005, with total counts of the main crops and species represented by macro-remains.

Phase	1 1600- 1400 cal. BC	2 1400-1100 cal. BC	3 800-400 cal. BC
No. of contexts	1	7	3
Field crops			
Oryza sativa (grains+fragments+spikelet bases)	--	220	2577
Triticum aestivum (grains+fragments+rachises)	--	262	17
Hordeum vulgare	--	2	1
Setaria italica	3	81,941	239
Panicum miliaceum	--	43	--
Fagopyrum cf. *esculentum*	--	2	--
Other inferred crops			
Chenopodium cf. *album*	--	788	7032
Cannabis sativum	--	769	--
Perilla sp.	--	130	456
Pulses			
Glycine cf. max	--	3	--
Fruits and nuts			
Prunus sp.	--	3	--
Prunus persica	--	3	--
Prunus armeniaca	--	4	--
Rubus sp.	--	6	--
Cucurbitaceae	--	1	1
Cucumis melo	--	--	1
Acorn indet.	--	--	1
Nut shells	--	2	1
Euryale ferox	--	1	1
Grasses			
Setaria viridis	1	9	6
Setaria cf *verticillata*	--	5	--
Echinochloa sp.	--	1	--
Digitaria sp.	--	2	3
Avena cf	--	4	--
Other wild weedy species			
Indet. Poaceae, wild	--	14	1
Verbena officinalis	--	1	--
Galeopsis sp.	--	--	1
Leonurus sp.	--	4	--
Torilis japonica	--	1	--
Sedges and other wetlands			
Cyperus sp.	--	15	--
Juncaceae	--	1	--
Carex sp.	--	4	--
Persicaria sp.	--	11	1
Najas sp.	--	1	--
Butomus sp.	--	2	--
Hibiscus sp.	--	1	--
Asteraceae	--	4	--
Fabaceae	--	--	1
Lamiaceae	--	--	1
Unidentified remains	--	2	1
Total charred macro-remains	4	84,263	10,342

Table 3. Summary of charred remains from hand-picked samples from trenches DT1104, DT1204, DT1304, DT1803, AT1901, AT2003, AT2004.

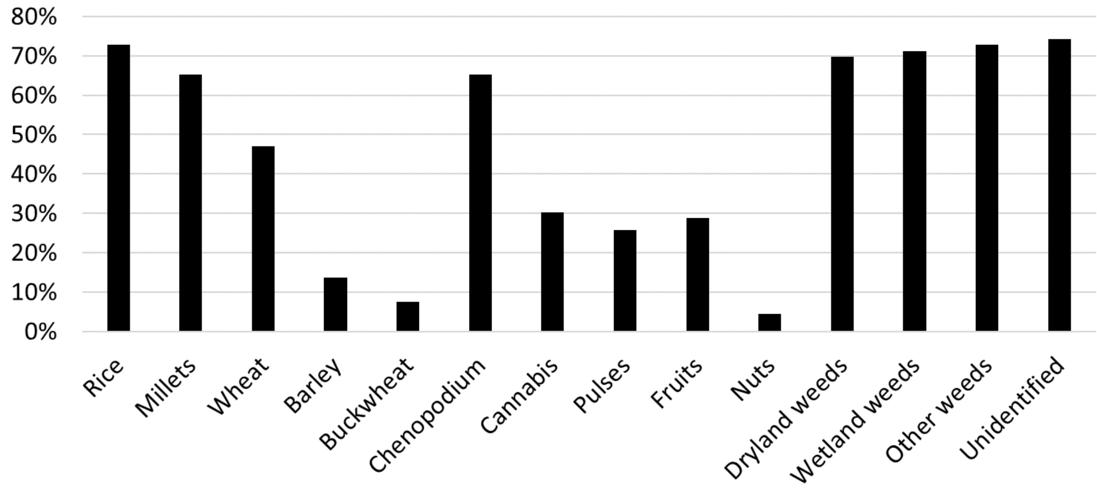

Figure 3. Ubiquity index of main archaeobotanical remains from all analysed samples (including systematically and hand-picked collected samples) from Haimenkou. Data from Xue (2010); Jin (2013); and Dal Martello (2020).

4.2. Field Crops

Annual crops are well represented at Haimenkou. Species retrieved include: rice (*Oryza sativa*), foxtail millet (*Setaria italica*), wheat (*Triticum aestivum*), barley (*Hordeum vulgare*), broomcorn millet (*Panicum miliaceum*) and buckwheat (*Fagopyrum* cf *esculentum*). *Chenopodium album* may also represent a crop, showing a ubiquity comparable to that of other cereal crops (Fig. 3). Crop remains are especially prevalent in hand-picked samples, and are the second most numerous categories after seeds of weedy taxa in the systematically collected samples from DT1003, DT1004, DT1005 (Tables 2 and 3).

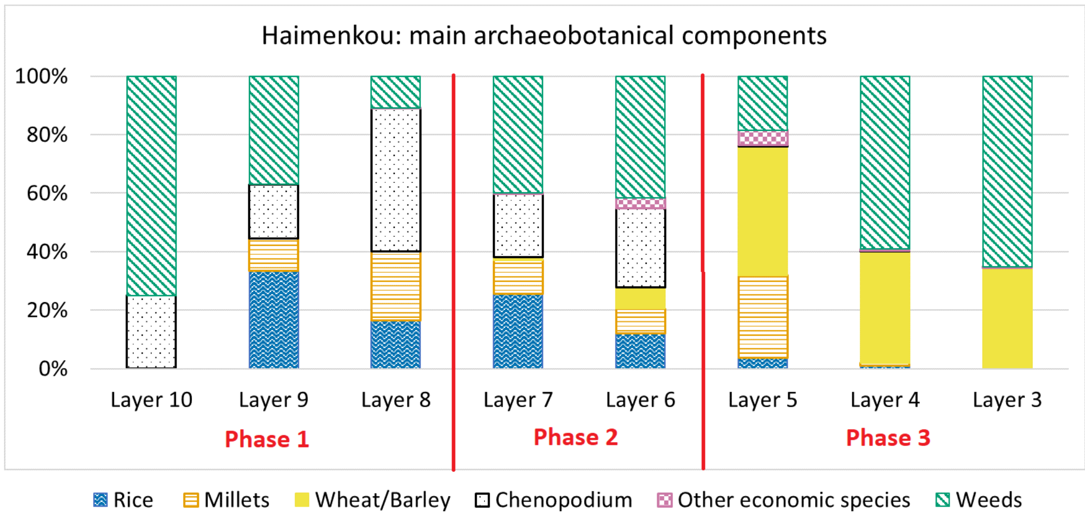

Figure 4a. Main archaeobotanical categories from systematically collected samples at Haimenkou plotted by layer, indeterminate remains have been excluded (See Supplementary Material Table S2 for total counts).

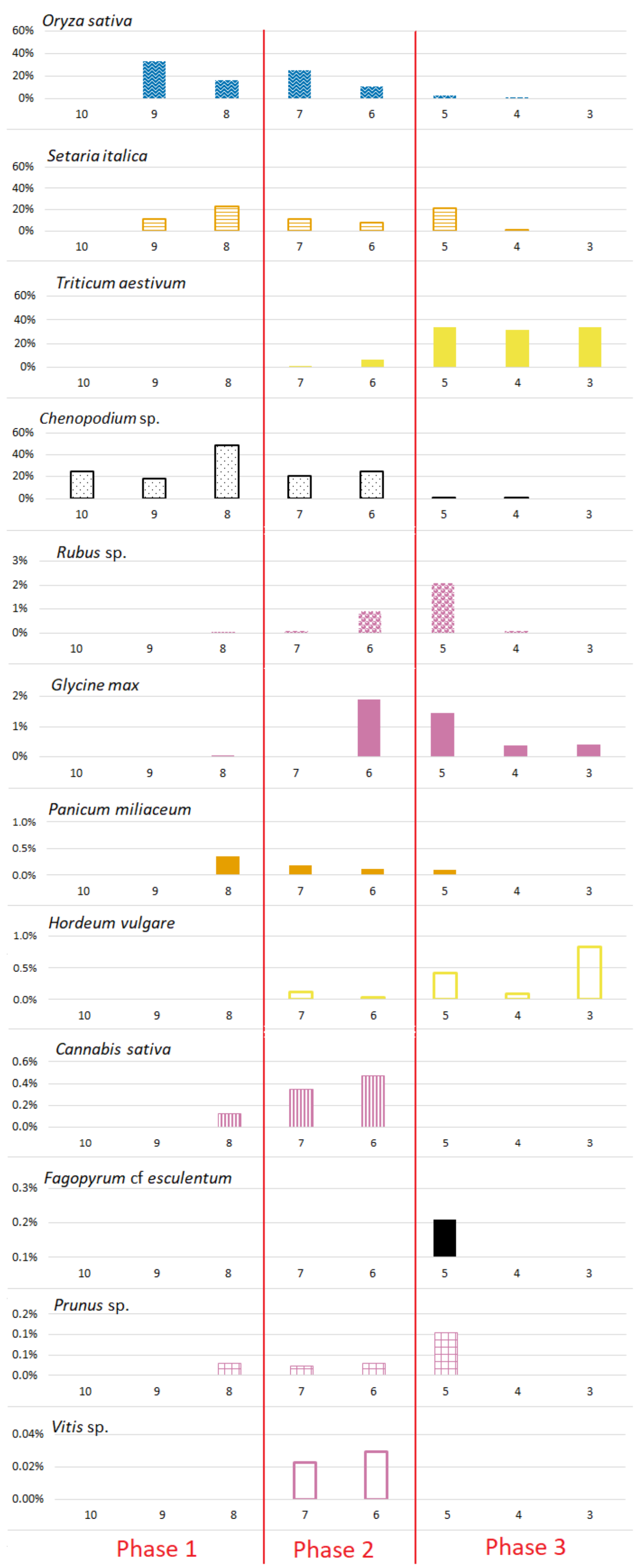

Figure 4b. Frequency of main archaeobotanical species from systematically collected samples plotted by layer (see Supplementary Material Table S2 for absolute counts).

4.2.1. Rice- *Oryza sativa*

From a stratigraphic point of view, rice remains were recovered from layer 9 to layer 4, however only 1 sample from layer 3 was analyzed and contained only few archaeobotanical remains (Supplementary Material Table S2; Fig. 4a, 4b). Rice remains include whole and fragmented grains, half of which had visible husks, and over 1600 spikelet bases (Table S2). These were mostly recovered from deposits from layer 8 to 6 (corresponding to the first and second phases of occupation, Fig. 4b). Rice spikelet bases recovered were almost all of the domesticated type. In hand-picked contexts DT1304⑥, DT1304⑤, and AT1901⑥ large “lumps” of charred rice have been recovered (Figs. 6; S4A; S4B); additionally, straws bundles have been retrieved from hand-picked context AT2004⑥ (Fig. S4K), however whether or not these represent rice straws is unclear.

Rice remains decrease over time in the DT1003, DT1004, DT1005 sequence, with a sharp decline occurring between the second and third phase of occupation; however, over 2000 rice grains have been recovered from hand-picked sample DT1304⑤, but these have not been directly radiocarbon dated. It is therefore unclear as to whether there was a strong temporal trend in rice or rather spatial variation across the settlement in terms of frequency of rice versus millet/wheat processing.

Ninety-eight whole and well-preserved rice grains were measured; the average width was 2.8mm (stdev 0.3mm); average L/W ratio was 1.7mm (stdev 0.19mm). All measured grains but one had a L/W <2.2mm (Supplementary Material Table S3), therefore, rice from Haimenkou has been classified as *Oryza sativa* subsp. *japonica* (as per Castillo et al. 2016). These grains fit amongst other domesticated *japonica* rice reported from China and Yunnan (e.g. Fuller et al. 2010; Deng et al. 2015; Dal Martello et al. in press). One rice grain from layer 9 (the earliest deposit where rice grains were found) was submitted for AMS radiocarbon dating and furnished a date of 1600- 1440 cal BC (Xue 2010).

Figure 5. Charred lumps of rice from context DT1304⑤. Photos by Rita Dal Martello (From Dal Martello 2020).

Early remains of rice have been found through flotation analyses in Yunnan at the sites of Baiyangcun (2600-2200 cal BC, Dal Martello et al. 2018; Dal Martello 2020) and Dadunzi (2200-1600 cal BC, Jin et al. 2014). It is generally believed that rice was brought to Yunnan from the Yangzi valley (Zhang and Hung 2010; Yao 2010), where it was cultivated by at least the seventh millennium BC and domesticated by the fifth millennium BC (Deng et al. 2015; Fuller et al. 2016a). No earlier rice remains are known from the province, and at Baiyangcun and Dadunzi rice is found together with millet remains from the earliest deposits. This would seem to suggest that both rice and millets reached Yunnan together already domesticated, possibly from Sichuan, where both rice and millet are found at the Baodun site (2700-1700 BC, d'Alpoim Guedes et al. 2013; D'Alpoim Guedes 2013).

4.2.2. Millets- *Setaria italica* and *Panicum miliaceum*

Two species of millet were found at Haimenkou: *Setaria italica* (foxtail millet), and *Panicum miliaceum* (broomcorn millet), although the latter is present in very low quantity (less than 0.3%), suggesting that this was rarely cultivated as a crop; it might have been a minor crop or even have persisted as a weed in fields of foxtail millet. Around half of all the millet grains recovered were husked, and charred lumps of millets were recovered from DT1003⑧, as well as hand-picked sample DT2004⑥; a close examination of these lumps revealed that they represent whole millet panicles, with grains still attached to the inflorescence (Fig. 6), an indication that they charred before most of crop-processing activities. This could be indicative that harvested millets (*Setaria italica*) were sometimes stored unprocessed and on the spike. One traditional method for storing panicles of foxtail millet that have been selected for propagation, rather than consumption, is to hang them in bundles and only thresh them the following spring before sowing (Li and Wu 1996). Similar storage of unthreshed spikes/panicles is also common among African millets (e.g. Cappers 2019).

A foxtail millet grain from layer 9 (the earliest deposit where foxtail millet remains were found) was submitted for AMS radiocarbon dating and furnished a date of 1610-1420 cal BC (Xue 2010). This date is in line with rice remains from the same deposit, indicating the importance of these two crops from the period of initial site foundation. Among the hand-picked samples, one contained an extremely high quantity of foxtail millet grains (AT2006⑥), most likely representing a storage unit.

A total of 54 grains of *Setaria italica* from Haimenkou were measured, averaging 1.30mm in length (stdev 0.10mm), 1.33mm in width (stdev 0.11mm), and 1.15mm in thickness (stdev 0.15mm). Average L/W ratio was 0.98mm (stdev 0.11mm). These measurements are comparable to domesticated foxtail millet reported from sites in central China (e.g. d'Alpoim Guedes et al. 2013; Stevens, unpublished data), and later periods in Yunnan (e.g. Yang 2016; Dal Martello et al. 2021). Moreover, two grains of *Panicum miliaceum* were also measured: average length was 1.66mm, width 1.98mm, and thickness 1.40mm; average L/W was 0.09mm (Table S3); these fit amongst domesticated *P. miliaceum* grains from central China from the Late Neolithic (Stevens et al. 2020).

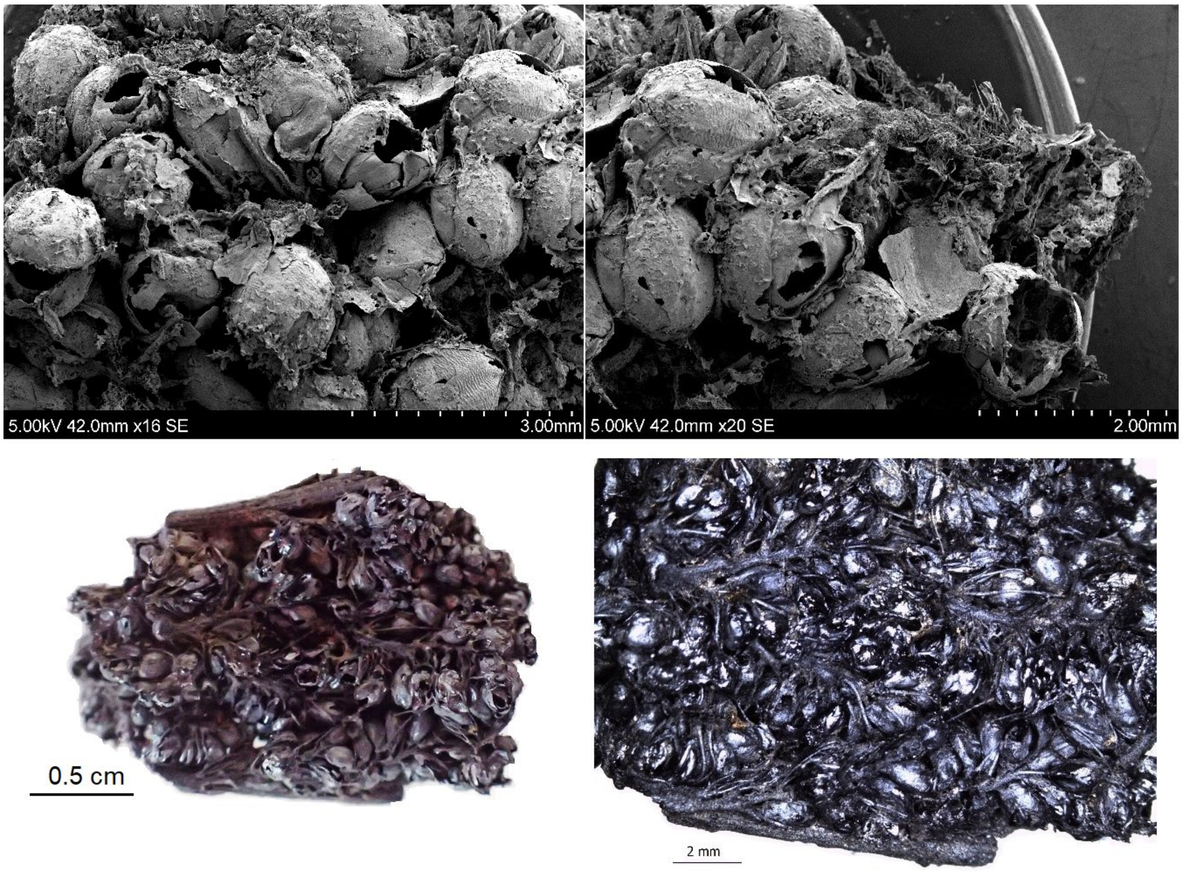

Figure 6. Top: SEM pictures of charred foxtail millet spike from context DT1003⑧. Bottom: Photo and close-up of charred foxtail millet spike from context AT2004⑥. Photos by Rita Dal Martello; from Dal Martello (2020).

Millets, both *Panicum miliaceum* and *Setaria italica,* were domesticated in North China by the sixth millennium BC (Stevens et al. 2020; Liu et al. 2019; Shelach-Lavi et al. 2019; Stevens and Fuller 2017; Crawford et al. 2016; Zhao 2011; Barton et al. 2009; Lu et al. 2009). Several domestication centers have been proposed in Hebei, Henan, Shandong, Gansu and Inner Mongolia (see Stevens et al. 2020; Liu et al. 2018; Stevens and Fuller 2017; Lu et al. 2009; Cohen 2011; Yan 1992; Zhu 2013; Bettinger et al. 2010; Zhao 2011; Ren et al. 2016). Some finds have suggested even earlier cultivation by 8000 BC (Zhao et al. 2020; Yang et al. 2012; Yang et al. 2015; Bestel et al. 2014; Zhao 2014). Nevertheless, in Southwest China, millets were introduced already domesticated, reaching Sichuan before 5000 years ago, and Tibet and Yunnan by ca. 4500 years ago (see Dal Martello et al., 2018; D'Alpoim Guedes 2013; d'Alpoim Guedes et al. 2015; d'Alpoim Guedes 2018; Zhao and Chen 2011). The earliest finds from Yunnan come from the Neolithic site of Baiyangcun, dating from ca. 2600 BC onwards (Dal Martello et al., 2018). At both Baiyangcun and Dadunzi (Jin et al., 2014), millets occupy a major percentage of the species recovered at the sites, suggesting a major role in the subsistence regime.

4.2.3. Wheat- *Triticum aestivum*

Wheat remains represent the third most popular crop at Haimenkou, appearing from the second phase of occupation (c. 1400 BC, layer 7) and showing an increase trend (Fig. 4a). Although a few grains of wheat were found in layer 8, direct AMS dating from sample DT1005⑧ of both rice and wheat grains furnished 1610-1460 cal BC and 1420-1300 cal BC respectively, and a further wheat grain from DT1005⑦ furnished a date of 1440-1310 cal BC (Xue 2010), providing a time frame for the arrival of this western domesticate to Haimenkou in the second period of occupation of the site (corresponding stratigraphically to layers 7 and 6 and dating to c. 1400-1000 BC), and highlighting the importance of directly dating cereal grains (Deng et al. 2020; Long et al. 2018).

Forty-one grains of wheat were measured (Table S3). Their average width was 3.37mm (stdev 0.37mm); L/W ratio was 1.46mm (stdev 0.17mm).

Glume wheat species (*Triticum monococcum* sensu lato*, T. dicoccon*) were originally domesticated in southwest Asia between 9500-7000 BC, with *T. cf. timopheevi* domesticated somewhat after this (Allaby et al. 2017; Arranz-Otaegui et al. 2016; Oliveira et al. 2020; Fuller et al. 2012; Lucas and Fuller 2018). Free-threshing wheat, including the hybrid bread wheat (*Triticum aestivum*) also evolves in this same general region, with early free-threshing tetraploids in the Levant by ca. 7500 BC (Feldman and Kislev 2007) and hexaploid bread wheats present in central Turkey before 7000 BC (Bogaard et al. 2017). In the eastward dispersal of the wheats, which had reached southern central Asia and Pakistan by ca. 6000 BC (Stevens et al. 2016), bread wheat becomes increasingly prominent, and is the only wheat species known to have been adopted in northern central Asia after 3000 BC (Spengler et al. 2016; Liu et al. 2016; Liu et al. 2017; Zhou et al. 2020) and in part of northern or eastern China after 2500 BC (Liu et al. 2017; Deng et al. 2020; Chen et al. 2020). On the northern edge of the Tibetan Plateau, wheat appeared around 1600-1500 BC, along with barley and sheep pastoralism (Chen et al. 2015). Haimenkou is the earliest site in Yunnan where wheat remains have been found so far. The evidence from Haimenkou is nearly contemporary to wheat and barley from the Ashaonao site in western Sichuan (1400–1000 BC, d'Alpoim Guedes et al.

2015) and a few centuries earlier than other finds in Southwest China, such as in Tibet at the Changguogou site (c. 1450-800 BC; Fu 2001). Stylistic similarities in ceramics, as well as an increase of sheep/goat animal bones in conjunction with the introduction of wheat and barley, suggests that the species came into Yunnan from Northwest China (Li and Min 2013).

4.2.4. Barley- *Hordeum vulgare*

Sixteen grains of barley have also been found in samples from layers 6 to 3; this represents less than 1% of the total identifiable remains (Table S2, Fig. 4b). These appear to be naked barley, based on rounded grain profiles (Fig. 8-F), unlike the hulled barley found at the later Dian era site of Dayingzhuang (Dal Martello et al. 2021). Like wheat, barley originated in Southwest Asia and these two crops tended to spread together eastwards to Central Asia and South Asia (Stevens et al. 2016), although some wild barley populations also occur into Central Asia (Morrell and Clegg 2007; Fuller and Weisskopf 2014). In China, however, finds of wheat are rarely accompanied by barley in the Early Bronze Age (Boivin et al. 2012), and on the basis on modern genetic diversity patterning, it has been suggested barley could have also come to China via the Southwest from India (Lister et al. 2018; Liu et al. 2017). In the higher elevation of Qinghai and the Tibetan plateau, barley is especially well-suited and it became a prominent crop in these regions from 1600-1500 BC (i.e. Chen et al. 2015; Lu et al. 2020). At Haimenkou, the co-occurrence of barley with wheat suggests that it was a minor crop or even contaminant that accompanied wheat into the region, also at about 1400-1100 BC. The distinction between naked barley at Haimenkou (ca. 1400 BC) and hulled barley at later sites, including Dayingzhuan (ca. 400 BC) (Dal Martello et al. 2021) and Guangfentou (Li and Liu 2016), suggests at least two introduction of different barley varieties. Further evidence is needed to disentangle the number of time and routes by which barley came into parts of China.

4.2.5. Buckwheat- *Fagopyrum esculentum*

Six nutlets of buckwheat were found in five different samples across all phases of occupation of Haimenkou (Table S2; Fig. 8-H). Reports of buckwheat remains from archaeological contexts in China are not numerous; a recent review by Hunt and colleagues (Hunt et al. 2018) individuated a total of 26 occurrences in published literature. Of these, 14 referred to pollen remains, of which only one from an archaeological cultural layer from a historic site in Inner Mongolia, and the remnant from loess-paleosol, alluvial sediments, peat and lake cores; two starch remains, and 10 macro-fossils from archaeological sites both from North and South China (Hunt et al. 2018). Based on this review, Hunt et al. (2018) suggest that buckwheat was probably initially domesticated at the margins of its wild distribution in North China by the fourth millennium BC, which is earlier than the inference of third millennium BC domestication prosed by other scholars (Weisskopf and Fuller 2013). Currently, the earlier evidence for buckwheat in China is based on inferred dates associated with reported pollen and starch finds (Hunt et al. 2018). Of potential concern, is therefore whether either of these micro-remains can be securely identified to domesticated as opposed to wild *Fagopyrum,* and how secure associated dating is. More securely identifiable macro-remains, however, are current still rather few.

At present, Haimenkou buckwheat represents the earliest macro-fossil remains found so far in archaeological sites in China; in Yunnan, 149 charred buckwheat seeds have also been reported from the site of Xueshan (south of Kunming), which has been dated by cultural association to the Dian Culture period (c. 700-400 BC; Wang 2014), indicating that buckwheat might have been exploited in the area from at least the late second millennium BC onward. The identification of *Fagopyrum* wild progenitor in the hills of Northwest Yunnan and Southwest Sichuan (Ohnishi and Matsuoka 1996; Ohnishi and Konishi 2001; Ohnishi 2004; Konishi et al. 2005; Konishi and Ohnishi 2007) supports Southwest China as the center of buckwheat domestication. Additionally, recent linguistic research on East Bodish languages from Eastern Bhutan suggested that the Eastern Himalayas might also have been a possible center of domestication of bitter buckwheat (*Fagopyrum tartaricum*) more than 2500 years ago (Hyslop and d'Alpoim-Guedes 2020), but it remains the case that any sequence of domestication process is not available.

4.3. Pulses

4.3.1. Soybean- *Glycine* cf. *max*

A total of 65 whole soybean grains, 18 half grains and 9 hylums have been found in the systematically collected samples. The majority of soybean grains (45) come from only one sample, DT1004⑥, belonging to the second phase of occupation of the site (c. 1400-1100 BC; Table S2; Fig. 8-J).

Soybean remains from early sites in Southwest China are rather rare, and in Yunnan only one other site has revealed soybean remains, Baiyangcun, which is located close to

Haimenkou in the Jinsha Basin, and has been dated to about 2600-2050 cal BC (Dal Martello et al. 2018). The finds from Baiyangcun are consistent, in terms of size, with being morphologically wild soybean, and there are wild populations of soybeans in Southwest China (Dong et al. 2001), interpreted as a disjunct from the core wild distribution in central and northern China. At Haimenkou, soybean remains are consistent with domesticated size and morphology (Table S3; Fig. 8; i.e. Fuller et al. 2014). In Sichuan, soybean remains have only been reported from one site, at Yingpanshan, and dated to about 3300 BC (Zhao and Chen, 2011), but it is unclear if these are similar in size to the semi-domesticated soybeans in the Yellow River region of this period (see Fuller et al. 2014). The lack of similar finds therefore from the surrounding regions (Sichuan and Middle Yangzi Basin) makes it challenging to investigate whether soybean came to Southwest China together with rice and millet as part of a package. These finds, therefore, raise interesting questions regarding the possibility of either a local domestication process from the wild population represented at Baiyangcun or a dispersal process of this crop in post-Neolithic times and later than the spread of rice and millets. Further evidence is needed on the early soybeans of southwestern China.

4.4. Other inferred crops

4.4.1. Hemp- *Cannabis sativa*

Over 800 *Cannabis* seeds have been recovered at Haimenkou, of which over 700 coming from a single context dated to 1400-1100 BC (1204⑥; Table S2). No hemp seeds have been found from the samples belonging to the third phase of occupation of the site (c. 800- 400 BC). Early Chinese texts such as the *Shi Jing* (Book of Odes) and *Zhou Li* (Rites of Zhou) have references in the use of *Cannabis* as food, fiber, and for medicinal and/or recreational purposes since at least the early first millennium BC (Li 1974a; Li 1974b; Huang 2000; Clarke and Merlin 2013; Ren et al. 2019). A recent review of the available archaeological evidence relating to *Cannabis* use, including pollen, achenes, fibers and textile impressions on ceramics, proposed that this species might have been domesticated multiple times across the Old World, as evidenced by early remains both in Europe and East Asia (Long et al. 2017). Within China, North China is traditionally considered the most likely center of origin, where *Cannabis* grains and hemp fiber impressions have been reported from as early as the fifth millennium BC (Long et al., 2017). The large quantities of *Cannabis* seeds from Haimenkou, suggest cultivation as an edible oilseed at this site, although other uses cannot be ruled out, and one unidentified textile fragment and a rope bundle have also been found from hand-picked sample AT2003⑥ (Figs. S4E and S4F).

4.4.2. *Chenopodium album* sensu lato

Over 15,000 charred *Chenopodium* seeds were recovered from the Haimenkou samples, making this species among the most prevalent at the site (Figs. 3 and 5). Charred lumps of *Chenopodium* have been recovered from hand-picked sample DT1304⑤ (Fig. 7) in association of similarly preserved remains of rice. In general, we infer an increasing importance in *Chenopodium* in the initial and last phases of occupation of the site. In the DT1003, DT1004 , DT1005 sequence there is marked increase from the early to middle levels. In the later period of site, Chenopodium remains from systematically collected samples decrease, however, large concentrations of *Chenopodium* have been retrieved from hand-picked sample DT1304⑤ (Table S2). The fact that large numbers of *Chenopodium* grains have been found in crop rich contexts, alongside rice and millet grains, and are as concentrated in those samples where rice and millet also occur also suggests the identification of *Chenopodium* as another crop (Table S2).

Varieties of *Chenopodium album* (syn. *C. giganteum*) are cultivated today in the Indian Himalayan region as well as in Tibetan villages in southern Gansu as a minor crop (Partap and Kapoor 1985a; Partap and Kapoor 1985b; Partap and Kapoor 1987; Kang et al. 2014; Kang et al. 2013). Modern *Chenopodium* cultivation is also attested among the Formosan tribes in highland Taiwan, where it is grown for its leaves and seeds (e.g. Fogg 1983). Many domesticated Chenopodium varieties had larger seeds with lighter coloured seeds and thinner coats, as recognized among Indian cultivars (Partap and Kapoor 1985a; 1985b; 1987), and illustrated by Fuller and Allaby (2009) on the basis on Taiwanese domesticated *Chenopodium album.* Many of the *Chenopodium* seeds appear larger and more rounded in profile than typical Chenopodium seed encountered as likely weeds in central Chinese sites. These observations together the sheer quantity of *Chenopodium* recommends a more detailed study of potential morphological domestication evidence through assemblages like those of Haimenkou (work is ongoing). It has been noted recently (Gao 2021) at several sites across Sichuan and Yunnan have produced substantial quantities of *Chenopodium*, as well as from western Han tombs from the Yangling mausoleum (Yang et al. 2009), further raising the prospect that this species was under cultivation in the later prehistory of South China.

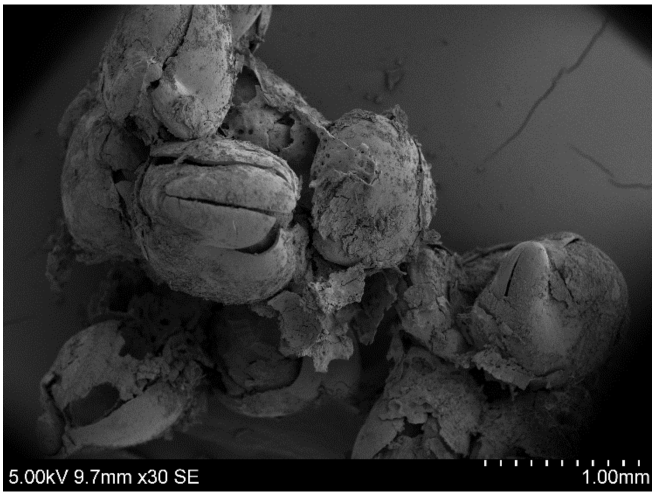

Figure 7. SEM picture of a charred lump of Chenopodium remains from context DT1304⑤. Photo by Rita Dal Martello (from Dal Martello 2020).

4.4.3. Sishoo- *Perilla frutescens*

Perilla frutescens occurs in large quantity in some hand-picked samples, suggesting that it was present at Haimenkou as a crop, although this species is also known to grow as a weed. The wild form of ths species (*P. frutescens* var *purpurascens,* and related wild diploid *Perilla* spp.) occurs throughout southern China, as well as Japan, Korea and the Indian Himalaya (Nitta et al. 2003; 2005; Hedge 1990). Cultivated forms include var. *crispa* (Chinese *zisu* 紫苏), which is grown for its aromatic leaves, and var. *frutescens* (Chinese *baisu* 白苏) grown for its seeds, which are significantly larger and softer (Lee and Onishi 2001). While this species is considered to have been domesticated in China, the possibility of more than one origin of cultivation might be suggested by separation between northern and southern oilseed varieties in some genetic investigations (e.g. Ma et al. 2019), while early finds in Jomon Japan, at least as early as those in China, suggest a separate domestication there (Crawford 2011).

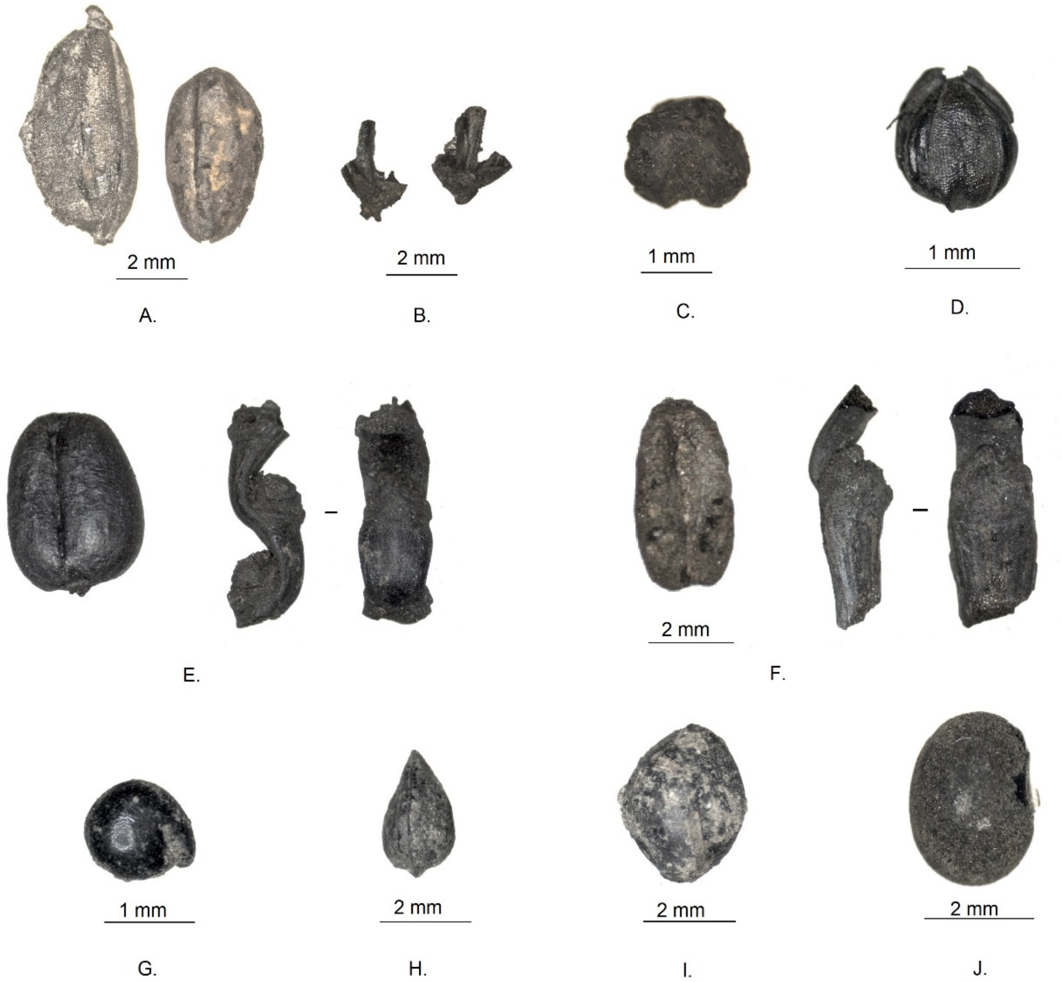

Figure 8. Archaeobotanical remains from Haimenkou: A: *Oryza sativa* grains; B. Rice spikelet bases; C. *Panicum miliaceum*; D. *Setaria italica* (husked); E. Triticum aestivum grain and rachis fragment; F. *Hordeum vulgare* grain and rachis fragment; G. *Chenopodium* grain. H. *Fagopyrum* cf *esculentum* grain; I. *Cannabis* grain; J. *Glycine max*.

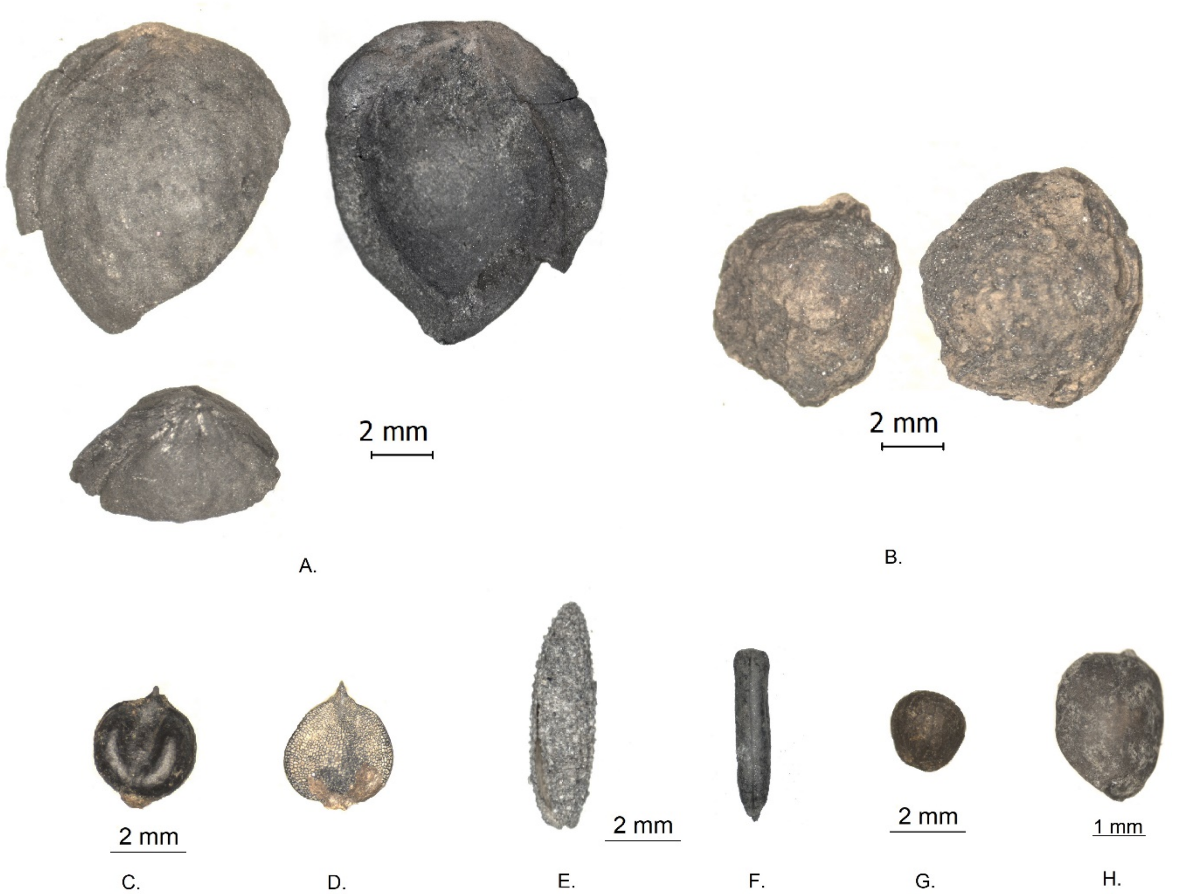

Figure 94. Archaeobotanical remains from Haimenkou: A. *Prunus* cf *persica*; B. *Prunus* cf *armeniaca*; C. *Polygonum persicaria*; D. *Carex* sp.; E. *Najas* sp.; F. *Butomus* sp.; G. *Perilla* sp.; H. *Galeopsis* sp.

4.5. Field weeds

Remains of several field weed species have been found in the archaeobotanical assemblage of Haimenkou, especially from samples from the DT1003, DT1004, DT1005 trenches, where these account for c. 22% of the total identified remains (Table S2, Fig. 4a). *Carex* sp. is the most frequently found field weed species, followed by *Scirpus* sp. Those two species together account for c. 8% of the total identifiable remains from systematically collected samples. As expected, hand-picked samples, which were taken during excavation due to visible concentrations of rice and millets, especially in form of lumps (see Supplementary material S4), have negligible quantities of seeds of field weeds (c. 3%).

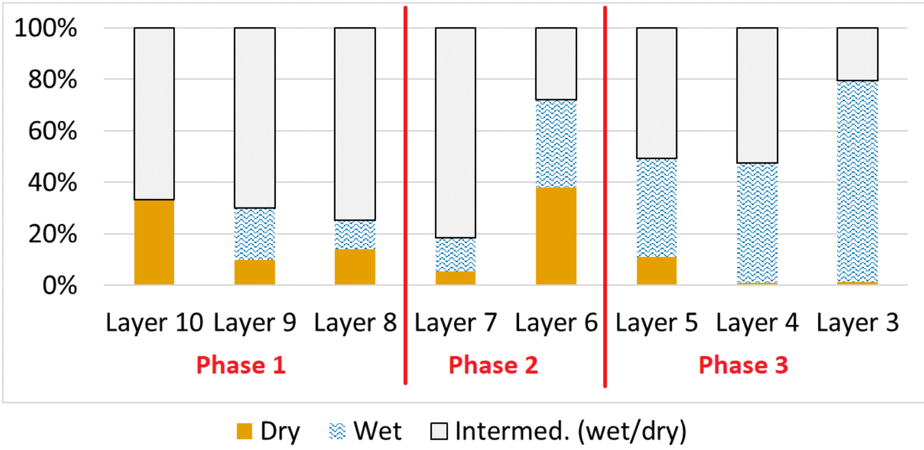

Figure 10. Comparison of field weeds category at Haimenkou plotted per layer (see Table S1 for absolute counts).

4.6. Fruits and Nuts

Several species of fruit have been recovered from the Haimenkou samples: 58 seeds of *Rubus* sp. (raspberry), 3 fragments of *Prunus* sp., 2 seeds of *Vitis* sp. (grape), and 1 seed of *Cucumis melo* have been recovered from trenches DT1003, DT1004, DT1005 (Table S2). Additional fruit remains were recovered from hand-picked samples, including 6 *Rubus* sp. seeds, 10 *Prunus* sp. fragments, 4 fragments of *Prunus armeniaca* (apricot, Fig. S4H in Supplementary Material S4), 3 fragments of *Prunus persica* (peach, Fig. S4I), two waterlogged stones of *Prunus* cf *salicina* (Japanese plum, Fig. S4G), and a waterlogged fragment of a jujube-*Ziziphus jujubas* fruit (Fig. S4J). Fruit remains represent less than 0,3% of the total identifiable remains and this low occurrence in the samples analyzed might indicate that fruit was a relatively minor component of the diet. Nevertheless, regional syntheses suggest that the apricots and peaches at this site are likely already domesticated forms that had dispersed from central China (Fuller and Stevens 2019). Length increase in peach stones in the Lower Yangtze region suggests the evolution of domesticated, larger-fruited forms was already underway in the third millennium BC, and that these had dispersed even outside China to Kashmir and Japan before the end of the second millennium BC (Fuller 2018). Hand collected peach stones from Haimenkou measure 26-27mm (Fig. S4I), comparable to domesticated second millennium BC and later specimens elsewhere. Similarly seed size data for melons from the Lower Yangtze indicates domestication processes during the third millennium BC (Zheng and Chen 2006; Fuller et al. 2014). The grapes, which have short stalk typical of wild species, are presumably a locally gathered wild species. Another gathered were wild raspberries (*Rubus* sp.), although these are only represented amongst waterlogged remains.

In addition, there is evidence for some possible used of wild nuts, but these are likely very minor. In the charred assemblages there is evidence for the aquatic foxnut (*Euryale ferox*), while hand-collected samples included acorns of *Lithocarpus* and cones of *Pinus yunnanensis,* which might have used for its oily edible seeds (pine nuts) (see Figs. S4C, S4D, S4L). Additionally, a section of rolled bark has been retrieved from hand-picked sample DT1305⑧ (Fig. S4M). Similar, rolled plant remains have been reported from Hulijia, a 3rd millennium BC site in Qinghai, western China, where it has been hypothesized it was consumed as food (Wang et al. 2015). Early Chinese texts, such as the second century AD *Sheng Nong Beng Cao Jing* (The Classic of Herbal Medicine), report the use of bark (especially of *Eucommia ulmoides* and *Magnolia officinalis;* i.e. Forrest 1995; Hu 1979) for medicinal purposes. Historical and ethnographic traditions from Scandinavia and North America, also attest to bark exploitation as a subsistence strategy (i.e. Östlund et al. 2004; Östlund et al. 2009; Bergman et al. 2004; Rautio et al. 2014; Swetnam 1984). How tree bark contributed to the early forest exploitation and management of Yunnan and broader China is an issue that deserves further study. *Euryale* and acorns were both amongst the wild food remains recovered from earlier Neolithic samples from Baiyangcun (Dal Martello et al. 2018). Their presence, together with fruits like *Vitis* and *Rubus,* indicates some continuity of gathering of wild forest products, probably focused on later summer or early autumn, but these were at most a minor supplement to economy focused on grain agriculture.

5. Comparative Discussion

Three main cereal crop species constitute the basis of the assemblage: rice, foxtail millet (by 1600 BC), and later wheat (introduced from the second period of occupation, c. 1400 BC onward). Shifts in abundance occur for rice, millets and wheat across time (Fig. 4a). Rice and millets are prevalent during period 1 and 2, with a shift toward wheat at the end of the occupation (from 800 BC). *Chenopodium* likely constituted another starchy staple, a pseudo-cereal, especially during periods 1 and 2 alongside rice and millet.

Chenopodium remains present a ubiquity comparable to cereal crops rice, millets and wheat, and concentrate in samples from layers 8 to 6 (c. 1600- 1100 BC); this is often present in higher absolute quantities than any other species (Table S2). This prevalence and association with rice and millets supports its identification as a food crop. Charred clusters of Chenopodium seeds further suggest a stored food crop, given the presence of similar clusters of millet and rice in the same samples. Another pseudo-cereal present throughout the site's occupation was buckwheat (*Fagopyrum esculentum*), although the very small quantities mean we cannot infer it to have been very important at Haimenkou.

A wide variety of other economic species included pulses (soybean), hemp (*Cannabis sativus*), and some cultivated fruits (mostly peaches and apricots). Other wild fruits and nuts were present, including grape and foxnut, but are generally of minor importance.

Seeds of field weeds concentrate on the lower and top levels (levels 10, 9, 7, and 4) and these provide potential information about cultivation ecology and crop-processing related activity patterns. Nevertheless, interpretation of these patterns is hampered by the mixed farming nature of the site as weeds may come from different crops. In all periods there is a mix of dryland and wetland weeds those that are here classes as "intermediate" as they can occur in wet or dry systems. The wet weeds presumably come mostly from rice cultivation in fields that were flooded, in low lying wetlands, or irrigated. Such field also will return large numbers of "intermediate" weeds. The dry weeds could come from millets, barley or wheat. With increasing intensification of irrigated rice, we would expect increasing wet weeds and fewer intermediate types (as per the pattern seed in Iron Thailand: Castillo et al 2018).

Stratigraphically, at the transition between period 1 and 2 (corresponding to layers 8 and 7), rice is the prevalent crop species retrieved across the site; seeds of wetland field weeds are slightly more numerous than dryland weeds, suggesting a generally suitable environmental for rice production in the wetlands of the river valley and lake basin. The high diversity of sedges and Polygonaceae, as well as a few charred examples of true aquatrics, such as *Butomus,* argue for wet, flooded rice cultivation. A shift occurs from layer 6 upward, where wheat remains appear, seeds of dryland field weeds increase (Fig. 10), and at the same time, rice remains decrease (Fig. 4a). After the abandonment of the site at the end of period 2 and its re-occupation after c. 300 years, wheat and millet are the prevalent crops on the DT1003, DT1004, DT1005 sequence. However, field weed remains are mostly constituted by wet and intermediate types (Fig. 10), possibly indicating that although the general production of rice decreased in favour of wheat, irrigation was likely practiced. One possible contributing factor for the decreased prominence of rice was the inferred deterioration of the monsoon in this period that might have affected rice productivity and resulted in an increased emphasis on wheat production (d'Alpoim Guedes and Butler 2014). Weeds such as *Galeopsis* and *Verbena* were likely hitchhikers with the introduction of wheat. Of note, is the appearance of wild oats (*Avena* sp.) in Period 2, the same horizon as wheat and barley, as this genus (*A. sterilis* and *A. fatua*) is native to the Mediterranean through western Asia and likely spread east as a weed of wheat or barley (Baum 1977; Loskutov 2008). Although *Avena* was found only hand-picked sampled, its presence is significant as marker the translocation of the wild/weedy form to this region. *Avena* cf. *fatua* type oats are also reported from Xishanping in Gansu as early as 4000-5000 BP. The establishment of *A. fatua* is important, as in due course it is secondarily domesticated to become hexaploidy Chinese naked oats (*Avena chinensis*), not to be confused with the diploid naked oats of western Europe (*A. nuda*). *A. chinensis* eventually became an important crop across parts of Mongolia, northwestern China and Tibet (Nakao 1951; Zheng and Zhang 2011).

To date, Haimenkou is the only second millennium BC site in Yunnan that has undergone systematic archaeobotanical investigation; two more sites, Mopandi and Shifodong, dated to the second millennium BC through cultural association, have limited, non-systematically retrieved archaeobotanical results. At Shifodong, a cave site located on the Mekong basin in western Yunnan, remains of rice and millets have been reported (Zhao 2010; Liu and Dai 2008), as well as two tree legumes, one of which has been identified as *Tamarindus* cf *indicus* (Dal Martello 2020). At Mopandi, rice remains were hand-picked during excavation (YPICRA 2003; Zhao 2003).

Our knowledge of the agricultural strategies in Yunnan during the first millennium BC is comparatively better than the previous millennium as more sites have recently undergone systematic archaeological research, including archaeobotanical analyses. Most of these sites, however, are located in the surrounding of Lake Dian in central Yunnan, and culturally associated with the Dian Culture. At these sites, it is increasingly evident that a highly mixed farming strategy was carried out, incorporating rice, millets, and wheat, taking full advantage of the vertical landscape zonation peculiar of Yunnan and possibly implementing a two-season agriculture, with the cultivation of summer rice in the lowlands, and a rotation cycle of summer millets and winter wheat in the surrounding hills (Dal Martello et al. 2021).

6. Conclusion

Archaeobotanical remains at Haimenkou suggest people were practicing a mixed-crop farming strategy, initially based on rice and millets, and from the mid-second millennium BC onward, with the addition of wheat. Cold and draught resistant crops such as millet and wheat seem to become more prevalent during the later phases of occupation of the site, this could be ascribable to the continued decline of the monsoon which would have affected the ability to successfully produce rice. *Chenopodium* remains are also found in very high numbers and show a comparable presence to other crop species, being found in more than half of the samples analyzed. *Chenopodium* is also strongly associated with other crop remains (rice and millets), indicating that people were exploiting this species, possibly as part of a risk reducing strategy in times of high climatic instability such as that attested for the region between the late second and early first millennium B.C.

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