# Trajectories of agricultural development in prehistoric China: From the beginning of crop cultivation to the period of agricultural intensification (c. 10000-3000 BP)

## I. Introduction

Fast accumulating archaeobotanical remains in China have shed new light on prehistoric subsistence not only inside China but beyond its borders in Central and East Asia. Examining the most recent archaeobotanical and archaeological evidence, this chapter delineates trajectories of agricultural development in prehistoric China. It focuses on the periods when initial farming began, when agriculture with year-round sedentism was established during the Middle Neolithic, and when agriculture was gradually intensified due to dramatic social, economic and cultural changes from the Late Neolithic onwards.

Debate on the origins of agriculture in China has focused on whether farming started in one center and spread to other regions or there were multiple centers of it (Zhao 2011; Qin 2012). The former viewpoint often fails to consider the importance of ecological and cultural diversity, which accounts for the diverse pathways to agriculture in different regions across time (cf. Fuller, Willcox, and Allaby 2012). Of particular importance is the environmental, ecological and cultural differences between the Yangtze and the Yellow Rivers, which define the fundamental difference in agricultural practices and food consumption patterns in these two regions. However, these regions were not isolated; rather, they were increasingly interwoven by long-distance interactions.

Therefore, in addition to the ecological and environmental diversity and its relationship with agricultural development, this chapter also focuses on the following two issues. First is the close entanglement between food production and formation of cuisines. As illustrated by some scholars, there is a long-standing tradition of boiling grains (rice and millets) in East Asia, which demarcates a profound departure from the bread-making tradition in West Asia from the very beginning of agricultural production (Fuller and Rowlands 2011). Within the broad context of agricultural development through time, this chapter will investigate the formation of food traditions and how it was closely intertwined with agricultural production and social changes (cf. Barker 2006; Haaland, 2007; Jones 2007; Sherratt 1999 for related theories on food production and social organizational changes in different parts of the world). The second important issue to be explored is the increasing movement of cultivars that continuously shaped agrarian landscapes of different regions. Related to these two perspectives are the recent theoretical developments which consider domestication and other food exploitation strategies a ‘cultural and ecological entanglement’, behind which human behaviors, including technological innovations and cultural adaptations, and genetic selections were closely tightened up together (Fuller et al. 2010, 2016). These theories contribute to compare and contrast cultural choices and food systems in a broader perspective.

## II. Origins of and transitions to agriculture: protracted process and remaining mysteries

Similar to the trend observed in the Fertile Crescent (Savard, Nesbitt, and Jones 2006), the transition from the Terminal Pleistocene to the Early Holocene in China also ushered in the beginning of a fundamental shift in plant food exploitation strategies, that is the consumption of small seeded grasses, which eventually led to the cultivation and domestication of some of the grasses. Not only did millet and rice begin to be consumed, other small-seeded plants such as barnyard grasses was also eaten (Yang, Fuller, et al. 2015). Such a shift resulted from dramatic environmental and ecological changes in the Pleistocene-Holocene transitional period. One of the most significant changes was the increase of atmospheric $CO_2$ level due to temperature increase, which would have been favorable to the growth of $C_4$ plants (Sage and Monson 1999). $C_4$ plants, such as millets and maize, have a special photosynthetic mechanism allowing them to fix carbon more effectively especially in dry and warm conditions. The dietary shift was also related to the revolution of food processing techniques. The invention of ceramics (with the earliest ceramics occurring around 20,000 cal. BP (Wu et al. 2012), for instance, triggered an unprecedented development of grain boiling, which would have potentially further emphasized the importance of small-seeded grains in the palaeo-diet. However, how and when exactly did this transition of food processing occur and what were the specific roles of early ceramic containers in this change remain controversial.

*Millets in the North*

Figure 1 shows sites containing early millet remains. They are located in different environments. This suggests, despite their small percentage in the archaeobotanical assemblages, millets were becoming a common plant food amongst these communities (Yang et al. 2015b). Consumption of millets lasted for almost 2000 years before millets were domesticated (Yang et al. 2012). Lack of archaeological discoveries in this prolonged period hinders our understanding of the domestication process of millets.

Whilst Cishan (ca. 8000?-7000 BP) in the Taihang-Yan Mountain region has long been considered as a place for early millet cultivation and domestication due to the discovery of tens (88) of large storage pits which might have been used to store millet grains

(Tong 1984), detailed information concerning how millets were cultivated remains unknown. Based on their pioneering research on the morphology of millet phytoliths, Lu et al. (2009) suggest that it was broomcorn millet rather than foxtail millet that was first cultivated and largely consumed. The earliest unambiguous evidence of millet cultivation comes from the archaeobotanical research at Xinglonggou (c.8200-7400 BP) in the Western Liao River (Figure 1), another potential area for independent domestication. Here broomcorn millets overwhelmingly predominate over foxtail millets (Zhao 2006, 2011). The abundance of weedy seeds (*Cerastium glomeratum, Astragalus* sp., etc.) suggests that millet farming was practiced but still at an initial stage. Indeed, characteristics derived from wild progenitors are still observable (e.g. the grain sizes are small and close to those of wild grains) (Zhao 2006).

The absolute number of sites that contain millet remains increases dramatically during this period (8500-7000 cal. BP). Broomcorn millet indeed was a more important cultivar than other crops. There is a popular opinion suggesting that this is related to the physiological advantage of broomcorn millet being able to adapt better to water stress (Dong and Zheng 2006), but how this co-evolved with environmental change and cultural selection remains to be demonstrated. Other plants, primarily different kinds of nuts, still accounted for the large majority of plant foods consumed.

*Rice in the South*

Compared to the myth concerning the domestication process and wild progenitor of millets, the story of the beginning of rice consumption, cultivation and domestication is relatively clear. Rice was consumed at the beginning of the Holocene (Liu et al. 2007). Rice had to be boiled before being eaten. By the early Holocene, pottery technology reached a peak, with the appearance of large-sized ceramic vessels and the sophisticated producing technology (Jiang 2013). Also very developed was the lithic industry, characterized especially by the production of very large-sized grinding stones (Jiang 2013) (Figure 2). Such technological breakthroughs must have been associated with fundamental changes in food processing and indicate an initial stage of intensifying food production. The latter would have involved management of wild habitats of rice and other grasses, paving the way for rice domestication.

The timing of rice domestication is, however, controversial. Some scholars, whilst acknowledging that it was a ‘long, non-linear’ process, suggest an early cultivation of rice during the ‘late Pleistocene/early Holocene’, mainly based on the measurement of many individual grains from a series of Early-Holocene sites. Others advocate that the domestication of crops was a truly prolonged process with increasing labor input and intensifying management of landscapes, which has been contested in the research of agricultural origins in the Near East (Fuller, Asouti, and Purugganan 2012). Fuller and colleagues, in their examination of the archaeobotanical remains recovered at Tianluoshan, fully and convincingly demonstrate that whilst the ‘non-shattering domesticated rice (*Oryza sativa*)’ occurred very early (8000-7700 BP), the cultivation of rice took more than 1000 years before reaching full domestication. This is characterized by the predominance of non-shattering rice spikelet bases in the floral assemblage (Fuller et al. 2009). In line with this dramatic increase was the decrease of wild gathered plant foods consumed at Tianluoshan, pointing to a heavier reliance on cultivated crops. These early rice farmers, deploying a range of methods such as land clearance and burning, were transforming ‘coastal wetlands’ into early paddy fields (Zong et al. 2007), but the function of these fields remains to be further demonstrated.

*Multiple centers and dead ends?*

Recent archaeobotanical research at a number of sites located in other regions than the Lower Yangtze River has provided new insight on the exploitation and cultivation history of rice and other crops. Rice was also consumed very early in the Middle Yangtze River. By around 8000 BP at Bashidang, abundant rice grains were recovered along with wild nuts, fruits, and aquatic plants (HPICRA 2006, 544-562). The shapes of these grains vary greatly. The rice remains at Shunshanji located in the Huai River are directly dated to around 8400 cal. BP (IANM and SM 2014). In addition, excavations at the contemporary Hanjing site reveal structures and soils that resemble those discovered at several later-period rice paddy fields. There is possibility that the Hanjing occupant already started changing water and soil conditions in the habitats of wild rice for initial farming.

The rice remains at Jiahu and Baligang (8700-8300 BP) are of similarly early ages (Deng et al. 2015; Zhang 2011). Even though the grain size continued to change, non-shattering rice spikelet bases were already abundant at Baligang, making the area another candidate for independent rice domestication. Moving further north in the Lower Yellow River, rice was also consumed at Yuezhuang (8000-7800 cal. BP, (Crawford, Chen, and Wang 2006)) and Xihe (8070-7900 cal. BP, (Jin et al. 2014)). However, percentages of rice in these early archaeobotanical assemblages remain low and non-shattering rice spikelet bases are rare. More dramatically, it seems that the rice, whether cultivated or domesticated, disappeared, before it re-appeared around 6000 cal.

BP in the region (Jin et al. 2016). This prompts speculation that this early rice encountered environmental and/or biological bottlenecks, which led to a dead end in its development (Fuller et al. 2010). Whilst this is a compelling case in the study of rice ecology and is supported by genetic evidence (cf. Fuller et al. 2010), it is still too early to conclude that there was definitely a dead end. Other possibilities such as migration or long-distance exchange of crops should be taken into account.

*Beginning of animal husbandry*

Dogs were domesticated in the Early Holocene. Between 8500-7000 BP, evidence of pig husbandry and domestication emerges in both North and South China, where archaeo-genetic research has confirmed them as independent domestication centers (Larson et al. 2010). At Jiahu, inter-disciplinary studies, which examine geometric morphometric (Cucchi et al. 2011), mortality patterns (Yuan and Flad 2002) and palaeo-diet (Luo 2007), have confirmed that some pigs have a similar diet to humans and most of them were culled under 2 years (81.4%) (Luo 2007), making Jiahu one of the earliest places for pig domestication in China. At Dadiwan, most of the pigs were culled at the age of 1-1.5 years. This suggests strong human intervention in the reproduction cycle of pigs as the age profile of pigs that were not managed by people would have been more scattered rather than being concentrated on 1-1.5 years. But this contradicts with results of isotopic research which points to an opposite scenario in which the diet of the pigs was different from that of the occupant. In other words, the pigs were not fed by leftover food from human (Barton et al. 2009). Other possible centers for early pig husbandry include Cishan, Xinglongwa (Liu et al. 2012) and Xihe (Song 2012), but none of the sites has unambiguous evidence for pig domestication yet. At Kuahuqiao and

Tianluoshan in the Lower Yangtze River, the debate on when and how pigs were domesticated is also ongoing, with recent evidence tending to support they were still wild or at least only at the initial stage of herding. The lack of consensus in these studies might also indicate that interbreeding between domesticated and wild boars was common in the early stage of pig husbandry, rendering it hard to pinpoint a clear baseline for domestication. Meat consumption of this period, however, still largely relied on hunting wild animals, especially different kinds of deer (e.g., SPIA and ATBC 2007).

## III. Middle Neolithic agricultural villages: Yangshao and Majiabang

### *Agriculture in Yangshao and its contemporaries*

In the Yangshao (c.7000-5000 BP) period agricultural villages, occupied by millet farmers and craftsmen all-year around, were established. The Yangshao farmers built settlements in various types of environments. Representative examples include Banpo, Jiangzhai, Dahecun, Xiawanggang (Figure 3), to name just a few (Underhill 2013). Located on river terraces or alluvial plains, these settlements are often very well planned, with buildings clustering as groups surrounding a central public space or forming a row of long houses (Institute of Archaeology 1963; XBM, SPIACR, and MLC, 1988). Close to these buildings were kilns, lithic workshops and other economic production units as well as cemeteries. This new economic development was supported by and further stimulated agricultural production.

The early and late Yangshao horizons at Dadiwan contain abundant millet remains, including grains and chaffs, with more broomcorn millets in the early phase (GPICRA 2006, 914-916) and more foxtail millets in the later phase. Millet remains have been found in a much wider geographic area during the Yangshao period (Liu, Jin, and Kong

2008, 165). Isotopic research provides semi-quantitative evidence for an increasingly important role of millet consumption in the palaeo-diet of Yangshao (Barton et al. 2009). The $\delta^{13}C$ values of human remains at many sites indicate ‘a staple role for millets’ (Pechenkina et al. 2005). At the Xipo cemetery, though there was emerging evidence for social stratification as demonstrated by the different quantities and qualities of burial goods amongst the burials, the generally high $\delta^{13}C$ values of the human remains show that these people, potentially of different social status (Institute of Archaeology and HPICRA 2010), had an equal access to the crop (but perhaps differential access to meat). Other indirect evidence for developed millet farming includes the pronounced increase in agricultural tools, especially ceramic and stone knives and sickles used for harvesting (Zhu 2013; Wang 2013) and bone and stone spades or shovels and hoes used for land clearance and ploughing (SPIA and ATBC 2007, 400-401; Wang 2013). These activities would have promoted the gradual expansion of arable lands that were occupied by crops and their wild relatives surrounding the settlements.

Benefiting from the much improved temperature and humidity conditions during this period (An et al. 2000), rice, which requires a significant amount of water to grow, was also cultivated in many regions of the Yangshao culture, notably the Guanzhong Plain in Shaanxi and the Central North China Plain which are presently relatively dry (Liu, Jin, and Kong 2008), according to recent archaeobotanical evidence. Phytolith studies suggest that rice was likely cultivated on river floodplains that had better hydrological conditions (Zhang, Lu, et al. 2010). But the importance of rice in local subsistence remains unclear. There is also evidence of vegeculture at some Yangshao period sites. A whole jar of vegetable seeds (species not identified), for instance, was found on the house floor at Banpo (Institute of Archaeology 1963). Other plants likely cultivated include *Brassica campestris* L., rape seeds (*Brassica*), *Perilla frutescens* (Linn.) *Britt*, etc. (PIACRG 2006; Kong, Liu, and Zhang 1999). All are plants often grown in gardens or near settlements.

In the Lower Yellow River, judging from the limited archaeobotanical evidence, millet farming was further developed in the Beixin (7000-6100 BP) and Dawenkou (6100-4600 BP) cultures. Foxtail millet grains have been recovered from a number of sites (Wang 2013; Liu, Jin, and Kong 2008). Similar to the trend seen in the Yangshao culture, abundance and styles of agricultural tools at Beixin culture sites also increased significantly, with spades, sickles and knives, as well as grinding stones, becoming a common set of food production and processing tools in the society (Wang 2013, 400). This implies that farming had now become a common practice in the 'villages'.

Rice disappeared after the Houli culture period and a new rice species was reintroduced to Shandong during the middle Neolithic period, as evidenced by the discoveries of rice remains in the coastal areas of Shandong and Jiangsu Provinces (Jin et al. 2016; Qin 2012, 275), pointing to a possible coastal route for the spread of rice. The role of rice in society varies. Whilst isotopic studies at some sites show that millets were a predominant source for food consumption (Zhang, Qiu, et al. 2010), by the late Dawenkou period, $\delta^{13}C$ values of some 'high-ranking individuals' suggest that they were consuming more $C_3$-based plants such as rice, compared to other members of the society who mainly consumed $C_4$-based plants including foxtail and broomcorn millets (Luan 2013, 414).

*Animal husbandry*

While the relationship between pigs and humans was already becoming closer during the previous period, by the Yangshao period, pigs were definitely domesticated. Most pigs were culled before 2 years old. There is also a consistent decrease of the M3 (teeth) length (cf. Wang 2011) through time. Isotopic evidence shows that pigs were fed with food leftover from humans. Along with this new tendency were the steady increase in pig meat consumption and the corresponding decrease of wild animals (e.g., PIACRG 2006). The social role of pigs also changed dramatically. Not only were pigs, along with other animals such as dogs, buried in sacrificial pits in cemeteries, pig mandibles were often collected and buried in graves too. The latter has been found at sites such as Diaolongbei and Baligang (Zhang 2012). In one burial (no. M13) at Baligang, 90 human skulls were buried, with more than 120 pig mandibles being placed on the platforms in the burial. The consumption of these pigs would have been a collective activity; the mandibles were likely kept as symbol of asset and/or social status. The socio-economic role of pigs became more prominent in the Dawenkou society. Burials enriched with elaborate goods would often contain one or several pig mandibles or whole piglets (Luan 2013).

*Agriculture in Hemudu and Majiabang in the Yangtze River*

At Chengtoushan (6500-5500 BP) in the Middle Yangtze River, rice became an important crop (70%); foxtail millet was also cultivated, but only in small proportions. The cultivation of rice and millet is corroborated by the presence of weed seeds. These weedy plants grew in both dry uplands and paddy fields during cultivation and were brought to the site together with crops when being harvested (Nasu et al. 2012). Wild plants, however, continued to be consumed in a large quantity. Except for the cultivation of millet, the plant food exploitation strategies in the Lower Yangtze River are similar to the ones at Chengtoushan. At Longqiuzhuang (7000-5500 BP), for example, there is a general trend which saw the increase of rice in the floral assemblage, gradually replacing water chestnut and Euryale (ATLS 1999). This trend can be seen at Luojiajiao around the Taihu Lake (Zheng, Sun, and Chen 2007) and at Tianluoshan. From the huge number of plant remains recovered at Tianluoshan, Fuller and colleagues found that 6900-6600 BP was the critical period for rice domestication, which saw increased domesticated rice spikelet bases from 27% to 39% and rice remains as a whole from 8% to 24% (Fuller et al. 2009). This culminated in the domestication of rice after 6500 BP.

Along with this clear shift were changes in settlement plans, the development of farming tools and the appearance of paddy fields. The last was particularly significant. One of the earliest rice fields was found at Chengtoushan. Located on an alluvial plain, the fields were continuously used, with simple irrigation and drainage features being gradually built (Pei 2008, cited from Qin 2012, 269). Slightly later on more paddy fields were found at more places. In this early stage of rice farming, draining during harvesting would have been very important. Great effort was made in micro-scale management of in-field ecology such as building embankments and digging small ditches and water outlets. These early farmers were managing different types of landscapes for rice farming. At Tianluoshan, early rice fields were built between 6650-6490 BP by opening up ‘marshes of dense reeds with fire and wooden or bone spades’ (Zheng et al. 2009). Contrast to this, at Caoxieshan and Chuodun (ca. 6200-6000 BP) located around the

Taihu Lake, paddy fields were built directly on top of relatively higher grounds. Here more labour was invested for digging well-connected water outlets and ditches.

*Movements of cultivars and formation of agrarian landscapes*

The Yangshao and Majiabang period witnessed large-scale human migration, which fundamentally transformed agrarian landscapes across China. First, millet farming was introduced to different parts of China by farmers from Central China (Guedes 2011; Qin 2012). As new crops in South China, local residents cultivated millets on the margin of their landscapes, as a supplement to rice farming such as the case at Chengtoushan and other sites (Nasu et al. 2012). Second, rice, potentially of new species, was introduced to North China by migrants from the south. Indeed, the favorable environmental conditions during the Middle Holocene were conducive to the growth of rice in areas as far northwest as the Upper Yellow River. Despite the controversy in their discovery contexts (Qin 2012, 273), the direct AMS dating of carbonized rice grains and abundant rice phytoliths from Xishanping in Northwest China suggest that rice farming was an important agricultural development in the area around 5000 BP (Li et al. 2007a, 2007b).

From the Middle-Late Yangshao period, rice and millets appeared together in archaeobotanical assemblages recovered in areas such as the Nanyang Basin in the intermediate area between the Yellow and Yangtze Rivers (Deng et al. 2015) and at Nanjiaokou in the Middle Yellow River (Qin 2012). Such a new phenomenon became more common during the Late Yangshao period. In addition to the Yellow River where rice was becoming a more important crop, in central Henan, Fuller and Zhang find that rice and millets appeared together and had high ubiquities (Fuller and Zhang 2007). The formation of such a mixed farming regime profoundly changed the seasonality of farming in these regions and its potential was further enhanced in the succeeding Longshan period.

Domesticated animals such as pigs would have been moved around by the migrants, so would technology, exotic goods, and ideology. But it is hard to track down the movement of pigs due to the lack of archaeo-genetic and other evidence. By the Middle Holocene, agriculture, along with craft production, had become the primary economic activities in the farming villages across vast areas of the Yellow and Yangtze Rivers. This established, village-based economy paved a solid foundation for the social and economic 'taking off' in the following period.

## IV. Agricultural intensification and emergence of early complex societies during the late Neolithic

The Neolithic saw dramatic social, economic and cultural changes across China, characterized by the emergence of walled sites of enormous scale, advancement in technologies and the introduction of new cultivars to China such as wheat, and domesticated sheep and goat, to name just a few. This led to the formation of early complex societies or states, which in turn further changed the organization of agricultural production. During this period, agricultural production was intensified, which took the form of crop diversification in some areas, whereas in other areas, it was the loss of crop diversity.

### *Agriculture of the Longshan period (c.5000-4000 BP)*

While climate as a whole was deteriorating during this time (Dong et al. 2010), rice was becoming a more common cultivar across North China. This was significant as it indicates that a more diverse and wider range of niches suitable for rice farming in the otherwise semi-arid environment began to be cultivated due to population growth as attested by changes of settlement patterns (Wagner et al. 2013). In Shandong, the Lower Yellow River, not only were the quantity and ubiquity of rice becoming higher than previously, rice fields were also built for rice farming. The latter is confirmed by a phytolith study at Zhaojiazhuang (Jin et al. 2007) in the coastal area. Similarly, rice appeared in many archaeobotanical assemblages examined in Henan Province, also with high ubiquities (Zhong et al. 2016). This rice was cultivated in wet fields, as suggested by phytolith studies (Weisskopf et al. 2014). The appearance of rice was more scattered in westward areas, as precipitation reduced. This created a distinctive difference between the eastern and western parts of North China in terms of crop choices, which was even more pronounced in the Bronze Age.

Millet farming was further intensified during this period. Foxtail and broomcorn millets were predominant (often more than 70%) in most archaeobotanical assemblages recovered from both large walled and small sites. The majority of these millet grains were full with a smooth surface. Broomcorn millet grains, though in smaller quantities, were on average larger (2mm) than foxtail millets (1.2-1.5mm) in length. Carbonised weed seeds accounted for only a small proportion (Zhao and He 2006; Zhong et al. 2016; Zhao and Xu 2004), which implies changes in crop processing and/or intensified farming practices in fields, such as more weeding during farming which would have eliminated many weedy plants.

Another important agricultural development in this period was the domestication of soybean. Recent research has confirmed very evident size increase of carbonized soybeans at a number of late-Neolithic sites in North China (D. Fuller personal communication). Whilst the study of soybean domestication is intrinsically difficult due to the lack of unambiguous evidence such as the non-shattering trait of seeds, size increase could be considered as a sign of human intervention in the biological properties of legumes. Well known for their ability to fix nitrogen (Postgate 1998), legumes would have been cultivated to compensate the potential loss of nitrogen levels of soils. Legumes were consumed from a very early period, with the earliest remains discovered between 8000-7000 BP (Kong, Liu, and Zhang 1999; Zhao and Zhang 2009), but the evident size increase seemed to only become widespread during this period. This prompts speculation that (1) the intensified consumption of soybean resulted in the 'secondary domestication' of it and/or (2) some of the legume species were actually domesticated outside China and introduced to China (see below).

Abundant charcoal has been commonly found amongst archaeobotanical assemblages, some of which are believed to be from tubers and other starch-rich plants such as roots. But without the help of other analytical means such as starch grain analysis, it is hard to ascertain what plants were actually consumed.

Though the main types of farming tools used in this period remain roughly the same, including 'shovels for digging, knives, and *lian* sickles for harvesting, and grinding stones and slabs for processing millet' (Zhao 2013, 249), the production of these tools were organized in a dramatically different way. The scale of production increased significantly. At Taosi, for example, a huge amount of sandstone flakes (20,930) were discovered in just one pit. According to Liu et al. (2013), 53.7 hours would have been needed to produce these from around 268 blanks. Related to this was the abundance of finished products discovered at large sites. The occupants at these large, walled sites had control of raw material available in their vicinity. The Dagudui Mount near (7.4km) Taosi was providing three main types of stones for Taosi. Similarly, the Wadian walled site was also directly controlling stone mines located in the nearby mountains. Raw material from these mines was mainly used for producing agricultural tools such as spades and axes, a kind of ‘loose specialization’ of production during the Longshan period, according to Pang and colleagues (2013). Agricultural tools produced at these sites might be then re-distributed to smaller sites, some of which might have specialized in agricultural production.

*Animal husbandry and ‘secondary product intensification’?*

Not only were pigs widely raised during this time, newly introduced domesticated animals, mainly sheep and cattle, were herded at some sites. At Taosi, for example, isotopic studies show that not only were pigs and dogs fed by food leftover from humans, which was $C_4$-based, $C_4$ plants also partly contributed to the diet of domesticated cattle (Chen et al. 2012). This suggests that millet agriculture was further intensified due to the animal husbandry as, at least at some key sites, millets were increasingly fed to animals.

Domesticated sheep appeared in around 5300-5000 BP in the Hexi Corridor of Northwest China (Cai et al. 2010). There is a growing consensus that the Hexi Corridor was one of the most important geographic areas where domesticated sheep, along with many other cultivars and new technology such as metallurgy, was introduced into

Central China. They arrived at Taosi around 4300 BP and the percentages of it in the faunal assemblage continued to grow, from 3.57% (MNI) in the early phase to 9.18% in the late phase (Li, Brunson, and Dai 2014). While sheep were raised, fed by $C_3$ grasses, and consumed as meat at many late-Neolithic sites of North China, recent evidence suggests that, at some key sites, it was kept for other economic purposes. At Taosi and Xinzhai, patterns in the culling age of the sheep were quite similar: at Taosi, 40% of them were killed at 4 years old (Brunson 2011; Li, Brunson, and Dai 2014); 25% of adult sheep were killed at 6 years old; more than 50% of sheep were killed in both phases 2 and 3 at Xinzhai. This lends some support to the hypothesis that the sheep were kept for wool production, though more study is desirable.

Like domesticated sheep, domesticated cattle were introduced to China around the same time. Cattle bones frequently appeared at sites in middle and eastern Inner Mongolia, with their percentages sometimes higher than 15% of the mammals (Yuan et al. 2007). Unambiguous evidence for domesticated cattle again comes from the Neolithic Hexi Corridor. At least around 4500 BP, domesticated cattle was found at sites in central China, with a pronounced increase in percentages through time (Yuan et al. 2007). Other domesticated animals introduced into China via the Hexi Corridor or other routes include camels and horses, although the timing of their domestication and spread remains highly controversial (Flad, Yuan, and Li 2009).

*Liangzhu and Shijiahe agriculture in the Yangtze River*

The areas around the Taihu Lake and the Jianghan Plain were densely populated by the Liangzhu and Shijiahe people, respectively. Amongst the increasingly concentrated settlements around the Taihu Lake, smaller sites appeared to play a more important role in agricultural production. Plant remains recovered through flotation are predominantly rice, including seeds, chaffs, stalks and other parts of rice plants from different archaeological contexts with high ubiquity. Future research needs to unpack crop processing and different consumption patterns at these sites. There is also clear evidence of agricultural intensification from the early to late Liangzhu period. This can be best seen in excavation of the well-preserved paddy field site at Maoshan. The size of the paddy fields increased significantly from the early (around 30-40m$^2$) to late period (up to 2000m$^2$). Along with this size increase was intensified water management through time as evidenced by greater control and management of ditches and water outlets, more careful management of in-field ecology and the beginning of soil amendment in the late period (Zhuang, Ding, and French 2014). In addition, ongoing research on agricultural tools also shows parallel changes in them through time (L. Qin personal communication). A huge hydraulic engineering project was built in the early Liangzhu period, situated to the north of the ancient Liangzhu City. It consists of low and high dams and covers a huge area (13km$^2$). These dams were mainly used for flood protection, but irrigation would have also been one of the main functions, though how and where it was supplying water to are subject to further studies.

A large number of huge walled settlements were built in the Jianghan Plain during this time (Zhang 2013), forming a very distinctive regional characteristic. The Shijiahe people were rice farmers too. Rice remains were the overall majority in the archaeobotanical assemblages examined (Deng, Liu, and Meng 2013). Weedy plants only accounted for a small proportion, which must have been an outcome of increased weeding in the field, but there is no physical evidence of paddy fields in the Shijiahe culture yet. Despite their small percentages, millets commonly appeared in the flotation samples at many sites (Deng, Liu, and Meng 2013; Wu, Liu, and Zhao 2010; Tang et al. 2014). These millet remains were sometimes found together with rice spikelet bases rather than rice seeds. Some think they were used to feed animals (Wu, Liu, and Zhao 2010). More in-depth surveys are required to understand the dynamics between rice farming and dry-land farming in the Jianghan Plain and how they adapted into local environmental conditions.

*Expansion of the interactive circle and consolidation of distinctive Chinese cuisine*

The interactive circle for the movement of cultivars and technological transmission expanded significantly during this time. The two ends of the Eurasian continent were closely interweaved and saw constant movements of goods, cultivars and ideas (Sherratt 2006; Jones et al. 2011). Millets traveled westward, reaching central Asia and further west (Hunt et al. 2008; Frachetti et al. 2010; Miller, Spengler, and Frachetti 2016). Along the eastern coast, millet agriculture spread southward to places such as Taiwan and northward to Northeast China and Korea (Crawford and Lee 2003), but the timing of these processes remains unclear. For those that were introduced to China, apart from the ones discussed above, the arrival of wheat and the introduction of metallurgy were most significant. Though it is still unclear how and through what routes wheat was introduced to China, it appears that the Hexi corridor was again important for this process, where wheat remains and evidence of metallurgical activities have been found at sites such as Donghuishan and Ganggangwa (Flad et al. 2010; Dodson et al. 2009). These new cultivars and the associated changes (e.g., modifying local environments for wheat farming and animal husbandry) drastically changed the agrarian landscape across China, almost to a point of no return that set the scene for the economic activities during the Bronze Age.

This agricultural development also revolutionized food processing and consumption in the society. Already in the Yangshao period, a whole set of ceramic cooking vessels appeared in houses and burials. At the aforementioned cemetery of Xipo, for instance, regardless of the wealthy status of the burials, each one would contain a whole cooking set including a stove and several bowls, potentially for boiling grains (Figure 4). This way of food processing, mainly relying on boiling grains, according to some scholars, derived from a long-lasting tradition of boiling cereals (Fuller and Rowlands 2011) and by the Yangshao period, benefiting from the agricultural development (millet farming), this culinary tradition was further emphasized. In addition to boiling, some recent research suggests that the Yangshao people might have already started making alcoholic beverages (Wang et al. 2016). Whilst this is controversial, there is increasing evidence of alcoholic consumption during the Dawenkou period. This is supported by (1) the pronounced increase of pottery drinking vessels and (2) scientific analysis of food residue discovered in such vessels. The latter finds that alcoholic beverages made from crops and other plants were consumed (McGovern et al. 2005). Indeed, by the Dawenkou period, fixed sets of cooking and drinking vessels became very common in burials. This led to the formation of a very salient ancient Chinese mortuary tradition, that is the enhanced role of food and drink in mortuary practices. This reached a peak during the late Neolithic when agricultural production grew and there is accelerating development of social stratification (Luan 2013). Elaborate egg-shell like goblets with high stem and very thin sections were produced and appeared to be used by elites. A large burial at Zhufeng contained many black-colored pots, along with a large number of elaborate items such as jade, some of which would have been used as drinking vessels (Luan 2015) (Figure 5). Such an emphasis on drinking is also seen in ordinary burials. At Dafanzhuang, nearly 100 ceramic vessels, most of average or poor quality, were placed in a single burial (Underhill 2002) (Figure 6).

**V. Bronze-Age agriculture: a short summary**

A full appreciation of Bronze Age agriculture in China suffers from the lack of archaeobotanical data derived from systematic investigations and a pronounced bias of archaeological research that is too heavily focused on pottery typology and city planning. It is not our intension to discuss these problems; rather, to draw out a few observations based on the emerging data. First, large-scale irrigation projects were constructed and maintained by the states. Structures of large-scale water management facilities are revealed in some recent archaeological surveys. At the late Shang capital Yinxu in Central China (ca.1300-1050 BC), Tang and colleagues have found a tree-like, highly organized water system, which was connected not only to palaces but all kinds of workshops and economic areas. Some of the canals were 2.8-4m in depth, 6m in width, and 2500m long in total (Tang et al. 2016). The actual functioning and maintenance of these irrigation projects are subject to further research, but it is undoubtedly true that the Bronze Age communities were radically transforming their landscape at an unprecedented scale for farming and other economic activities. This further stimulated agricultural intensification. Second, this increased capability in landscape transformation also meant that the farmers were able to engineer local environments and provide growing conditions for different types of crops, even though climate as a whole was deteriorating during this time (Dong et al. 2010). Zhao and Xu (2004)'s recent archaeobotanical work at the Western Zhou (c.1050-771 BC) capital Zhouyuan in the Western Loess Plateau suggest that even though domesticated wheat was already introduced to this area during the late Neolithic, it was not until the early Bronze age that wheat farming of a proper scale began to take shape, which must have benefited from the construction of large-scale irrigation facilities consisting of a large pond and several ditches (Song and Xu 2016). Third, the elites continued to enjoy certain crops and animal products during the Bronze Age. In addition, there is clear evidence, such as that recorded in oracle bone inscriptions, that food played a central role in ritual activities (Chang 1977; Song 1994).

## VI. Conclusions

It is clear that from very early period onwards, there is a distinctive difference in subsistence between the Yellow and the Yangtze Rivers, mainly due to their intrinsic differences in environmental and ecological conditions. Despite the chronological gap between the earliest millet remains and the cultivated/domesticated ones, the former area witnessed the early domestication of millets and pigs and their increasing importance in food production. In the latter, whilst the consumption of rice also began early, there was a long period in which the consumption of wild plants and animals remained predominant. Between 7000-5000 BP, full domestication of cultivars was completed and agricultural 'villages' with year-round sedentism were established in both areas. It is also a period with growing regional interactions, characterized by the introduction of different cultivars to different regions, which profoundly transformed agrarian landscapes in these regions.

The production and consumption of food were closely related to social development. Boiling and steaming have been a salient culinary characteristic in prehistoric China. With the rapid accumulation of agricultural surpluses from 7000 BP onwards, this tradition also became an important part of mortuary practices with fixed sets of cooking vessels gradually becoming a norm in burials. By 5000 BP, such pottery sets were augmented by the addition of drinking vessels. Drinks made of crops and herbs were enjoyed by the elites and possibly other classes of the society. Indeed, the differential access to food was one of the stimuli for the socio-economic evolution in the late Neolithic (cf. Liu 2003). The elites were controlling raw materials for the production of agricultural tools, food and 'secondary products'. Prestige goods and special foods were consumed by the elites on important occasions, through which they further enhanced their social status. Rites involving the consumption of all kinds of foods contained in special food vessels were gradually developed and became a very distinctive characteristic of ancient China. This indeed defined the Chinese way of agricultural and economic intensification, which is driven by the endless demand of the elite. However, trajectories to intensification vary greatly from region to region due to the elites' different tastes in both prestige goods and foods. This is the question that requires further research.

## FURTHER READING

Half a century ago, the prominent Chinese historian, Ho Ping Ti, published his influential book, *Loess and the Origin of Chinese Agriculture* (1969). Though being criticized for the lack of a full assessment of archaeological evidence, this book still serves as a good guide to understanding the nature of the debate over where and how agriculture developed in China. An updated view on the ecology of the beginning of farming in China can be seen in Liu et al. (2009). For the fast accumulating archaeobotanical data, Zhao's 2011 article provides a good overview of several independent centers for domestication of plants and some unsolved problems. The multiple centers of agricultural origins are further unpacked by several articles synthesizing the most recent archaeological and archaeobotanical evidence (e.g., Fuller et al. 2012; Zhuang 2015). An excellent summary of currently available archaeobotanical data on the beginning, development and intensification of rice and millet farming is Qin (2012; but in Chinese). This is then complemented by Liu, Fuller, and Jones (2015). For a huge place like China, the best way for an in-depth understanding of agricultural development would be to break it down into different regions. The volume edited by Underhill (2013) serves a good purpose for this task. Though not specifically focused on prehistoric agriculture, each chapter discusses subsistence developments in each region within their wider social-economic backgrounds in the light of recent archaeological discoveries.

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