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Assembling Chinese Domestications: multi-focal agricultural origins

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Introduction

In this paper we present evidence that the origins of agriculture in China was more complicated than a single or double centre of origin, but was instead a mosaic in space and punctuated in time, such that numerous local traditions contributed to developing the agricultural diversity of prehistoric China. We also highlight how is unknown about the origins of many Chinese domesticates from obscure crops to smaller animal domesticates, but even some of the major crops. Chinese archaeology provides a rich opportunity for archaeobotanical and archaeozoological studies aimed at unravelling the diversity of domestication pathways and how these various domesticates were assembled into the agricultural systems of early historic times.

China has long been accepted as a centre of independent agricultural origins, distinct from the Near East or the Americas. Indeed in the Harlan's (1971) classic definition of centres of domestication China, comprising the plains of the Yellow and Yangtze rivers, was one of the three region of "centric" agricultural origins, defined as a place where a package of crops was brought into cultivation more or less together and which formed a coherent regional agricultural package. While some Chinese authors have pointed three differentiated zones from crop origins, a northern, Yangtze and tropical far south focused on tuber cultivation (e.g. Li 1970; Zhao 2011), this view has gained little ground in wider archaeological syntheses that focus on just one or two primary processes of domestication. MacNeish (1992) saw Harlan's centres as the region of true primary agricultural origins, from which the dispersal of farming inspired subsequent local domestications in other regions that came under Harlan's concept of "non-centres". This view of single foci and farmer dispersal remains prominent, for example in Bellwood's (2005) summary of the Chinese Neolithic in the context of a farming-language dispersal hypothesis. In synthesis that explicitly built parallels between China and the Near East, Cohen (1998) suggested that a sedentary Pottery Pre-Neolithic ("PPN") of the terminal Pleistocene and early Holocene of the Yangtze basin started domestication processes just as the Pre-Pottery Neolithic ("PPN") had in the Near East. In this schema rice cultivation came first and inspired millet cultivation on its drier northern periphery, in particular in the Peiligang culture the southern limits of which took in the early rice zone represented by Jiahu. Despite an absence of archaeobotanical evidence, this rice-and-then-millet model of origins harmonized with attributing agricultural origins to Younger Dryas climate change and seeing agriculture as mainly spread by migration, and it came to be widely promulgated in Western scholarship (e.g. Harris 2003; Bellwood 2005; also, Yasuda and Negendek 2001. For a critique of Younger Dryas prime mover see Fuller and Qin 2010). More recently as archaeobotanical evidence has pushed rice domestication later, and millet cultivation earlier, Bar-Yosef (2011) has reversed this model, suggesting an initial start of the Holocene (or Younger Dryas) advent of millet cultivation in the climatically more marginal north of China, which later had the knock-on effect pushing Yangtze populations into rice cultivation.

In the present paper we eschew a simple model or grand narrative and emphasize instead the dispersed and patchy evidence of plant and animals remains themselves. These data increasingly point to often slow processes of initial domestication, slow shifts from wild gathering to cultivation, and slow incorporation of animal-rearing as the core of protein production. Ecologically the origins of rice and millet farming systems were quite distinct, and although there were clearly cultural interactions over the long-term between these zones there is no evidence favouring single push towards agriculture beginning in just one part of China. In both the rice and millet cultivation zones, several other secondary or minor plant domesticates came to be cultivated in due course. These were also important contributors to past agrobiodiversity and which require further study. Unlike the situation in West Asia, where a large package of crops, including several cereals and pulses as well as others, in the two Chinese cases cultivation began focused on just one or two species, rice or millets. Subsequent additions were later and although locally important in some regions, it was the millets or rice which

were emphasized. In exploring this mosaic of agricultural origins in China (Figure 1) we begin first with a treatment of each regions's primary crop, followed by the lesser known secondary crops. We then consider some domesticates of the peripheries After plants we turn to animals. First, there was the pig, the Chinese domesticated meat source par excellence, but which also was secondarily supplemented by more poorly understand domestications of several bird species, chickens, ducks and geese. Table 1 summarizes the common names and Chinese names of taxa discussed in this paper.

Table 1. Nomenclature of crop species discussed in this paper. Botanical nomenclature follows the *Flora of China* (www.efloras.org), but see also Hu (2006) for additional Chinese names.

Botanical/ Latin	English	Chinese & Pinyin	Japanese
<i>Boehmeria nivea</i> (L.) Gaud.	Ramie	苧麻 , Zhu ma	
<i>Brassica juncea</i> (L.) Czern. <i>sensu lato</i> .	Brown mustard, includes leaf mustard, Swantow musard	芥菜 , Jie cai	<i>Karashi</i> , <i>Takana</i> , <i>Irana</i>
<i>Cannabis sativa</i> L.	Hemp	大麻 , Da ma	
<i>Chenopodium giganteum</i> D. Don,	Giant chenopod	杖藜 Zhang li	
<i>Cucumis mwlo</i> L.	Melon	甜瓜 Tian gua	
<i>Eleocharis dulcis</i> (Burm.) Trinius ex Henschel	Chinese water chestnut	荸荠 Bi qi	
<i>Euryale ferox</i> Salisb.	Foxnut	芡实 Qian shi	
<i>Fagopyrum esculentum</i> Moench.	Buckwheat	荞麦 Qiao mai	Soba
<i>Glycine max</i> (L.) Merrill	Soybean	大豆 Da dou 黄豆 Huang Dou	
<i>Nelumbo nucifera</i> Gaertn.	Lotus	莲 Lian, 藕 Ou (lotus rhizome), 莲子 Lianzi (lotus seed)	
<i>Oryza sativa</i> L.	Rice	大 米 Da mi 稻 Dao	
<i>Panicum miliaceum</i> L.	Broomcorn millet, proso millet	黍 Shu 黄米 Huang mi 糜子 Mei zi	
<i>Perilla frutescens</i> (L.) Britt	Beefsteak plant, perilla	紫苏 , Zisu	<i>Egoma</i> , <i>shiso</i>
<i>Sagittaria trifolia</i> subsp. <i>leucopetala</i> (Miquel) Q. F. Wang (syn <i>Sagittaria sagittifolia</i> auct. Pl.)	Arrowhead	慈姑 (茨菰) Ci gu	
<i>Setaria italica</i> (L.) P. Beauv.	Foxtail millet	小米 Xiao mi 粟 Su 稷 Ji	
<i>Spodiopogon formasanus</i> Rendle	Taiwan Hill millet	台湾油芒 Taiwan You mang	
<i>Trapa natans</i> L. (syn <i>T. bispinosa</i> Roxb., <i>T. bicornis</i> Osbeck	Water chestnut, water caltrop	菱角 Lingjiao	

<i>Zizania latifolia</i> (Griseb.) Trucz ex Stapf., syn. <i>Z.</i> <i>caduciflora</i> (Trin.) Hand.-Mazz	Manchurian water rice	菰 Gu, 菰米 Gu mi (grain) 茭白 Jiao bai (culm as vegetable)	
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Protraction and entanglement in rice domestication

Recent empirical research has required a major shift in thinking about the origins of rice agriculture, from an earlier domestication to a later domestication, from a rapid beginning to a slow evolutionary trajectory. We can summarize this as a shift to a paradigm of “protraction and entanglement” (sensu Fuller 2010). Protraction, or slow domestication processes, are demonstrated from quantified archaeobotanical evidence. Only in the past few years has systematically collected archaeobotanical samples begun to make possible the documentation of rice domestication in terms of the evolution of morphological domestication traits, the development of arable habitats, and the shift in reliance from wild gathered foods to cultivated rice (Fuller and Qin 2010). Recent work documenting preserved rice spikelet bases track the shift from shattering rice panicles that characterize wild-type seed dispersal to the dominance of non-shattering panicles reliant human harvesters for seed dispersal (Zheng et al 2007; Fuller et al 2009; 2010). These data suggest that the evolution of non-shattering may have taken ca. 3000 years, which parallels recent evidence from southwest Asia for the protracted evolution of this domestication trait in wheat and barley (Purugganan and Fuller 2011; Tanno and Willox 2012). Similarly evidence for grain size change, especially in terms of grain plumpness (breadth and/or thickness), changes gradually over millennia in the lower Yangtze. Both of these key changes in domestication appear to have gradual and to have occurred at different paces (Figure 2). What is more as these changes were underway already over the 8th and 7th millennia BP, wild foods, represented by massive quantities of acorns, *Trapa* waterchestnuts and aquatic foxnuts (*Euryale ferox*) remained major components of diet, plausibly even more important than rice at the early cultivation site of Tianluoshan in the Lower Yangtze region (see Figure 2).

Archaeobotanical evidence from the middle Yangtze region is less robust but suggests generally parallel trends to those of the lower Yangtze, perhaps even starting slightly earlier (e.g. Zhao and Gu 2011; Cohen 2011). Bashidang (9000-8000 BP) produced large quantities of rice grains, but without any clear indication of domestication traits, nor unambiguous evidence for cultivation as opposed to collecting. The site also has a diverse wild seed flora (Liu and Gu 2006), suggesting extensive use of wild resources, like at Kuahuqiao and Tianluoshan in the Lower Yangtze. The somewhat later site of Chengtoushan (after 6500 BP), also lacks clear domestication indicators, but cultivation is clearly indicated by its weed flora at Chengtoushan, ca. 4300–3800 BC (Nasu et al. 2011). In addition the presence of other crops implies cultivation. This included the cultivation of adopted foxtail millet on a small scale (Nasu et al 2009). There is also the possibility that the “Shiso” (*Perilla frutescens*) and melon (*Cucumis melo*) were cultivated at Chengtoushan, although morphological domestication evidence is not yet clear (Nasu et al 2011). The possible rice field preserved here suggests a differing cultivation system, based on embankments to keep water in rather than pits to retain and drain water, from that of the Lower Yangtze Majiabang culture, represented by Chuodun and Caoxieshan (Fuller and Qin 2009).

To summarize, we can state that current archaeological evidence makes the end of the domestication process clearest, both from the growing quantity of archaeobotanical evidence and preserved field systems. Direct evidence for intensive wet rice agriculture comes from preserved field systems, found at two sites in the Lower Yangtze at 4200–3800 BC, Chuodun and Caoxieshan, and one site in the Middle Yangtze, Chengtoushan, at ca. 4500 BC (Fuller and Qin 2009; Nasu et al. 2011). When cultivation began, whether just around 6000 BC or a millennium or two earlier, remains unclear (Fuller and Qin 2009; 2010).

Other regions in China have also been claimed as potential areas of rice domestication or early cultivation, but evidence is even less clear. Some recent studies based purely on modern genetics have claimed the Pearl River delta in Guangdong as the source of domesticated rice (e.g. Huang et al 2012), but such studies can be dismissed for lack of recognition of the lost wild rice populations of the

Yangtze and further north, and for being contradicted by the large body of archaeological evidence (Fuller et al 2010a; Fuller 2011). Based on archaeobotanical finds, the upper Huai river and the Shandong peninsula may both be areas of where wild rice was collected, where it was under pre-domestication cultivation, or even where selection for domestication traits was taking place, but we simply lack adequate archaeobotanical evidence one way or the other. Some regions may have been dead ends in relation to the traditions of rice agriculture and the genetic lines that persist to this day (as suggested for Jiahu by Fuller et al 2007; cf. Liu et al 2007; Fuller et al 2008). Material culture traits shared with the Yellow River region on the one hand and Yangtze Neolithic on the other may have much to do with this site's peripheral position to both cultural worlds, rather than indicating some core source of all of China's Neolithic as Cohen (2011) seems to imply (also contra Sagart 2008). Further to the south and west in Henan, new data from the lowest levels of the site of Baligang do suggest that non-shattering rice was evolving and being cultivated here alongside acorn gathering by ca. 6500 BC (unpublished observations). Nevertheless there is lack of evidence of continuity. The next stage of human habitation on this site is with an almost thousand years gap in between and has a millet-rice mix agribulture tradition. An evolutionary dead-end of early rice cultivation is also likely the case for Shandong (Fuller 2011) where the few finds show no continuity in later cultures (the Beixin and early Dawenkou are millet focused, with rice apparently reintroduced during the Dawenkou period: Song 2011). Taken together, however, the evidence for early rice consumption in several contemporary parts of China between 9000 and 7000 years ago, suggests a mosaic of sedentarizing collectors and early cultivators, some of whom persisted in cultivation over the millennia and changed the rice plant into the domesticated crop we know today. Our best guess today is that there were at least two persistent pathways, the middle and lower Yangtze, as well as regional dead-end trajectories in which rice was abandoned and subsistence on rice failed. Early rice cultivars are likely to have required long growth seasons, at least 6 months or so, since short duration cultivars appear to be much later historical introductions (cf. Ho 1956), thus seasonality changes as well as general temperature or rainfall declines over the course of the Holocene would have made wild rice and easy rice cultivation habitats in northern China increasingly scarce. Instead the less thirsty rainfed millets, with growth seasons under four months were better suited to become the staple crops of Yellow River regions and areas further north.

Thus rice domestication was not a singular event, but may have occurred more than once and extended across a considerably period of time in the early and middle Holocene. In addition to the processes indicated for the Yangtze, separate development in early rice cultivation in the Ganges river basin in India are indicated over this period, including evidence from the site of Lahuradeva and many later sites (see Fuller and Qin 2009; Fuller 2011). Another lesson of Chinese rice domestication is that geographically it is not well-defined by the *modern* distribution of the wild progenitor. Instead we must consider the former extent of wild rice, which extended further north, as inferred from climatic difference of the early and middle Holocene and late Holocene historical sources that indicate where wild rice was available prior to habitat destruction by humans (see Figure 3)

Additive domesticates of the rice cultivators: aquatic nuts, tubers and vegetables

Rice appears to have been domesticated on its own, and not as part of crop package. This example is contrary to the suggestion of some, based on the Near East, that agricultural origins should be based on crop packages and to have occurred only where the wild progenitors of these packages overlapped (e.g. Abbo et al 2010). It is also worth noting the only other plant domestication process that can so far be documented for the Lower Yangtze region is that of melons (*Cucumis melo*), which occurred rapidly in the later 5th millennium BP, long after rice domestication had finished (Zheng and Chen 2006; Fuller 2012). This can be regarded as a secondary domestication process of a subsidiary garden crop by established rice farmers. The rapidity with which this domestication occurred, suggests conscious selection, perhaps for larger fruits that led to a linked increase in seed size. It is unclear whether the Chengtoushan melon seeds represent a parallel or even earlier domestication in the middle Yangtze region.

Several other potential plant domestications of the region were also wetland species like rice. These include the as lotus (*Nelumbo nucifera*) for seeds and tubers, arrowheads (*Sagittaria trifolia*

subsp. leucopetala, or “*Sagittaria sagittifolia*” in many source) and Chinese water chestnuts (*Eleocharis dulcis*) for tubers, and nuts such as foxnut (*Euryale ferox*) and water chestnut/ water caltrop (*Trapa natans sensu lato*). Most of these are largely undocumented in terms of domestication process or dates. *Nemlembo* tuber fragments have been reported from Jiahu before 6000 BC but there is no evidence that these were from cultivated plants. This is illustrated by the water caltrop, *Trapa natans* (includes *T. bispinosa*). While these eventually evolve larger seeds with bigger, curved and hollow horns, as found in modern cultivars (conventionally separated as *Trapa bicornis*), when this occurred is unclear. The large assemblage from Tianluoshan (7000-6300 BP) and finds from the Majiabang peiord (6200-5800 BP) show no signs of this morphological change, suggesting domestication was later and not associated with the period of rice domestication. Another potential domesticate of this region is the “Manchurian water-rice” (*Zizania latifolia* (Griseb.) Trucz ex Stapf., syn. *Z. caduciflora* (Trin.) Hand.-Mazz.), which was apparently originally cultivated for its grains, and was originally known as one of the six grains (*liu gu*) in the book of rites (early-mid First Millennium BC), but in later period came to be grown exclusively as vegetable for forms with a swollen stem infected by the fungus *Ustilago esculenta* (Li 1983), known as *jiao-bai* (Hu 2006). The mint “Shiso” (*Perilla frutescens*), found at Chengtoushan in the Middle Yangtze (Nasu et al. 2011) could represent another domesticate of this broader region. Although this species is cultivated from Japan through China to the Indian Himalayas today, its origins are placed somewhere in China, perhaps between middle Yellow river or the middle Yangtze (cf. Lee and Onishi 2003; Nitta et al 2005a; 2005b).

A note should also be made of a probable fibre crop domesticate from this region, ramie (*Boehmeria nivea*). Ramie is a fibrous, shrubby perennial, related to nettles, which is used for fibres both for ropes and textiles. As plants are usually unisexual and readily cross-pollinate (Lokeshwar 1997), selection for cultivars probably focused on vegetative propagation. This, together with harvesting focused on stems, means that seeds will be rare in the archaeological record. Cloth of *Boehmeria* was recovered, alongside silk, from the late Liangzhu waterlogged context of Qingshanyang (ca. 2200 BC) (Wang and Mou 1980). It is also mentioned in one poem of the *Shijing*, which attests to its use in central China in the earlier first millennium BC (Keng 1974). Although cultivated in India, especially in lower Gangetic basin and Assam, this species does not occur wild in India. A number of other small trees and shrubs of the genus *Boehmeria* occur in the Himalayan foothills, especially in ravines (Duthie 1903), so there is potential for confusion in identification. *Boehmeria* fibre associated with a fishhook was reported from Narhan, 1400-800 BC (Saraswat et al. 1994: 287), which if confirmed to species level would imply its diffusion from China already by this date.

Non-centric origins of Chinese millets

The earliest cultivated cereal crops in North China were *Setaria italica* and *Panicum miliaceum*, which appear to be earlier than undisputed domesticated *Oryza* in the south (Fuller et al. 2007; Bettinger et al 2010 Bar-Yosef 2011; Yang et al 2012). The beginnings of millet cultivation are poorly understood, and morphological domestication evidence are lacking. This partly a problem of preservation since their cultivation probably has its origins in mobile hunter-gatherers societies of Early Holocene north China (Bettinger et al. 2010; Zhao 2011; Cohen 2011), in opposition to the sedentary collectors who developed rice cultivation. Such mobile societies leave behind thinner deposits and much less preserved plant remains. Early finds are not concentrated in any core area (Figure 4) but instead there is a scatter of culture zones represented by the sites such as Dadiwan, Tanghu (Peiligang culture), Cishan, Yuezhuang and Xihe (Houli culture), Xinglonggou (Xinglongwa culture), which seem to be settling into more sedentary millet agriculture around 6500–5500 BC (Liu et al. 2009; Bettinger et al. 2010; Zhao 2011). The earliest claims for cultivation come from a few millennia earlier, although in both cases questions remains about reliable identification of domesticated or cultivated status and data. In the case of *Panicum miliaceum*, the earliest evidence comes from phytoliths from the site of Cishan, retrieved from pits in stratigraphic section (Lu et al 2009). Morphological identification of these phytoliths as *Panicum miliaceum* is entirely convincing. However, in the absence of comparative material from the wild progenitor of *Panicum milicaum*, the identity of which is disputed and which may be extinct (Hunt et al 2008; 2011), The oldest associated radiocarbon dates, AMS dates on sediment from the pit which was interpreted as

decomposed millet grains, are ca. 10,000 BP (Lu et al 2009). However, given the wide range of dates from this pit (from 10,500 to 9500 BP), and their reversed stratigraphic order, it is difficult to support the suggestion that they represent an intact, decomposed grain store from 10,000 years ago. Previous archaeological excavations on this site indicate that the main Neolithic occupation was around 8000 BP. The phytolith evidence suggest by this period a small amount of *Setaria italica* may also have been cultivated. This site could have been an early millet-farming village or it could be seen as a seasonal site of social gathering and grain storage amongst a more mobile society, even of gatherers. Further evidence is needed,

In the case of *Setaria*, new starch grain studies have identified the likely presence of foxtail millet processing and consumption at the start of the Holocene (Yang et al 2012). The authors suggest some trend towards more larger *italica*-type starch grains in later levels at Donghulin, Beijing (ca. 7500 BC) contrast to smaller wild-type starches of earlier Nanzhuangtou, Hebei (ca. 9500 BC), but the sample size and the number of time points are too few to provide a really convincing trend. Given potential environmental and genetic effects on starch formation, further work is needed before this can be taken as a fully acceptable proxy for domestication. It is also clear that other grasses and tubers were processed almost in equal amounts to millets (Yang et al 2012), suggesting millet consumption (whether gathered or already cultivated) was part of a broad spectrum adaptation (Qin 2012). In this case *Panicum miliaceum* phytolith have been recovered only from the very latest levels at Donghulin, ca. 8000 BP. Taken together these two studies could indicate geographically distinct starts to cultivation of *Panicum* and *Setaria*, although this evidence remains very limited. At a slightly later period charred grains from early *Panicum miliaceum* has been found at widely dispersed sites, including at Xinglonggou (ca. 8000-7500 cal BP), where there is a small amount of *Setaria italica* (Zhao, 2005, 2006), Dadiwan (ca. 7800-7350 cal BP), where there is no *S. italica*, (Barton et al 2009), and Yuezhuang (ca. 7900 cal BP), where there was some (wild?) rice but only one *S. italica* grain (Crawford et al. 2006). Late Peiligang sites in the Yiluo valley produced some *Setaria italica* but no *Panicum* grains (Lee et al 2007), but recent phytolith sampling at Peiligang period Tanghu reports positive identification only of *Panicum miliceum* type husk phytoliths (Zhang et al. 2012). Any argument for the primacy of broomcorn or foxtail millet for northern Chinese cultivation as a whole is problematic, but it does appear that broomcorn (*P. miliaceum*) was a more prominent, even dominant, part of subsistence across a number of north Chinese cultures by 8000-7000 BC, in contrast to later millennia in which foxtail millet (*S. italica*) usually dominates archaeobotanical evidence. Instead a mosaic of separate and multiple pathways into cultivation for both of these taxa can be suggested, with local preferences possibly determined by micro-environmental conditions as much as anything else.

Unfortunately, studies of the wild progenitors of these species do not help to resolve their origins, in terms of numbers of domestications of where these took place. The wild progenitor of *Setaria italica* is well identified as *Setaria viridis*, green foxtail, which is widespread across Eurasia, and throughout central and north China. Genetic evidence supports that it was brought into cultivation in China, perhaps at least two or three times (Fukunaga et al. 2006; Eda et al 2013). A separate Afghanistan domestication is possible but only for apparently quite localized landraces. Use of the wild progenitor could have been extensive and non-intensive as the period for flowering, ripening and shattering in a given stand may last for up to four months, during which time there would always be some spikelets ready to harvest (Lu, 1999:61). Domestication brought about a major change in the architecture of the plant, from many tillers and auxiliary branches ending in a short inflorescence in *Setaria viridis* to few tillers, no auxiliary branches and long inflorescences, typical of domesticates, in *Setaria italica* (Doust, et al, 2009:138). While domesticated foxtail millet is non-shattering, archaeologically preserved evidence that might record this change is so far elusive. Grain size and shape also change, and this has a much higher potential to be tracked archaeologically, although such studies are still needed. In some assemblages identification issues may be compounded by the presence of immature millet grains (Song et al 2012).

There is continued debate about the progenitor of *Panicum miliaceum* which could be extinct (cf. Hunt et al 2008; 2011). *Panicum miliaceum* ssp. *rudemale*, a common maize and millet crop weed growing in northern China through eastern Europe is the best candidate (De Wet 1995; Zohary and Hopf 2000), but it is also possible that this species represents a feral derivative of the domesticate. Unlike *Setaria viridis* which has persisted in some wild-type habitats, such as on river banks, it seems

likely that the more drought tolerant wild broomcorn millet has been more heavily impacted by human activities, including cultivation and animal herding. In the absence of ecological information on the wild progenitor of *Panicum miliaceum* it is unclear whether a rapid domestication, as postulated by Bettinger et al (2010) is likely or whether a protracted process, and long periods of wild use, as seems likely for rice and wild foxtail millet, should be inferred.

Neither *Panicum miliaceum* nor *Setaria italica* need irrigation, so pre 5000 BC domesticated millets are likely to have been from rain fed summer crops for instance (Hunt *et al*, 2008:S14, Zhao, 2006, Yan, 1992:117, Zohary and Hopf, 2000:83). Nevertheless there are disagreements over whether the early millet cultivation was practiced in shifting cultivation, and if so whether this requires settlement mobility (as inferred by Bray 1984; Chang 1986) or could have been practiced by field rotation around sedentary sites (as per Ho 1977). Nevertheless, it has suggested that for successful cultivation *Setaria italica* needs regular rotation or shifting fields to prevent overwhelming increases in weeds, pests and diseases (Lu, 1999:136). The lack of substantial archaeological villages in the early Holocene prior to ca. 8000 BP, suggests that early cultivation of both millet was carried out by more mobile societies, perhaps seasonally mobile hunters (as per Bettinger et al 2010), and/or practicing the shifting of millet fields. Sedentarization and fixing of agricultural land took place then after 8000 years ago, making millet cultivators more apparent in archaeological evidence. This process may have followed slightly different timing across the northern China from Gansu to Chifeng, and the extent to which morphological domestication was still underway at this time remains unknown.

From ca. 5000 BC, with the start of the Yangshao tradition (Banpo Phase), evidence for an integrated dryland agriculture in north China becomes widespread. Sites normally produce evidence for both *Panicum miliaceum* and *Setaria italica* (e.g. Lee *et al*, 2007; Barton *et al*, 2009). In addition some sites have produced evidence of *Brassica* sp. seeds, such as Banpo and Dadiwan (Underhill, 1997: 120, Yan, 1992:114). At Linjia, a Majiayao culture site in Gansu (ca. 4700 BP), *Cannabis sativa* has also been found in pits and ceramic pots on house floors (Underhill, 1997:125, Yan, 1992:114). It was into this cultural context, of the regionally expansive Yangshao tradition that rice was adopted alongside millet cultivation in the later 5th or early 4th Millennium BC. At the site of Nanjiaokou such rice appeared in small quantities by the end of the Early Yangshao phase (4500-3800 BC), with direct AMS-radiocarbon dates of ca. 3900-3800 BC, with more evidence from the Middle Yangshao (3800-3000 BC) at this site and several other sites in the region (Fuller et al 2010). Further north at Xishanping in Gansu and in the Sushui river of Shanxi rice finds date to the Yangshao period by ca. 3000 BC, and occur beyond the reach of modern rice cultivation, allowed by the somewhat warmer and wetter conditions of that time (Li et al 2007; Song 2011). Underhill (1997: table IV) notes incidences of *Oryza sativa* during the early Yangshao at Xiawanggang and Xiaji (Xiachuan, Henan), but dating evidence and lack of systematic sampling on these sites means that questions remain. Recent phytolith studies of exposed site section also put the introduction of rice into central China into the Early Yangshao period, although such studies do not provide direct or precise dates for this introduction (e.g. Zhang et al 2012). Despite the presence of rice, however, the predominant staple crops in Yellow River area during the Yangshao period were millets, and *Setaria italica* tends to dominate over *Panicum miliaceum* (Lee et al 2007; Fuller and Zhang, 2007:945; Song 2011).

Stable carbon isotope provides a means of assessing the relative importance of millets, with a C-4 photosynthetic pathway, in the diet in contrast to other plants, which are mainly C-3 (including rice, wheat, pulses, fruits). Data from the late Neolithic to early Bronze Age in central China indicates that despite the archaeobotanical presence of rice and wheat, millets dominated the diet, at sites like Taosi, Xinzhai and Erlitou (Yuan and Campbell 2009). Data from more sites and earlier periods, however, shows the potential to highlight diversity in the dietary significance of millets. Humans at the Yangshao period sites along the middle Yellow, such as Jiangzhai, Shijia and Xipo (based on pig and dog remains) has a millet dominated diet with $\delta^{13}\text{C}$ of -10 or less (Pachenkina et al 2005). For earlier period there is still limited data. Isotopic evidence from the Dadiwan culture is mainly from fauna, and includes only C-3 (wild-type diet) pigs but some C-4 dogs, implying scraps from a human millet-focused diet (Barton et al 2009). At the Houli culture (ca. 5500-6000 BC) site of Xiaojingshan skeletons had $\delta^{13}\text{C}$ of around -17, suggesting that C-4 millets contributed only less than 25% of the diet (Hu et al 2008). This points to predominantly C-3, and probably wild, plant foods, although a small amount rice (which could be wild) is reported from Houli culture sites (Crawford et al 2006; Jin

et al. 2013). In the northeast of China, represented by Xinglonggou (ca. 6000-5500 BC), millet consumption was already extremely important with reported $\delta^{13}\text{C}$ of human between -11 and -9 (Liu et al. 2012). The contrast with C-3 diet pigs at Xinglonggou, implying that they were wild, should be noted. As more isotopic studies are carried out and put alongside archaeobotanical evidence it will become increasingly possible to map the changing importance of foxtail and broomcorn millets and other dietary contributors. Nevertheless, for the northern China as a whole it seems clear that it was millet cultivation that played the dominant role in food production, despite the evidence for some adoption of rice.

Additive domesticates among millet cultivators: hemp, soybean, and *Brassica*

While early cultivation in northern China appears to be focused on the caloric staple millets, this was also a region in which a diverse range of cultivars was drawn from wild sources. As with the situation reviewed above for the Yangtze region, initial cultivation was not based on balanced packages of different types of crops, but a focus on millets, especially *Panicum milicaeum* in the earliest phases of cultivation. Other resources, then were likely wild, although some protein derived from pig-keeping is also likely for some of the early millet culture (see discussion of pigs, below). Nevertheless, as sedentary millet farming communities came to dominate the loess and adjacent zones of northern China, a number of additional crops came to be cultivated, including those with proteinaceous and oily seeds, and fiber crop. These later domesticates have received may be less well-documented than the millets, but they are nevertheless important, representing a process of agricultural diversification through the Yangshao period which made production increasingly the dominant component of the economy over forms of collection.

In addition to the three species treated here, it is possible that *Chenopodium* could have sometimes been cultivated as a pseudo-cereal (cf. Lee et al 2007), although the best evidence for its cultivation comes from the western/southern periphery of China. In addition the mint “Shiso” (*Perilla frutescens*), already referred to from middle Yangtze find, could also be an early North Chinese subsidiary crop. In addition, it is likely that at least some tree fruits had come to be cultivated by the Longshan period, such as jujubes (*Ziziphus jujube*) and peaches (*Prunus/Amygdalus persica*) (cf Fuller and Zhang 2007).

Soybean

The bean crop *par excellence* of East Asia is the soybean. This is today a crop of global importance and produces more protein per cultivated acre than any other source, whether meat, eggs or another legume crop (Simoons 1991: 71). The wild ancestor is *Glycine soja*, which is found from the Yangtze river northwards to northeast China, the Russian Far East, the Korean peninsula, and Japan (Fig. Map). On the grounds of cultivar diversity and the geography of the wild relatives, domestication in northeast China is often suggested (Hymowitz 1970; Li 1983). Recent genetic studies have found regional patterns in genetic variation shared by cultivars and wild populations (Xu et al 2002; Abe et al 2003). Such evidence could be the result of regular introgression within each region after the introduction of domesticated soybeans, possibly including some escapes to the feral condition. However, it may indeed represent multiple regional episodes of domestication, of which at least three seem likely, including separate origins in Japan, northeast China/Korea and central China (Yellow river).

On the basis of available archaeological finds, the earliest use, if not cultivation, of soybeans is to be found in Central China, south of the Yellow river and on the Yellow river basin, not in the northeast. Quantities of *Glycine* have been found for example at Jiahu, dating the later 7th millennium BC (Henan Provincial Institute 1999); this species seems particularly significant in light of recent systematic wet sieving (e.g. Zhao 2010). Soybeans at Jiahu have small seed size, consistent with a wild population. Large quantities of soybeans, generally of small seed size, from Yangshao period sites (Fuller and Zhang 2007; Lee et al 2011) suggests intensive collection, if not the beginnings of cultivation by this period. This can be contrasted with Longshan period finds, such as from Wangchengang, by which time some seed size enlargement is evident at least at some sites (Lee et al 2011). But larger seeds and a bimodal size distribution are particularly clear from the Shang period. Size data from Korean archaeological soybeans fits roughly into the same chronological trendline as that in the Yellow river region, which could link these two regions into one domestication pathway,

or if not two closely parallel pathways (separate domestications e.g. favoured by Lee et al 2011). By contrast an earlier and independent domestication in Japan is indicated by Middle Jomon soybeans from Shimoyakebe (Lee et al 2011). The evidence therefore points to a late Neolithic domestication of soybean, during the Longshan period and certainly by the Bronze Age, among the cultivators of millets and rice of north/central China.

Hemp

Hemp (*Cannabis sativa*) is an oilseed and fibre crop as well as a drug, and it was well-established as an edible seed crop and drug by the time of early Chinese written sources (see Li 1974a; 1974b). The original wild range of *Cannabis* is problematic because this species is highly successful as a colonizing weed, especially at colonizing nutrient rich soils of human middens, abandoned camps and fallow fields (Vavilov 1992). Broadly speaking, wild *Cannabis ruderalis* is distributed across temperate Asia from eastern Europe (southern Russia and Ukraine) through central Asia, parts of the Himalayas to Mongolia and Manchuria (Vavilov 1992). These free-growing plants readily interbreed with crops, and have traditionally all been grouped into a single species *Cannabis sativa* (Small and Cronquist 1976). Nevertheless, as argued already by Emboden (1974) there are morphological and geographical grounds for separating *C. indica*, including most drug crops, from *C. sativa sensu stricto* which includes the larger-seeded oilseed cultivars. Recent genetics tend to support such a division, and probably imply at least two origins of cultivars. Hillig (2005), for example, recognizes three species, a west Eurasian *C. sativa sensu stricto*, which included fibre of oilseed landraces from Central Asia, West Asia, Europe and eastern Asia, and *C. indica*, including all of the various drug cultivars, and feral populations in South Asia, which are common in the Himalayas, and Chinese fibre cultivars. Although modern flora treatments do not regard *Cannabis* as wild in China. . Li (1983) regarded it as native to open environments of the semi-arid loess highland of northern China. A more easterly wild distribution, or pre-agricultural translocation, might even be suggested given early finds in Korea and Japan. It is a likely “dump-heap weed” that would have readily colonized human middens or abandoned sites (see Vavilov 1992: 116), and as such could have easily sprouted in transported by hunter-gatherer groups.

Hemp is likely to have been used for fibres as well as being an oilseed crop and a drug (Li 1974a; 1974b; 1983). However, high-fibre producing cultivars appear to be a later development out of drug lineages introduced from South or Central Asia (Hilig 2005). and may not be prehistoric at all. Archaeological reports of *Cannabis* require critical appraisal. The seeds themselves should be distinctive, but report of pollen and fibres may be more prone to mistaken identification. The bast fibres of *Cannabis* may be very difficult to separate from the bast fibres of several fibre crops that are widespread in our region, e.g. *Urtica*, *Boehmeria*, *Chorchorus*, *Linum*, although most should be separable microscopically (see Catling and Grayson 1982). It is reports of “hemp” textiles that have mainly misled scholars into exaggerating our knowledge of the history of this crop (e.g. Flemming and Clarke 1998; Merlin 2003). For example Lower Yangzhe Liangzhu period “hemp” which has been widely cited in the English literature (e.g. Flemming and Clarke 1998; Merlin 2003), is well-identified as ramie (*Boehmeria*). On the other hand fibres that probably were hemp were reported from mid-late Yangshao Qingtai, Zhang and Gao 1999; Zhengzhou Archaeological Cultural Relics Institute, 1999). Bronze Age hemp textiles were also identified far to the South at Kwo Lo Wan, Hong Kong, ca 1300-1000 BC (Meacham 1994: 184-185). Seeds have been reported from Majiayao culture Linjia, Gansu (ca. 4700BP, Gansu Cultural Relics Team *et al.* 1984; Plant Institute in Northwest Normal University and Gansu Museum 1984), Shang Dynasty Taixi, Hebei (ca. 3500 BP) (Geng and Liu 1985) and Daxinzhuang, Shandong (Ca. 3500 BP, Chen, X. 2007). A report from as early as 3000 BC from the South Korean site of Daichonri must be regarded with caution given apparent mis-identifications of other plant remains on this site (Lee 2011: S313). Even earlier is a report from Japan, at the Early Jomon shell midden of Torihama, which could be 4th millennium BC or earlier (Crawford 1992; Fujio 2004). This site has other cultivars, such as *Perilla frutescens* and bottlegourd (Fuller et al 2010c), and it could be that cultivation for its psychomimetic properties, or its camp-following habit, led to its early translocation to Japan.

Mustards

The mustards, and related leaf and tuber vegetables (turnips, swedes, cabbages, mustard

greens, etc.) are a taxonomically complex group due to hybridization and polyploidy, as well as extensive selection under cultivation for highly variable cultivar forms (Hemingway 1995). One taxon which is probably truly ancient in China as well as India is *Brassica juncea*, the brown mustards which also includes several leaf vegetable forms popular in China. A jar of stored *Brassica* seeds was reported from Banpo (Early Yangshao Neolithic) (Li 1983; Simoons 1991: 134). Of similar age is evidence from Dadiwan site (Gansu Museum and Qin'an Cultural Center 1982). The quantity found at Banpo, a storage jar full, might suggest cultivation, although without specific identification criteria it is not possible to rule out the gathering of a wild species. Given that this predates any evidence for other domesticates diffusing into China from outside, the find suggests an indigenous domestication of a *Brassica*. On biogeographic grounds, the best candidate is *B. juncea*, which also has the widest range of traditional cultivars in China. Whether this crop was grown primarily as a green, or was indeed processed for oil from its seed is unclear, although large quantities of stored seeds might actually argue for oilseed use rather than as a vegetable. The absence of reports from later periods may be due in part to the development of mainly green vegetable cultivars.

Accounting for pigs amongst the deer and fish

As the most important domestic animal in Chinese history, pig has attracted much more attention than any other animals, and archaeologists never stop searching for the origin of pig domestication. Recent research suggests that pig was first domesticated in China perhaps around 10,000 years ago (Yuan and Flad, 2002). Since domesticated pigs were widely distributed at Neolithic sites of the 'Yangshao Period', which spanned from 5,000 BC to 3,000 BC (Chang, 1987), Luo (2007) proposed that the 'Pre-Yangshao Period' (approx 9,000 – 6,900 BP) should be the crucial era for pursuing the origin of domestic pig in ancient China. These 'Pre-Yangshao Period' sites from early to late includes: Zengpiyan (12,500 – 7,600 BP) (Institute of Archaeology CASS et al., 2003), Jiahu (9,000 – 7,800 BC) (Henan Province Institute of Relics and Archaeology, 1,999), Xinglongwa & Xinglonggou (8,200 – 7,000 BP), Kuahuqiao (8,200 – 6,900 BP) (Zhejiang Provincial Institute of Cultural Relics and Archaeology and Xiaoshan Museum, 2004), Dadiwan (7,800 – 4,800 BP) (Gansu Provincial Institute of Archaeology, 2006, p705-707), Cishan (7,400 BP) and Hemudu (7,000 – 5,300 BP) (Zhejiang Provincial Institute of Cultural Relics and Archaeology, 2003).

Zengpiyan in southwest of China has the earliest reported domesticated pigs in China, although the result is complicated. The pig remains were studied by different scholars in the past three decades and the conclusions varied. Li and Han's (1978) results showed that 85% individuals were younger than two years old, while on the other hand, Yuan and Yang's (2003) results disagreed with them, suggesting the age profile was dominated by adult individuals and the size of M³ and M₃ were too large to be domesticated. In addition, the proportion of pigs was very low (less than 10%). However, recent research has found out that the LEH (Linear Enamel Hypoplasia) index value of pigs from Zengpiyan is higher than the wild boar samples, perhaps implying an early stage of pig management, especially in the later stages of the site (Dobney et al., 2006, Luo, 2007). Nevertheless, geometric morphometric analysis of teeth from this site links them clearly with wild boar populations (Cucchi et al 2011)

The pig remains from Jiahu were systematically researched by Luo (2007, 2008), and the existence of domesticated pig was stated, starting from stage one. In Luo's argument, domesticated pigs were identified based on five criteria. First of all, the crowding of dentition in pigs' mandibles was quite prominent. The age profile showed that individuals that were younger than 2-years-old were a high percentage of the assemblage (up to 81.4%). Third, pig remains make up a relatively higher proportion of the faunal assemblage, compared to other sites of this age. In addition, there was a special phenomenon that pig jaws and teeth were buried with human in tombs. The LEH index value was much higher than that of wild boar, and similar to other confirmed domesticated pig from Neolithic sites, suggesting domestication at Jiahu (Luo, 2007, 2008). In addition recent research on geometric morphometrics, places the Jiahu pig remains among domestic pigs, close to those from the Yangshao period site of Xishuipo (Cucchi et al 2011).

Pig domestication is doubtful at Xinglongwa and Xinglonggou in Inner Mongolia, at the middle Yellow River region. Both sites are only 10 km from each other, and of same period, around 8,200 – 7,000 BP. Domestication has been argued mainly from the special cultural phenomena at both sites: two pig skeletons were buried in a tomb with human at Xinglongwa (Inner Mongolian Team of

Institute of Archaeology CASS, 1997) and several skulls were found in a house at Xinglonggou (Inner Mongolian Team of Institute of Archaeology CASS, 2004). In addition, the frequency of LEH at Xinglonggou is higher than that of modern wild boars (Luo, 2007). However, the statistical analysis of geometric morphometrics found the pig remains here to have the strongest wild boar signature of any of the analysed archaeological samples (Cucchi et al 2011). This wild identification is further supported by stable isotopes which show the pigs had a C3 plant diet in contrast to the millet-eating (C4) humans (Liu et al 2012).

In the lower Yangtze River Region, incipient pig domestication has been reported at the site of Kuahuqiao, an 8,200 – 7,000 years old site at the Hangzhou Bay. The domesticated pigs were identified based on three criteria: 1) the crowding of dentition which appeared at the early stage at Kuahuqiao; 2) the average length of M₃ was up to 38.58 mm, and it decreased from the early to late stage; 3) the age profile also showed a getting-younger trend through time (Yuan and Yang, 2004). However, it should be noticed that the remains of wild boar and domesticated pig were not separated; therefore the statistics could have shown the situation of a mixed faunal group of both wild and domesticated pigs. Further investigation is still required to discuss this question.

The pigs from Dadiwan, a middle to late Neolithic site in northwest China, have been considered as domesticated, for mainly two reasons. First, there was a decrease of teeth size, e.g. the average length of M₃ was 37.06 mm; second, almost 2/3 of pigs were killed between 1 to 2 years old, and the percentage of individuals older than 2 years was very low (Qi et al., 2006). Isotopic evidence, however, points to Dadiwan period pigs being wild, or managed with wild type diets. By contrast in the Yangshao phase at the site some pigs, like dogs, had a C-4 dietary signature suggesting consumption of millets or human kitchen scraps from millet farmers (Barton et al 2009).

The identification of domesticated pigs from Cishan is based upon three criteria: 1) age profile, with a considerable majority (over 60%) of pigs killed at the age of 0.5 to 1 year-old (Zhou, 1981, Yuan and Flad, 2002); 2) tooth measurement (M₃), with an average length of 41.4 mm, which is similar to the domesticated pigs from Yangshao period sites (Zhou, 1981) and other Neolithic sites (Yuan and Flad, 2002); and 3) complete pig skeletons have been found buried at the bottom of pits, underneath large amounts of millet (Hebei Province and Handan Relics Preservation Institute, 1981). However, the data of pigs from Cishan are too few to be fully convincing, e.g. only three measured M₃.

Recent studies show that the incipient stage of pig domestication may last for a long time in Southern China, at least no earlier than the Hemudu period. Remains of domesticated pig were reported at the site of Hemudu (Zhejiang Provincial Institute of Cultural Relics and Archaeology, 2003), but there was not enough detailed morphological recording which could be compared with that from other sites such as measurement of teeth. Recent excavations at Tianluoshan has revealed new materials for the research of Hemudu Period and 'Hemudu Culture'. The pig remains make up nearly 10% of the mammalian assemblage from the site (Zhang et al., 2011). Comparing to other animal resources such as deer, pig was relatively less important. Besides, the size of M₃, with the average length of 39 mm and average width of 17.5 mm, was closer to the measurements at Kuahuqiao and Mayer et al's standard of wild boar, but much larger than other confirmed domesticated pigs later in the same region (Zhang, 2009).

Table 2 summarizes the proportions of pig, deer and other ungulates (such as water buffalo, cattle and caprine) from the sites with early domesticated pig remains. The statistics show that the total number of various deer is always more than pigs, indicating the importance of hunting in the subsistence economy. This can be the characteristic of the incipient domestication of pig. In the Yangshao, the proportion of pigs increased remarkably and the domestication of pig became prosperous (Luo, 2007). In addition to the evidence that pig was a minority component of mammal derived meat, Yangtze Neolithic sites are particularly rich in fish bone remains, and fishing many have been as important in the economy and diet as hunted mammals (Yuan et al 2008). A methodological challenge is quantifying the relative importance of fish to large animals. It seems clear, however, that fish were far more important in the Yangtze Neolithic than along the Yellow river. This would seem to be in keeping with a plant-food economy in the Yangtze in which aquatic collection (*Trapa*, *Euryale*) and early cultivation of rice indicated a focus on wetland habitats (Fuller and Qin 2010). By contrast in the north China rainfed millets and deer hunting require less tethering to rivers in the landscape. With the growth of sedentism and small scale adoption of rice in the Yangshao period river probably

became increasingly important and this may also have pushed Yangshao economies towards greater reliance of pig-keeping and a reduction in hunting.

	Zengpiyan		Jiahu		Xinglongwa		Xinglonggou		Kuahuoqiao		Dadiwan		Cishan	Tianluoshan	
	NISP	MNI	NISP	MNI	NISP	MNI	NISP	MNI	NISP	MNI	NISP	MNI		NISP	MNI
Pig	4%	4%	11%	9%	25%	38%	36%	38%	16%	14%	38%	48%	---	4%	12%
Deer	85%	61%	70%	68%	72%	54%	59%	41%	33%	32%	48%	42%	most	34%	61%
Other ungulates	2%	3%	2%	2%	1%	2%	2%	5%	36%	16%	11%	3%	---	3%	5%

Table 2. Proportions of pig, deer and other ungulates at the Pre-Yangshao Period sites. The statistics are adopted from the excavation reports and zooarchaeological research papers.

Elusive fowl domestications

Based on early archaeological finds, it has often been suggested that chickens were domesticated from junglefowl in the region of the Indus Valley at 2000 BC, from the evidence at Mohenjo-Daro (Carter, 1971, Crawford, 1984, Zeuner, 1963). West and Zhou (1988) hypothesized that chickens were first domesticated in Southeast Asia from the red jungle fowl *Gallus gallus* before the sixth millennium BC and taken north to become established in China by 6,000 BC prior to the Yangshao period (West and Zhou, 1988). However, as was the case with wild rice, wild red junglefowl may have previously been present further north than their modern Southeast Asia distribution. As discussed by Fuller (2007), there was a plausible parallel with rice domestication, in that separate Chinese and Indian domestications seemed plausible. Recent genetic data on chickens and red junglefowl also points to multiple domestications across their range in India, Southeast Asia, and south China, and there could have been more than two domestications (Kanginakudru *et al.* 2008; Berthouly-Salazar *et al.* 2010). It is also now clear that Chickens have moved a lot between various parts of Asia and across the Indian Ocean (see Fuller *et al.* 2011). These movements must account for all yellow-legged forms of Chicken, since the yellow-leg gene appears to derive from hybridization with South Indian wild grey junglefowl (*Gallus sonneratii*) (Eriksson *et al.* 2008). Archaeologically, however, chickens may not have reached South India before ca. 1500 BC (Fuller 2007), indicating that yellow-legged forms have dispersed only since that time. This form is found in China as elsewhere. Archaeology is still a long ways from tracking the story of chicken origins and dispersals.

Within China, archaeozoological evidence for chickens remains problematic. Chicken remains were reported at Neolithic sites such as Cishan in Hebei Province (Zhou, 1981), and Beishouling in Shaanxi Province (Zhou, 1983), which if confirmed would put them back more than 7000 or 7500 years in the Yellow River region (West and Zhou 1988). Measurements were suggested to indicate that these chicken remains were larger than junglefowl but smaller than modern domesticated chickens, indicating a status of early domestication. However, this evidence did not clearly demonstrate that these were in every case chicken bones and not some other similar-sizes bird or galliform. At least some of the reports have subsequently been re-identified as pheasants rather than chickens or junglefowl (Serjeantson 2009: 270; see also, Lawler 2012) Yuan (2001) proposed that chicken was not yet domesticated in Neolithic age. According to the description in the Bronze Age in China, chicken could have been domesticated by then, i.e. ca. 3500 BP. Chickens were used in daily diet (Chang, 1980) as well as special events such as the sacrifice ceremony (Ma *et al.*, 1955); Due to the little data and research on chicken, the origin and development of chicken domestication is still indeterminate. The existing archaeological records may have suggested that the long period from middle Neolithic to early Bronze Age is quite crucial for this question.

Although chicken bones have been reported from many sites, their detailed study has been rare, such that accurate identification may be questioned, and there is no basis for inferring morphological domestication. The evidence for the domestication of duck and goose is even less clear, and we are left only with ancient Chinese written sources as evidence. Geese were consumed in daily life in the Zhou dynasty, Late 2nd Millennium BC to early First Millennium BC (Chang, 1980), and figurines of these three species of birds had been regularly found in tombs since the Shang Period, possibly implying the presence of domesticated ducks or geese by 3500 BP (Chen, 2002).

Ducks and Geese

The other domesticated fowl, ducks and geese, both must have early, and possibly prehistoric, domestication histories but they are poorly documented. Domesticated geese have been suggested to have undergone multiple domestications across the Eurasian region, from wild greylag geese (*Anser anser*) in the west, and wild swan geese (*Anser cygnoides*) in China, although these two species and their domesticated derivatives are able to interbreed (MacDonald and Blench 2000). While art historical and some archaeozoological evidence documents the presence of domesticated geese in ancient Egypt since Third Millennium BC (Houlihan and Goodman 1986), archaeozoological evidence in China has been inadequately explored in relation to geese. The situation with domesticated ducks is the same. Archaeologically there may be limited scope to identify domesticates on morphological grounds, although there is some trend towards size decrease, but many domestication traits are in plumage (Serjeantson 2009). Watson (1969) inferred the presence of both domesticated ducks and geese in central China in Longshan period on the basis of ceramic models (also Chen 2002), but how we can be sure these represent domesticated as opposed to wild animals is less clear.

Ducks, by contrast to geese, are generally inferred to have been exclusively Chinese or Southeast Asian in origin, despite the widespread distribution of the mallard, their wild progenitor (Zeuner 1963; Luff 2000). Domestic duck-keeping, as opposed to trapping, is regarded as late in Europe, medieval and post-Roman (Luff 2000; Serjeantson 2009), a contrast with geese. This implies the spread of domestic ducks westwards across Asia, at a date that is broadly late or post-Classical in European terms. Duck keeping is generally greater in southern China and southeast Asia, and co-management of ducks and rice is advantageous as ducks feed on rice pests such as land crabs and locust nymphs (Luff 2000), thus it is tempting to infer that duck-keeping began among early rice farmers, such as those of the Lower or Middle Yangtze. The earliest written records are apparently from the late First Millennium BC (Luff 2000, the Warring States period, which might fit with this not being a domestication from Yellow River region of the early states of central China (Xia-Shang-Zhou). Neither domesticated duck nor goose were identified among the several wild bird meats and chicken in the food provisions of a noble woman's tomb at Mawangdui, near Changsha, Hunan (Yu 1977). Given the quite comprehensive range of grains, fruits, domestic mammals in this tomb's inventory, this absence could point towards duck and geese keeping only becoming really prominent in this region later. First century AD texts from one Wang Mang (AD 9-23) indicate that in large scale animal sacrifices chickens were substituted for ducks or geese and dogs for deer (Sterckx 2002: 60), implying that many of these animals may have come from the wild or at least waterfowl were not kept abundantly in central China at that time. This points to a late domestication or one far from central China.

Another potentially important line of evidence would be well-identified archaeological eggs, a secondary product of fowl domestication. Indeed eggs have been recovered intact in jars in tombs of the Western Zhou period (1046-771 BC) (Excavation Team of Zhenjiang City Museum, 1979; Lin et al. 2006). However, while these were presumed to be duck eggs on the basis of recent traditions of pickling and preserving duck eggs, not anatomically based taxonomic identification is available, it remains unclear whether these eggs were from chickens or ducks.

Marginal local crops: buckwheat, *Chenopodium* and Taiwan hill millet

In this section we draw attention to three local plant domesticates, which highlight a role for peripheral areas of China in crop domestication. These are peripheral in relation to the plains of the Yangtze and Yellow river basin where rice and millet cultivation, respectively, fueled Neolithic demographic and cultural expansion, but peripheral areas may have contributed many vegetables, fruits, and secondary animal domesticates like the ducks and geese reviewed above. The three taxa reviewed here, however, are all potential starchy seed crop staples. In one case, that of buckwheat, a local domesticate spread to become a widely cultivated crop across Eurasia, while in another case, that of Taiwanese hill millet, we find a crop which never appears to have spread beyond its initial homeland, although how important it might have been to early cultivators there needs empirical investigation.

Buckwheat

Common buckwheat (*Fagopyrum esculentum* Moench) and the lesser used bitter or tartary buckwheat (*F. tataricum* (L.) Gaertn.) are important non-grass pseudo-cereals. Common buckwheat is grown in nearly every Eurasian country that cultivates grain crops and is usually consumed locally. It is mainly grown for the starchy white endosperm of its seeds which produces buckwheat flour. Based on philological interpretation De Candolle (1886), assumed that *F. esculentum* originated in Siberia or the Amur region but later botanists found wild buckwheat only growing in Southern China. The wild progenitor of *F. esculentum* is now well characterized morphologically and genetically as *F. esculentum* ssp. *ancestralis*, and occurs in parts of western Yunnan and Sichuan on the eastern edge of the Tibetan plateau (Ohnishi and Konishi 2001; Campbell 1997). Wild tartary buckwheat, *F. tataricum* ssp. *potanini* is more widespread across the Tibetan plateau (Figure 5). *F. esculentum* ssp. *ancestralis* has a narrow distribution in Southern China, growing at 1000-1500m above sea level in barren rocky habitats with poor soils along the Jinsha River, Yunnan and the Yalong River in Szechuan, never entering cultivated fields. The crop extends easily to above 3000 meters under cultivation, grown alongside barley at the highest elevations. Tartary buckwheat is likely a secondary domesticate, even better adapted to the highest elevations, upto ca. 4000 meters

Archaeological remains are rare, and the oldest finds are based mainly on finds of pollen. Assuming accurate morphological separation of *Fagopyrum* pollen from other Polygonaceae, the occurrence of this pollen in quantity in areas outside its wild range can be taken to indicate cultivation and the beginnings of the dispersal of the cultivar. Pollen finds in three areas of China from ca. 4500 BP suggest that cultivation began by the early Third Millennium BC at the latest. Find include from the Liaohe river basin in northeast China after ca. 4400 BP (Li et al 2006), Xishanping in Gansu to the northwest, where pollen could be ca. 2500 BC but due to stratigraphically inconsistent AMS dates might be only about 3000 BP (Li et al 2007). Palynological evidence from the Lower Yangzte could indicate some buckwheat cultivation in the hills south of the Yangzte as early as 4500 BP but certainly by about 2000 years ago (Yi et al 2003). A few macro-remains finds can be placed in the First Millennium BC, including from central Nepal (Knörzer 2000) and at Haimenkou, Yunnan (unpublished data from authors L. Qin and D. Fuller). Later evidence from Nepal is that of Kohla, a site at over 3000 meters from the 12th-13th century AD (Asouti and Fuller 2009). Linguistic evidence suggests that the Chinese name for Buckwheat was borrowed from eastern Tibeto-Burman speakers to the southeast of the Han Chinese sometime in the last two thousand years (Bradley 2011). Thus some dispersal around the peripheries of Chinese civilization may have started as early as 4500 BP/2500 BC, but as a more widespread staple crop buckwheat's importance may be more recent still.

Earlier claims appear problematic. Most often cited is the solitary carbonized nutlet from the apparently Early Jomon Hamanasuno site in Hokkaido, Japan (Crawford et al 1976). This single specimen, while clear in morphology, has subsequently been directly AMS-dated and found to be intrusive (160 BP, Beta-176046) (Obata 2011: 168). Apart for this single seed evidence consists of a few reports of buckwheat pollen from millennia later at Late Jomon sites, such as Ishigame and Higashikazanomari for the Second Millennium BC (Fujio 2004), perhaps suggesting an arrival in Japan after 4000 BP. The claims for early buckwheat in northeastern Europe near the Baltic Sea also rest on pollen diagrams, but are few (Janik 2002). At two sites in Latvia such pollen falls after 2500 BC, in line with period of early dispersal in eastern Asia, but the few earlier claims seems dubious and have not been backed up by more recent systematic archaeobotany. This is especially true of one 1950s claim from Denmark for Neolithic buckwheat, which has seen large scale systematic archaeobotany in recent years, without any finds of Neolithic buckwheat (reviewed by Robinson 2003). Systematic sampling and reliable identification of buckwheat in western Europe only start from the 13th and 14th centuries (e.g. Kuhn and Akeret 2002; Ansorge et al. 2003), in agreement with written sources that suggest introduction in the Middle Ages (Montanari 1994: 102).

Chenopodium

A pseudo-cereal cultivated in parts of ancient China was *Chenopodium giganteum* (Chinese *zhang li*), which is generally regarded as a domesticated form of *Chenopodium album*, a ubiquitous weed (Chinese *li*). Recent genetic studies place polyploid *C. album* and *C. giganteum* together in a single species complex (Rana et al 2012). Cultivation of *Chenopodium album/giganteum* today is

quite scarce in China as whole but widespread geographically (Zhu et al 2003), but it remains important in parts of the highlands of Taiwan as part of swidden grown millet (Fogg 1983), parts of Burma and Vietnam (Burkill 1966), and through the Indian Himalayas, especially between 1500 and 3000 meters elevation (Prartap and Kapoor 1985a). Archaeobotanical evidence suggests that there was some Iron Age cultivation in Europe (Stokes and Rowley-Conwy 2002), and Bronze Age cultivation in Gujarat, India, has also been suggested (see Weber 1991: 121), all of which could point towards multiple parallel domestication processes in prehistory for a crop that is now relict. Unambiguous archaeobotanical evidence for cultivated *Chenopodium* in China comes from an offering jar from a Han dynasty tomb at Yangling near Xian, from 141 BC (Yang et al 2009). Like other domesticated *Chenopodium* spp., of the New World (Smith 2006), modern domesticates have thinner seed coats which are lighter in colour (brown, red or to whitish) in contrast to the thicker black seed coat of widespread wild and weedy *Chenopodium* (Fig 7.8 in Fuller and Allaby 2009; see also Partap and Kapoor 1985b; Zhu et al 2003). There is also a change in seed shape, with domesticated seeds having a rounder or truncate cross-section in contrast to the acute edge in wild *C. album* (see Fig. 7.8 in Fuller and Allaby 2009). As reported in a study of Indian Himalayan cultivars there is a range of seed colours, with a mixture on individual plants, from predominantly shiny black (wild-type) through brown and red, with larger seed-size on average associated with red-seeded cultivars (Partap and Kapoor 1985b). All of these forms have dense drooping inflorescences and non-shattering perianths, i.e. they are domesticated in terms of seed dispersal. However, to develop reliable identification criteria will require large-scale comparisons across the full range of native Chinese and Indian *Chenopodium* spp., including seed coat thickness measurements and quantitative documentation of shape, like that which has been done for South American chenopods (Bruno 2006). Contrary to the notion in the botanical literature that domesticated *Chenopodium* in Asia diffused from origins in India (e.g. Zhu et al 2003), the possibility of independent origins in China needs investigation.

Archaeological *Chenopodium* species are widespread in the archaeological record of central China in sites dominated by millets, but in these cases such remains likely represent weeds, such as in the Ying valley, where at least two *Chenopodium* taxa must have been present based on variation in seed size (Fuller and Zhang 2007). Nevertheless, in the context of the Yiluo valley survey archaeobotany in Henan, Lee et al. (2007) note that some of the *Chenopodium* seeds, for example from the site Loukou, had a truncate margin and cellular testa pattern like North American archaeological domesticates, and this could be indicative of cultivation of a morphologically domesticated *Chenopodium giganteum/album* in Central China by the Second Millennium BC. However, the quantities of *Chenopodium* are small (upto 3% of seeds) in assemblages from this region, where millets clearly dominated cultivation. There are also some early Neolithic sites with significant presence of *Chenopodium* that could indicate use as food, such as Xihe in Shandong (ca. 6000 BC) and Xinglonggou in inner Mongolia of similar Age (Jin et al 2013). However, more striking evidence suggestive of *Chenopodium* cultivation comes from southwestern China, including Yingpanshan (Sichuan) 5300-4600BP (Zhao et al. 2011), and Haimenkou (Yunnan, ca. 3500 BP, unpublished data from authors L. Qin and D. Fuller), where large quantities of *Chenopodium*, equal to or in excess of clear crops in the same samples has been found. For example at Yingpanshan, *Setaria*, *Panicum* and *Chenopodium* occupied almost the same amount by the absolute number of seeds (29.4%, 27.0% and 30.1%, respectively). The early date of Yingpanshan suggests indigenous domestication, rather than dispersal from India. This also points to Southwestern China as a primary source of early *Chenopodium* cultivation, which could perhaps be seen as part of regional domestication complex with buckwheat and yak (*Bos grunniens*).

Taiwan Hill Millet

Spodiopogon formosanus is a rare cultivar endemic to Taiwan between 1000 and 2000 meters elevation. While the Flora of China refers to it as “cultivated in Taiwan” there is almost no serious literature on this species, at least in English. It has recently received attention from a Japanese ethnobotanist, Takei (2008). This species was first described by Rendle (1904) in his contribution on the grasses of Taiwan. Rendle classified this by comparison to *Spodiopogon sibiricus*, indicating that the comparison suggests “a cultivated form of that species”. Notable contrasts in *S. formosanus* includes the absence of sessile spikelet (typical of *Spodiopogon*), less hairy spikelets, “the almost complete disappearance of the awn on the fertile glume”. Most of these traits are plausible adaptations

of the domestication syndrome: a reduction in dispersal aids (i.e. it is awnless) and the development of non-shattering pedicel in place of a dehiscence scar, a trait which is paralleled in the evolution of non-shattering in domesticated pearl millet, *Pennisetum glaucum* (see Manning et al. 2011).

So this is a domesticated species. However, it remains unknown whether its wild progenitor was it brought into cultivation only in Taiwan, or was formerly distributed on the mainland. The wild species *S. cotulifer*, also in Taiwan and on the mainland, is perhaps the best candidate for a wild progenitor (Takei 2008). When this was brought into cultivation remains obscure. Was this an indigenous independent domestication by native of Taiwan, or was this a secondary domestication immigrant farmers of millets and rice after they arrived in Taiwan, which is conventionally suggested to have occurred around 3000-2500 BC (Tsang 2005; Hsieh et al 2011). Was this species ever more widespread, e.g. in Fujian or Lingnan, or was it always highly restricted? Systematic archaeobotanical sampling in Taiwan (and elsewhere) with this species in mind is badly needed. Nevertheless, like buckwheat, it highlights that not all crops came from the loess plateau like the main Chinese millets or the Yangtze centre of rice domestication.

Concluding remarks.

The beginnings of cultivation in China remains elusive. Clear evidence for the human behavioral change of cultivation, soil management and crop planting, is basically non-existent, and few crops provide clear evidence for morphological change which can be recognized as domestication in the biological and genetic sense. Rice in the Lower Yangtze provide evidence for morphological changes, but equivalent data are not yet available from sequences in other regions where this crop was likely an early crop. For later, additive domesticates, there is some evidence for morphological change, including Lower Yangtze melons and Yellow river soybeans. In these cases too, there is uneven documentation across all the regions with early use and potential independent starts of cultivation or domestication processes. Nevertheless, the evidence is suggestive of a Chinese mosaic of domestication processes occurring in parallel in several regions, based on millet or rice. One thing which does appear to be consistent in China is the lack of an early crop package. Instead, soybeans, melons, hemp, perilla, *Chenopodium*, may all be later additions to cultivation which was initially focused just a single starchy staple or two, millets in the north and rice in the south. This in marked contrast to the complementary and redundant package of crops represented by early farming in Southwest Asia, with multiple cereals, pulses and oilseed flax all domesticated early (Fuller et al 2012), and according to some as a single process in a small region (e.g. Abbo et al 2010; cf. Fuller et al. 2012).

Amongst animals, only the pig is a well-documented candidate for early animal herding, and suggestions for local pig domestication are widespread across both early millet and rice cultures. How these multiple potential domestications fit with current genetic evidence for a single widespread Chinese domesticated pig lineage, and many local wild boar gene pools which have not contributed to pigs (Larson et al. 2010), is unclear. It may be that there were some dead-end starts to pig keeping that parallel false starts in early rice cultivation. Nevertheless, pig as focal meat producing animal, emerged gradually, which parallels the evidence that wild plant resources, especially nuts, were only gradually given up in favour of cropping.

China has been a rich source of other domesticates, many of which are very poorly studied, and some of which may have been independently domesticated in what might be regarded as the 'peripheries' in relation to central China. Buckwheat and a relict Taiwanese millet provide clear plant examples, while ducks, geese, cyprinid fishes (carp), provide animal examples. Chickens and silk worm, while highly prominent in Chinese cultural traditions are simply under-studied and somewhat challenging subjects in terms of domestication.

The dispersed evidence of early cultivars in China is increasingly suggestive of a mosaic of origins over wide areas, rather than agriculture dispersal from a single core area. For northern Chinese millets the ca. 6000 BC cultures (Dadiwan, Cishan, Peiligang, Xinglonggou) are plausibly independent and parallel pathways into cultivation. This are distant in terms of ecology and material culture links from the early rice cultivators of the middle Yangtze (Pengtoushan) and lower Yangtze (Kuaahuqiao) that it is hard to see all of these are distinct trajectories. While these culture might be associated by deeper cultural proclivities in China, e.g. in cooking (Fuller and Rowlands 2011), there is no sense of the cultural transmission of a single notion of farming. In this regard, the Chinese

evidence parallels that from southwest Asia where domestication processes appear to have been decentralized, taking place in parallel across various parts of the fertile crescent (Fuller et al 2011d; 2012). In the Near East it was still largely within one broad ecological zone, the Mediterranean parkland or park steppe amongst more or less sedentary hunter-gatherers that cultivation began. However, in the case of China cultivation began in quite disparate environments, across the dry steppic grasslands of the loess-derived soils of the north and the sub-tropical wetlands of the Yangtze basin. These differing environments supported very different hunter-gatherers and early farmers, mobile foragers of the north who may have remained seasonally mobile when they began to cultivate millets, perhaps initially focused on the shorter season *Panicum miliaceum*, in contrast to the sedentary collector-fishers of the Yangtze valley who came increasingly to depend on managed wetlands and ultimately cultivated rice. These more sedentary collectors may have been better placed to begin pig-keeping, while the settling down processes among millet-farmers may have also drawn wild boars into the village environment. The longer term development of civilization in China drew on both of the millet and rice traditions, and over time acquired a number of added domesticates both from the local flora and from the southern peripheries that transitioned to agriculture later.

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List of Figures

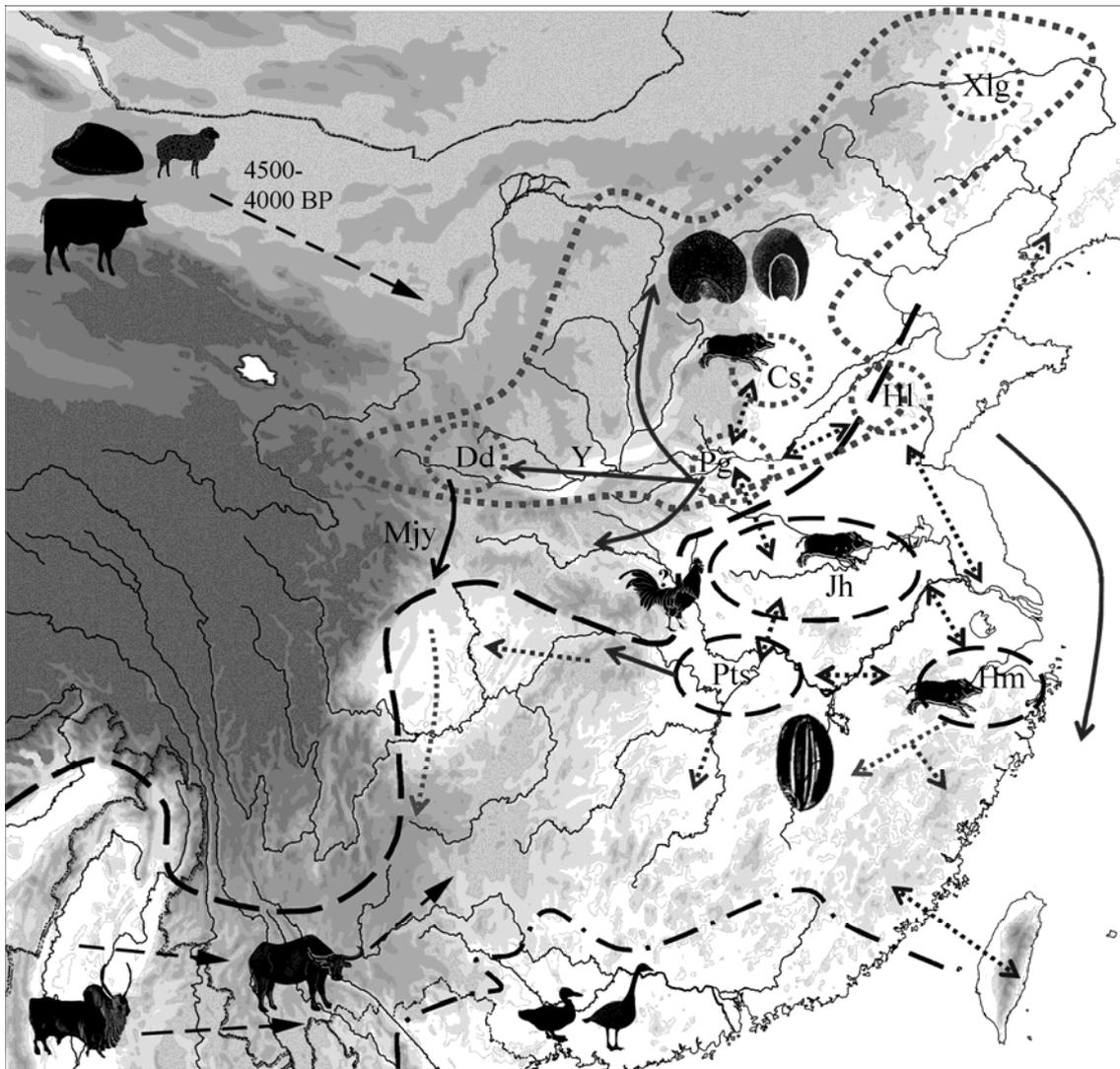


Figure 1. A schematic map of mosaic of Chinese agricultural origins, indicating the plausible zones of primary rice and millet domestication and the interaction between regional Neolithic culture. Later or peripheral and introduced domesticates are indicated schematically. The grey dashed zone in the north indicates the likely zone of wild millets, within which archaeological cultural foci were Dadiwan (Dd), Peiligang (Pg), Cishan (Cs), Xinglonggou (Xlg) and Houli (Hl). The black dashed lines indicates the northernmost limits of wild rice for the early Holocene and the southern glacial refugia zone of wild rice (after Fuller et al 2010). Between these lines are indicates the cultural foci of the Pengtoushan (Pts), Hemudu (Hm), and Jiahu (Jh) cultures. Those cultures zones that may have contributed to pig domestication are indicated by pig silhouettes. Dashed lines with arrows on both ends indicate cultural interaction, while those with a single arrow head indicate directions of the diffusion of domesticates. Solid lines with arrows represent likely migratory expansions, including the Yangshao culture (Y) and the Majiayao (Mjy). Later peripheral additions are indicated: wheat, sheep and taurine cattle from central Asia; ducks and geese from tropical south China; zebu cattle and water buffalo from South Asia/Yunnan.

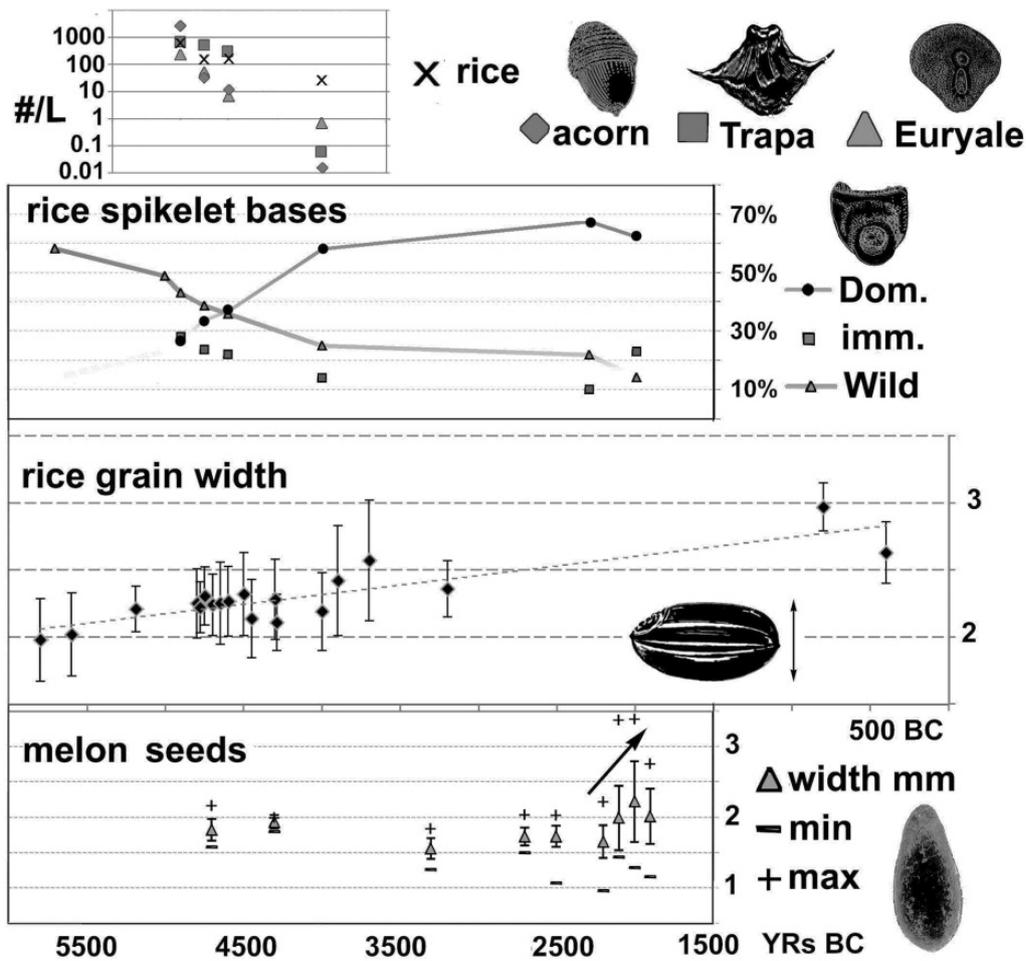


Figure 2. Lower Yangtze archaeobotanical time series: density of wild staples versus rice (Fuller et al 2011, and unpublished data from Caoxieshan); spikelet bases indicating morphological domestication (Fuller et al 2009; 2010a, and unpublished data from Caoxieshan); gradual increase in grain size (from Fuller et al 2010a); seed change data indicating rapid and late melon domestication. (from Zheng and Chen 2006; Fuller et al 2011a; Fuller 2012).

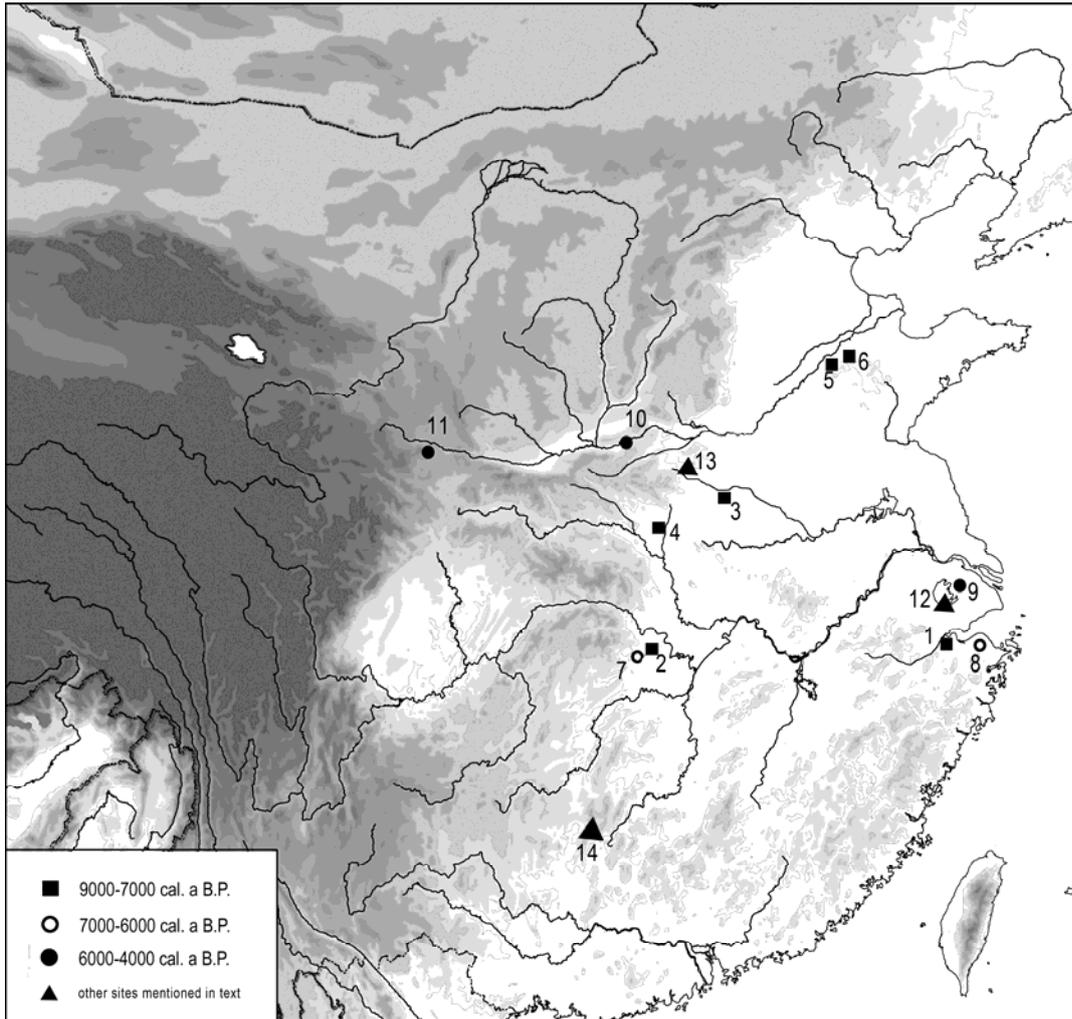


Figure 3. Sites with early evidence for rice numbered: 1. Kuahuqiao; 2. Bashidang; 3. Jiahu; 4. Baligang; 5. Yuezuang; 6. Xihe; 7. Chengtoushan; 8. Tianluoshan; 9. Chuodun and Caoxieshan; 10. Nanjiaokou; 11. Xishanping. Additional sites shown on this map: 12. Qianshanyang (see silk section); 13. Wangchenggang (see soybean section); 14. Zengpiyan (see pig section).

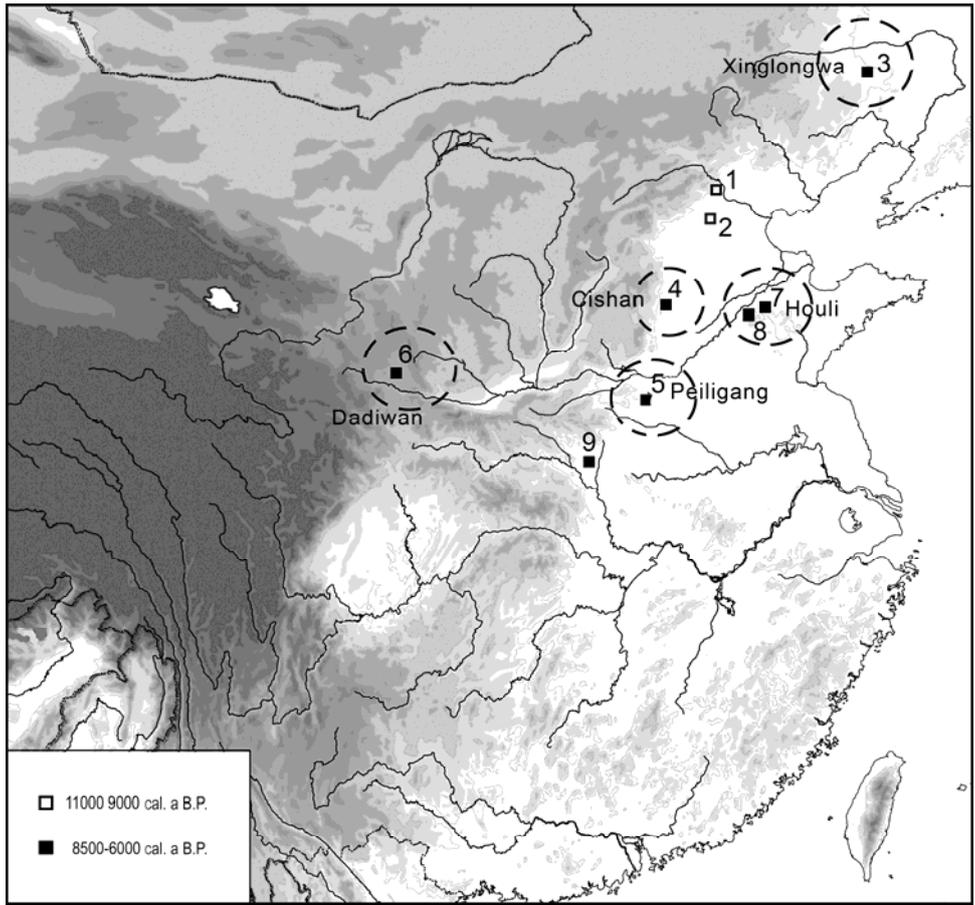


Figure 4. Sites and culture areas that are important for early millet cultivation. Site numbered: 1. Donghulin; 2. Nanzhuangtou; 3. Xinglongwa; 4. Cishan; 5. Tanghu; 6. Dadiwan; 7. Yuezhuang; 8. Xihe; 9. Baligang.

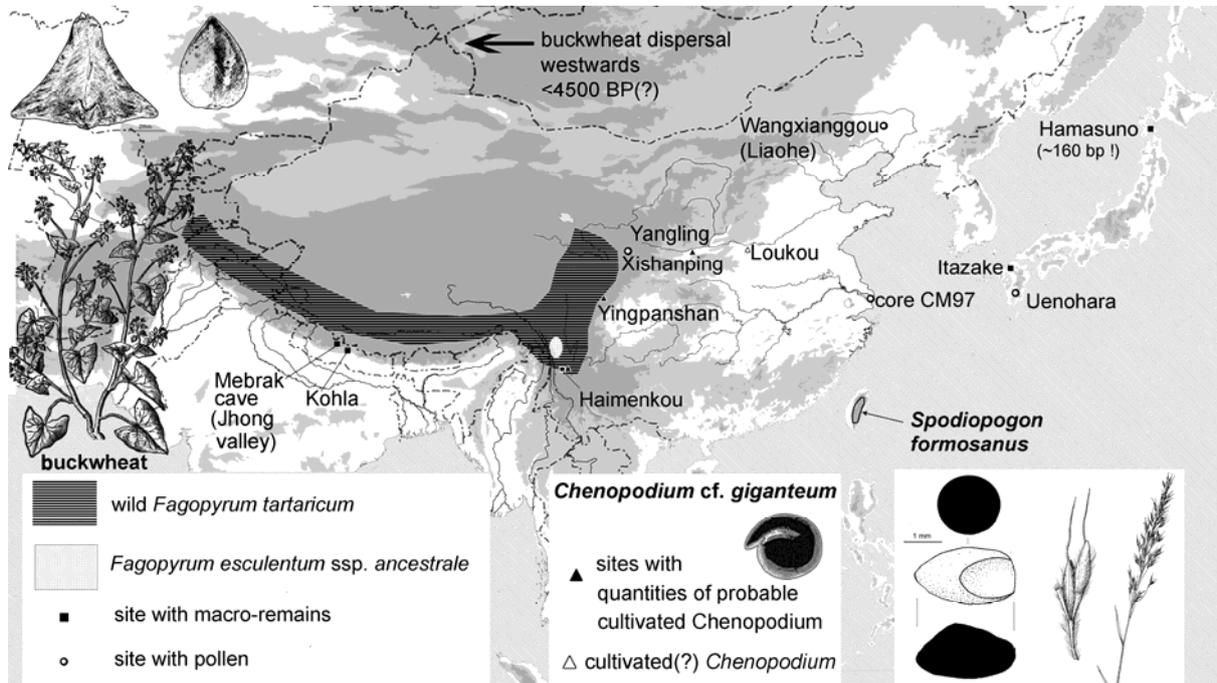


Figure 5. Map of peripheral crops of early China, indicating the wild range of buckwheat species (*Fagopyrum esculentum* and *F. tartaricum*), the range of modern cultivation of Taiwan hill millet

(*Spodiopogon formosanum*), and sites with evidence for possible cultivation of buckwheat and *Chenopodium*. Images illustrate seeds, fruits and/or plants of these crops.