Cereals, soils and iron at Sanyangzhuang: Western Han agricultural production in the Central Plains

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Research

Archaeological research on food-production systems has focused heavily on the origins of agriculture and animal domestication; the agricultural practices of early states are comparatively less well understood. This article explores archaeological evidence for crop cultivation, field-management practices and the use of farming implements at the Western Han (202 BC–AD 8) village of Sanyangzhuang in Henan Province, China. The authors analyse the implications of these practices for the newly developed smallholder mode of production. By combining diverse strands of evidence, this investigation provides new insights into the status of agricultural production in the Central Plains during the Western Han Dynasty.

Keywords: China, Sanyangzhuang, Western Han agriculture, smallholder, micromorphology

Introduction

Archaeological research on food production has focused predominately on the origins and processes of plant and animal domestication (Bellwood 2005; Crawford 2006; Fuller *et al.* 2009). In contrast, much less attention has been devoted to the archaeological study of intensive agricultural systems in state-level societies. These trends are especially notable in China,

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where there has been much research on the origins and expansion of food-producing economies (Zhao 1998; Fuller *et al.* 2007; Lee *et al.* 2007; Lu *et al.* 2009; Liu *et al.* 2010), but relatively little consideration of agricultural systems following the end of the Bronze Age (*c.* 2000–500 BC). This indifference to the intensive agriculture of early states is regrettable, as these food-production systems underpinned the pre-modern economy of China, historically one of the largest and most populous states in the world.

The sophisticated agricultural systems of the Western Han Dynasty (202 BC–AD 8), in particular, represent the foundation of an agrarian economic structure that persisted for nearly 2000 years (Bray 1978, 1984). Built on the accomplishments of the preceding but short-lived, Qin Dynasty (221–206 BC), the Western Han consolidated political power and established an imperial system ruled by a powerful emperor who governed through a vast bureaucracy that permeated into almost every aspect of society and the economy. Whereas ancient Rome relied on an advanced commercial network, the prosperity of the Western Han Empire was based largely on its agrarian economy (Hsu 1980). Why did agricultural production in the Western Han Dynasty flourish and how did it establish a foundation for the next two millennia of farming in China? What factors contributed to the development of agriculture during this time period? Questions concerning Western Han agriculture have attracted but puzzled scholars for decades. A comprehensive understanding of the nature of Western Han agricultural systems is a prerequisite for addressing these questions. Text-based research has contributed most of our current knowledge of Han agriculture (Hsu 1980; Bray 1984; Loewe 1986). This historical research, however, has several limitations. First, historical writings focus on the interests of literate and, usually, urban or suburban elites, rather than the concerns and actions of ordinary farmers. Thus, any details regarding the daily lives and agricultural strategies of farmers are lost. Second, the literature originates from varied sources and is frequently contradictory and open to conflicting interpretations.

Beyond these elite-biased and sometimes contradictory historical sources, little other information on Western Han agriculture has been available to date. While archaeological evidence should play a more significant role, the dominance of the historiographical approach means that there has been little emphasis on the archaeological investigation of Qin-Han or later rural agricultural sites or remains (Falkenhausen 1993). In this article, we discuss recent discoveries at the Sanyangzhuang site that have shifted historical perspectives on Western Han agricultural systems (Liu *et al.* 2004, 2010). Situated in the Central Plains of China, Sanyangzhuang is one of the best-preserved Western Han settlements. Here, we present archaeological evidence for cultivated crops, field-management practices and farming implements—material that complicates the dominant, text-based view of Western Han agricultural systems.

Background: the Sanyangzhuang site

Sanyangzhuang is a modern village located in Neihuang County, Henan Province, China (Figure 1). In 2003, as a part of the 'Xiaohe River Unblock Project', an irrigation canal was cut across an abandoned channel of the Yellow River, revealing a large quantity of roof tiles. Following this, two large-scale excavations were conducted at Sanyangzhuang,

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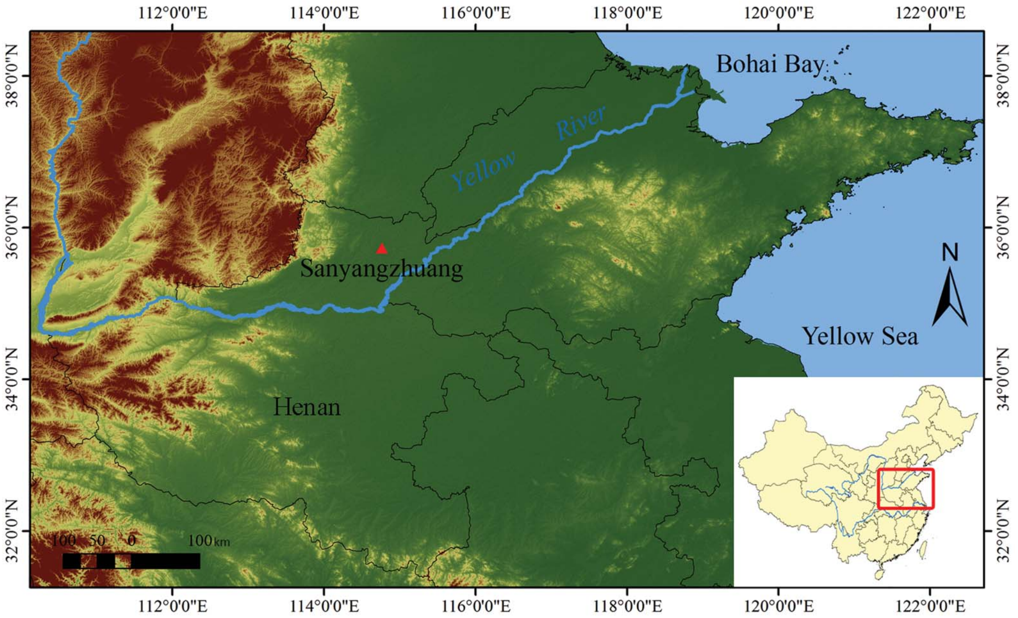

Figure 1. Location of the Sanyangzhuang site (figure by Zhen Qin).

uncovering four residential compounds. Subsequent surveys and test excavations have found 14 exceptionally well-preserved residential compounds scattered across a 1km^2 area (Figure 2; see Figure S2 in the online supplementary material (OSM)), along with the intact remains of agricultural fields, cart tracks, activity areas, latrines, wells and ceramic roof tiles—all concealed beneath 5m of sediment (Figure 3). Analyses of artefacts, notably the coins (Figure 3f), indicate that the site was active from *c.* 140 BC to no later than AD 23. The sediment evidence further suggests that the site was buried by a massive Yellow River flood *c.* AD 14–17. (Liu *et al.* 2004, 2010; Kidder *et al.* 2012a & b).

At Sanyangzhuang, the field systems are so well preserved that the ridge-and-furrow features and the prints of human feet and animal hooves still survive. These represent the only excavated agricultural fields in the Central Plains dated securely to the Western Han Dynasty. Other artefacts relating to agricultural practices, including stone mortars, millstones, iron ploughs, axes and sickles, have also been recovered. The exceptional preservation facilitates a vivid reconstruction of rural life during the Western Han Dynasty and offers evidence of the agrarian economy that supplements and expands upon the historical literature.

Archaeological investigation: cereals, soils and iron

Despite the discovery of these unique archaeological features at Sanyangzhuang, systematic research on their significance for understanding Western Han agricultural production has, to date, been lacking. To explore these issues, we investigated three classes of evidence from Sanyangzhuang associated with agriculture: cereals, soils and iron. Specifically, we have undertaken microbotanical analysis on artefacts to recover ancient cereal starch grains,

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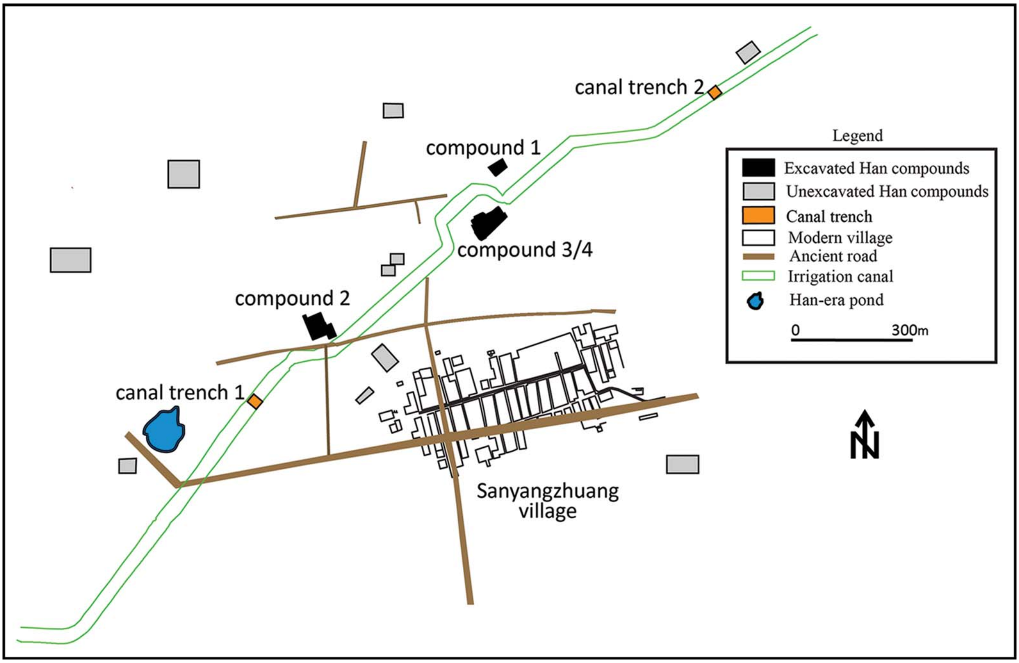

Figure 2. Sketch map of the Sanyangzhuang site area, after Kidder et al. *(2012a). Note the dispersed distribution of Han-era compounds and the highly concentrated distribution of modern compounds at the bottom of the figure, as well as the ancient road system (figure by Zhen Qin & Tristram Kidder).*

micromorphological analysis on the ridge-and-furrow soils to identify ancient field-management practices, and typological analysis on iron farming implements to identify their potential use.

Cereals: crop diversification and double (or multiple) cropping

The flotation of samples taken in 2016 from buried field system features at Sanyangzhuang has so far not yielded any macrobotanical remains. Instead, here we turn to starch residues from ground stone tools used in food-processing to identify ancient crops (Figure 4). These stone tools have yielded 733 identifiable starch grains for classification according to their morphology and size, through comparison with modern specimens. We identified eight species of starch grains including three cereals (Figure S1): millet (*Setaria* sp.), Job's tears (*Coix* sp.) and wheat (*Triticum* sp.). Additionally, we also identified plant starches from *Colocasia* sp., Fabaceae, *Nelumbo* sp., *Quercus* sp. and Dioscoreaceae that may have originated from the processing of taros, legumes, lotus root, acorns and Chinese yams, respectively.

Analysis of starch grains on the stone tools demonstrates the diversity of cultivated crops at Sanyangzhuang. A distinct residue present on several stone tools from a single residential compound, for example, contained an assemblage of starch grains from millet, Job's tears, wheat and legumes—a collection that represents the traditional staple foods in the Central

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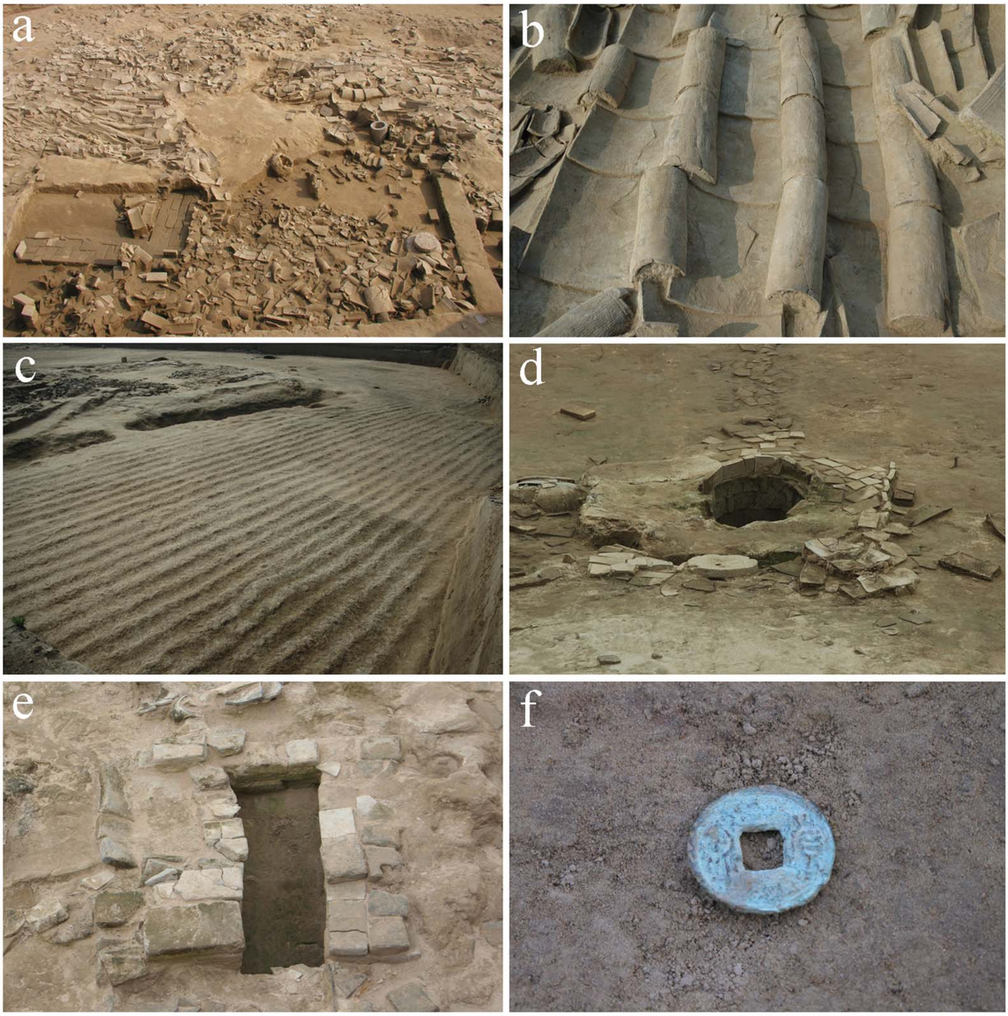

Figure 3. Archaeological features and artefacts at Sanyangzhuang: a) residential compound; b) roof tiles; c) agricultural field; d) well; e) latrine; f) Huoquan (货泉) coin (photographs by Haiwang Liu).

Plains that persisted for over 1500 years until the introduction of maize and potatoes from the Americas. These diverse crops each thrive under different climatic and soil conditions, and are harvested at different times of the year. The coexistence of drought- and high-temperature-resistant millet, humidity-sensitive wheat, hygrophilous taros and aquatic lotus root shows that Han farmers recognised the habitats of these crops and exploited diverse microenvironments for cultivation.

While we acknowledge that the quantity of starch grains does not necessarily reflect the importance of specific crops, our quantitative analysis suggests that the two most common dryland crops in northern China—millet and wheat—were probably the dominant food

Figure 4. Stone tools for food-processing at Sanyangzhuang: a) millstone; b) stone pounder; c) rounded mortar; d) square mortar (photographs by Haiwang Liu).

crops at Sanyangzhuang (Figure 5). The presence of numerous millet starch grains is unsurprising, as this crop was domesticated locally and had been a primary cereal grain since the Early Neolithic (Lu *et al.* 2009; Liu *et al.* 2012). The large proportion of wheat starch grains, however, is particularly significant. Although wheat was introduced into the Central Plains of China from South-western Asia at the end of the third millennium BC, archaeobotanical and isotopic studies suggest that it constituted only a small portion of the Chinese diet (Lee *et al.* 2007; Dodson *et al.* 2013). Wheat started to become significant in the diet of Central Plains populations only during the Western Han Dynasty (Hou *et al.* 2012; Dong *et al.* 2017); the data from our starch grain analyses are consistent with these previous macrobotanical and isotopic studies.

Increasing wheat cultivation was a product of the development of double/multiple cropping systems during the Western Han Dynasty. Millet, which is native to the East Asian monsoon climate, is sown in spring and harvested in autumn (April–September). Conversely, wheat is adapted to the Mediterranean climate, and is sown in autumn and harvested in the early summer (September–May). Western Han farmers mastered the different growing seasons of these two crops and developed an intensive double-/multiple-cropping strategy in place of the former practice of harvesting a single crop of millet per year. The establishment

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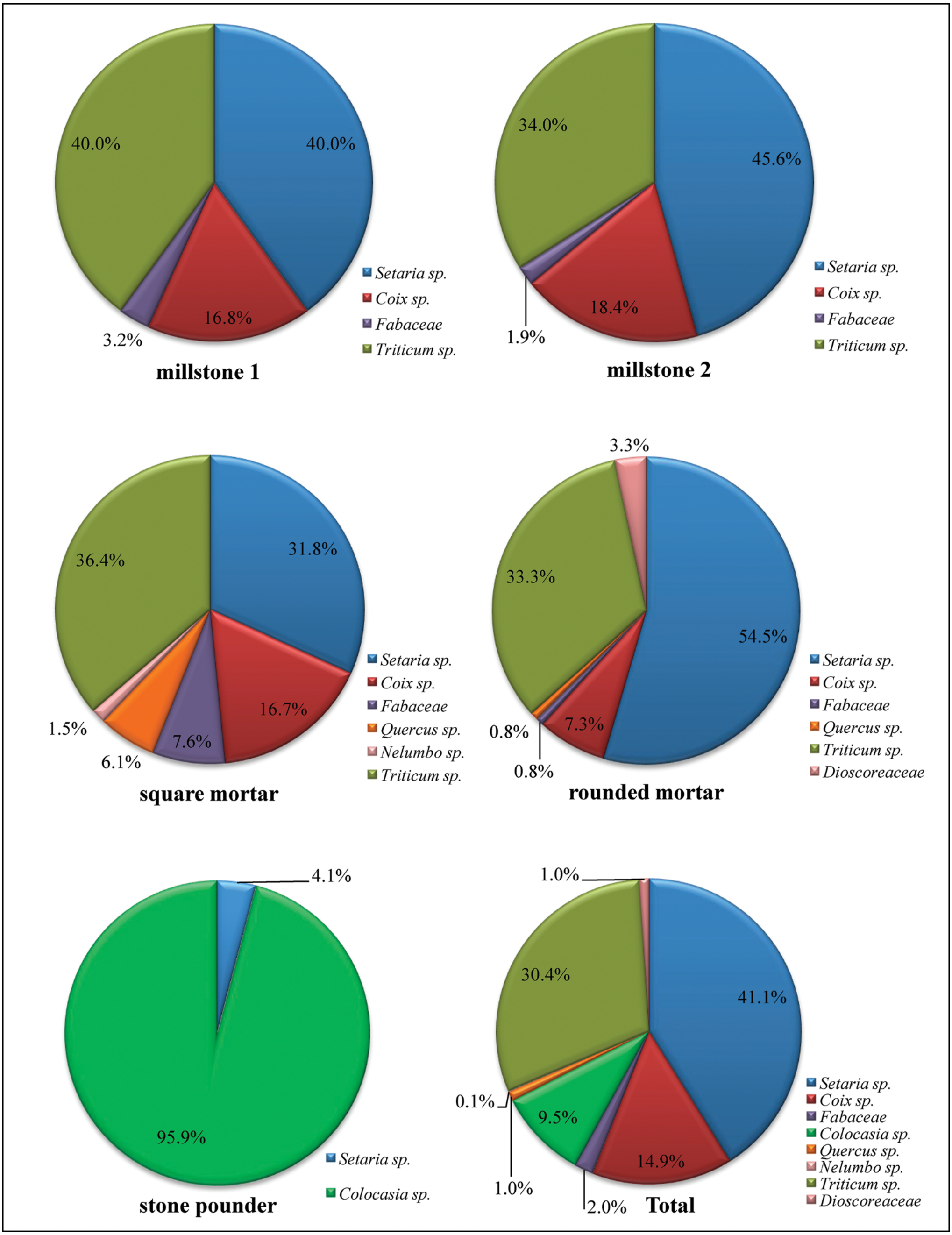

Figure 5. Quantitative analysis of starch grains from stone tools at Sanyangzhuang (figure by Zhen Qin).

of a mature agricultural system built around the double/multiple cropping of millet and wheat was a critical innovation that formed part of a larger pattern of agricultural intensification during the Western Han Dynasty.

Our analysis of the microbotanical remains at Sanyangzhuang reveals that farming practices both diversified and intensified during the Western Han Dynasty. The varied assemblage of starch grains indicates that farmers at Sanyangzhuang diversified their crops to minimise loss from potential environmental risks, such as the Yellow River flooding, or declines in summer rainfall (Chen *et al*. 2015; Kidder & Zhuang 2015). Furthermore, they exploited the specific growing seasons of millet and wheat to achieve multiple cropping in order to maximise productivity at a time when populations were increasing and available arable land was limited.

Soils: field-management practices

Field-management practices, such as tillage, manuring and irrigation, are essential for the maintenance of soil fertility, and thus directly reflect strategies for enhancing agricultural productivity. Historical accounts indicate that new deep-ploughing methods were developed during the Western Han Dynasty (Ban 1962). Concurrently, the dynastic government constructed large, complex water-management systems designed to create new land for farming (Sima 1959). The extent to which these new methods were adopted is, however, unclear. Nor is it evident from the texts whether smaller-scale, local irrigation systems were developed. Archaeological investigation of these past agricultural practices is difficult because such activities are largely ephemeral in the landscape. Fortunately, recent advances (Stoops *et al*. 2010; Macphail & Goldberg 2018) in micromorphology allow us to gain a deeper understanding of past field-management techniques. We have collected and analysed five micromorphological samples from the buried Western Han fields at compound 1, compound 3/4 and canal trenches 1 and 2 (see Figures S3–6), to examine the microscopic evidence for tillage and manuring. We also use macroscopic evidence to investigate irrigation.

Tillage

The visible ridge-and-furrow pattern in the fields at Sanyangzhuang are definitive evidence of Western Han tillage practices. The intensity of tillage can also be interpreted from micromorphological analysis, as ploughing practices are reflected through changes in soil microstructure and pedofeatures (Stoops *et al*. 2010). The latter are defined as "discrete fabric units present in soil materials that are recognisable from an adjacent material by a difference in concentration in one or more components or by a difference in internal fabric" (Stoops 2003: 101). Microstructural signatures include an increase of porosity, a change in microporosity from vertical channels to planar voids, the vertical and lateral translocation of silt and clay particles, an altered coarse to fine sediment ratio and an increase in blocky or prismatic aggregates (Jongerius 1983; Wilson *et al*. 2002; Lamande *et al*. 2003; Pagliai *et al*. 2004; Stoops *et al*. 2010; Lewis 2012). Pedofeature indicators of past tillage include the presence of excrements, silty clay coatings and amorphous iron and manganese oxide nodules (Davidson 2002).

Thin sections taken from the Western Han agricultural fields demonstrate almost all of these tillage-related features. Planar voids and blocky angular structure are common (Figure 6d). Rounded to subangular clay aggregates, along with charcoal pieces and fine

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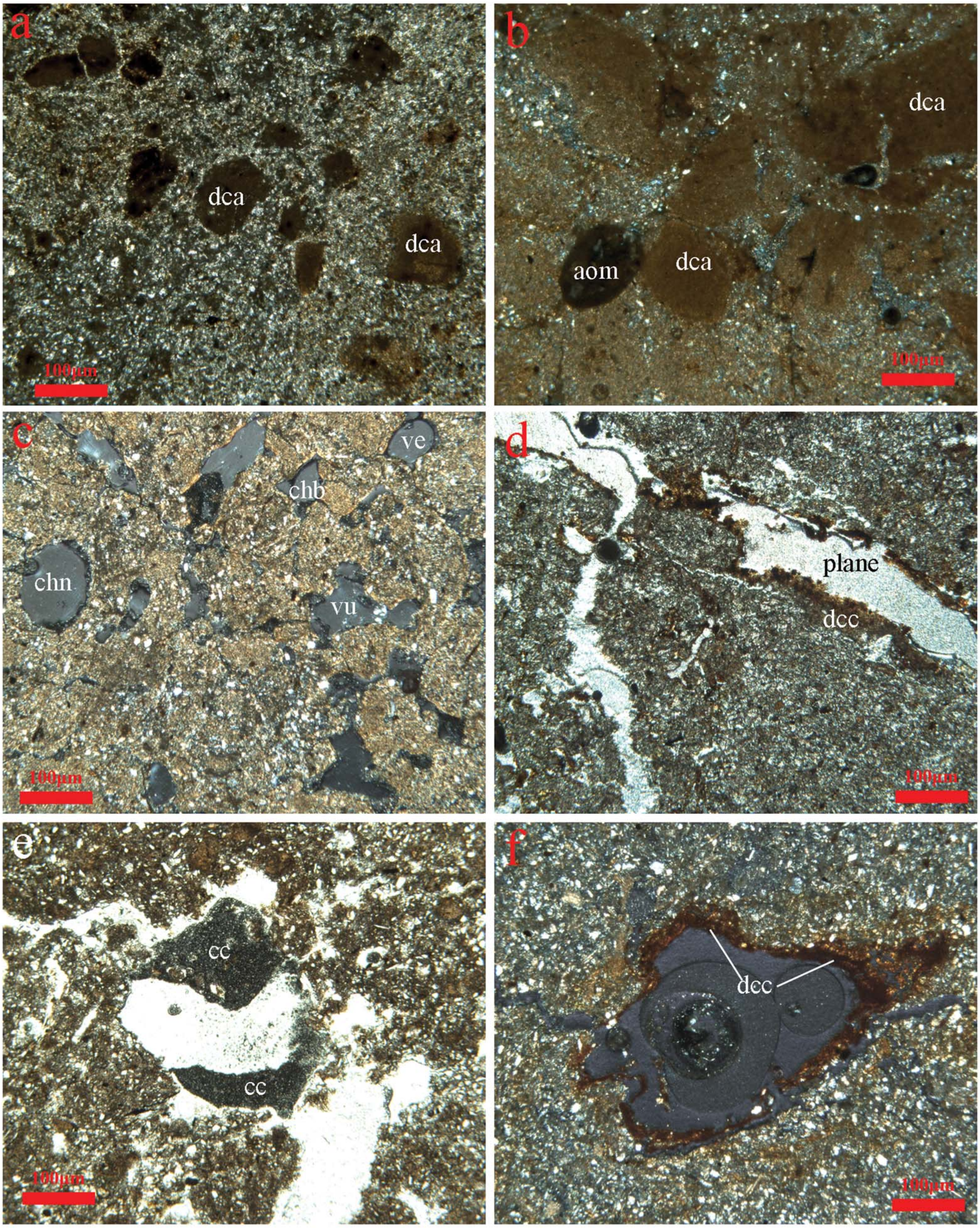

Figure 6. a) Translocated dusty clay aggregates (DCA) with sharp boundaries (XPL), from canal trench 2 (CT2-Han); b) coarse amorphous organic matter (AOM) and DCA plain polarised light (PPL), from canal trench 1 (CT1-Han); c) various void types, including vesicles (VE), channels (CHN), chambers (CHB) and vughs (VU) cross-polarised light (XPL), from compound 1 (CP1-Han-2); d) a planar microstructure; also note dusty clay coatings (DCC) and hypocoatings along the voids (XPL), from compound 3/4 (CP3/4-Han); e) pieces of charcoal (CC) in the void (PPL), from compound 1 (CP1-Han-1); f) DCC along the void; note the absence of extinction (XPL), from compound 3/4 (CP3/4-Han) (images by Zhen Qin).

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organic matter, are mixed within a silty groundmass (Figure 6a–b); and dusty clay coatings and hypocoatings—characterised by the lack of extinction under cross-polarised light (XPL)—are located along the voids (Figure 6d & f). Although different processes can lead to the creation of similar micromorphological features—illuvial processes and bioturbation, for example, can both result in the translocation of clay aggregates—the co-occurrence of all these features indicates that the Western Han fields at Sanyangzhuang were subjected to intensive tillage.

Manuring

The application of manure to soils results in high concentrations of stable forms of organic carbon, including charcoal, bone fragments and other charred residues, all of which are microscopically observable (Woods *et al.* 2006) in archaeological soils. The addition of organic fertilisers also increases microporosity and changes pedofeatures such as carbon and clay coatings within the soil profile (van Oort *et al.* 2008; Stoops *et al.* 2010). Figure 6 shows many charcoal clasts and amorphous organic matter in soil samples from the fields at Sanyangzhuang (Figure 6b & e). While caution should be taken in drawing firm conclusions concerning the origin(s) of these features within the soil, they are probably either the by-product of straw-and-leaf burning (ash manure), or coprogenic aggregates (dung manure). These samples also exhibit an increase in microporosity and dusty clay coatings (Figure 6c & f). In addition to these micromorphological features, an element analysis of bulk samples from Sanyangzhuang profiles reveals elevated levels of phosphorus (P) in the Western Han sediment (Storozum *et al.* 2018a). Both micromorphological and geochemical analyses, therefore, demonstrate that people applied fertilisers to the fields around Sanyangzhuang during the Western Han Dynasty.

Irrigation

Micromorphological features of irrigation include the disaggregation of micro-aggregates, a reduction in porosity and the formation of textural coatings preserved in ferric nodules (Brinkman *et al.* 1973; Stoops *et al.* 2010). These diagnostic features, however, do not preserve as well as those left by ancient tillage and manuring. That the thin sections taken from Sanyangzhuang contain no evidence of these features is probably due to post-depositional disturbance by floods or tillage. Therefore, our discussion of irrigation at Sanyangzhuang is based on larger archaeological materials and features.

Archaeologists have unearthed two wells at Sanyangzhuang, both of which are similar in shape and structure to other Han-period wells found at nearby sites (Wang 2013). Unlike contemporaneous wells located within compounds that were used for domestic water, the Sanyangzhuang wells are located outside the courtyard and close to the farm fields. Their location suggests that they provided not only drinking water, but also water for small-scale irrigation. In addition to the wells, archaeologists also found a large, shallow pit (23.6m long × 17.5m wide × 0.7m deep) adjacent to the west wall of compound 2 (Liu *et al.* 2010). Although the pit's function is unclear, the laminated silty clay at the bottom of the pit suggests that it probably served as a reservoir for water storage and irrigation.

Although large-scale irrigation features are absent at the Sanyangzhuang site, large irrigation canals have been found at Anshang, a village 15km to the north (Kidder & Liu 2017). Subsequent research suggests that these canals were initially built as early as 1100 BC (Storozum *et al.* 2018b), and were still in use during the Western Han Dynasty; they may even relate to Sanyangzhuang itself, as one of the canals extends southwards in the direction of the village. This type of large-scale irrigation canal system is not described in the historical literature, yet our archaeological research suggests that irrigation systems may actually have been widespread during the Western Han Dynasty.

Iron: the widespread use of iron implements

Farming implements play a significant role in enhancing agricultural productivity. A remarkable feature of Western Han agriculture is the widespread use of iron tools (Bray 1980, 1984). In recent decades, archaeometallurgical research has revealed the wide distribution of large-scale smelting workshops throughout the Central Plains at this time—evidence supporting the historical record of intensive iron production (Bai 2005; Wagner 2008). Most of these archaeometallurgical studies, however, have focused on production processes, leaving aspects of the distribution and acquisition of iron implements at a site-scale poorly understood.

We recovered 21 iron tools from Western Han contexts at Sanyangzhuang (Liu *et al.* 2004, 2010). The majority (16 of 21) of the tools, including ploughshares, axes, hoes, sickles, swords, knives and several unidentified artefacts (Figure 7), were recovered from compound 2. This quantity of iron tools within a single household indicates that even rural peasants had access to iron implements. The 16 identifiable tools were used for tillage, cutting, weeding, harvesting and food preparation, suggesting that individual rural households could manage the entire range of food-production processes.

Of all the iron tools recovered at Sanyangzhuang, the two iron ploughshares are particularly noteworthy, as they represent two of the largest examples found in China of Western Han or earlier date; one is 0.47m long × 0.40m wide (Figure 7f), and the other is 0.40m long × 0.30m wide. Furthermore, although iron ploughshares were probably an Eastern Zhou (770–256 BC) invention in the Central Plains, the triangular shape of these two iron ploughshares suggests that the form of this farming implement has been developed and transformed during the Western Han Dynasty (Bai 2005). The emergence of these uniquely large and newly developed ploughshares had several significant implications for agricultural practice. First, the shape and size of the plough facilitated deep tillage to maintain soil fertility and moisture, with the deep tillage being a possible response to the development of multiple cropping. Second, the large shape, size and weight of these ploughs would probably have required the use of animal traction. Indeed, the presence of cattle hoofprints in an agricultural field at Sanyangzhuang provides some of the earliest direct evidence for the use of cattle as draught animals in the Central Plains (Figure 8). This investment in iron ploughshares and cattle signifies increasing intensification in ploughing through technological innovation, manifesting in an early form of mechanisation.

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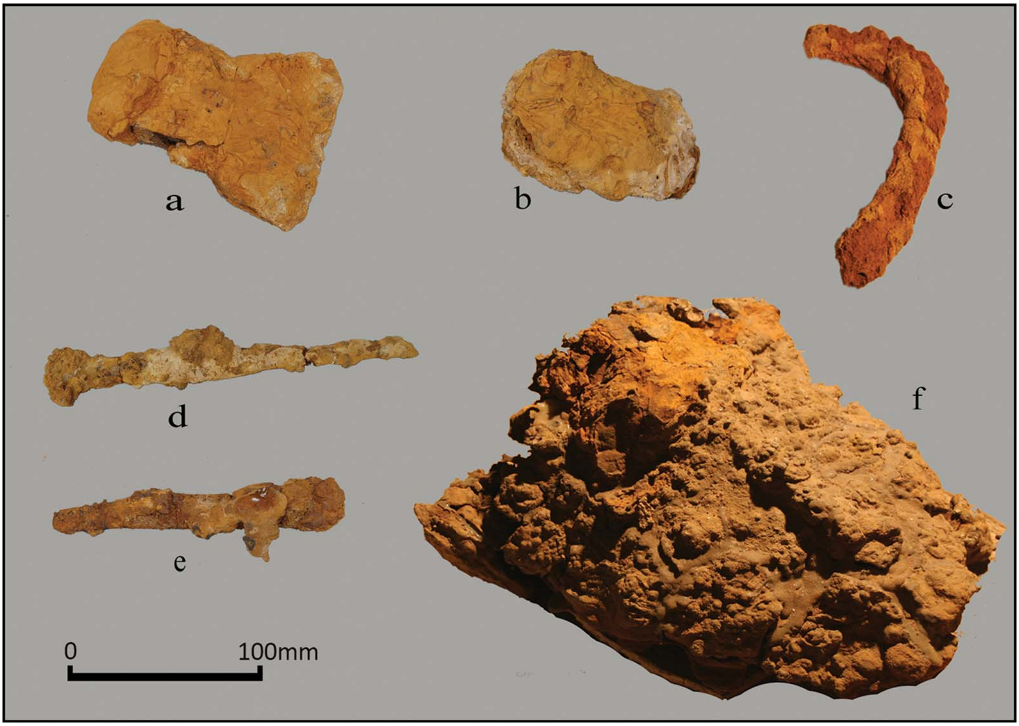

Figure 7. Iron farming implements found at Sanyangzhuang: a) axe; b) hoe; c) sickle; d) knife; e) chipper knife; f) ploughshare (photographs by Haiwang Liu & Zhen Qin).

Discussion

Productivity factors

The microbotanical, micromorphological and typological data on ancient cereals, soils and iron from Sanyangzhuang provide new evidence for the organisation of agricultural production in the Central Plains during the Western Han Dynasty. Our data show that productivity factors—indicated by the types of crops cultivated, increasingly elaborate field-management practices, the use of sophisticated farming implements and emerging mechanisation—were dynamic. Farmers diversified their food production by manipulating various micro-environments to promote wheat cultivation and multiple cropping. Deep tillage, manuring and both large- and small-scale irrigation were applied intensively. Iron tools were common among rural households, and the use of large iron ploughs and cattle power indicates the onset of agricultural mechanisation.

Developments in these productivity factors were not isolated but synergistic. Alongside the emergence of multiple cropping, for instance, Western Han farmers adopted more sophisticated field-management practices, such as deep tillage and manuring, in order to maintain soil fertility and moisture. The need for improved field-management techniques in turn stimulated the production of iron tools and the development of innovative farming implements, such as the large, triangular-shaped iron ploughshares. Conversely, the

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Figure 8. Cattle hoof prints on the Han agricultural field at Sanyangzhuang (photographs by Haiwang Liu).

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widespread use of iron implements facilitated innovative field-management practices. Likewise, the promotion of wheat cultivation and the construction of irrigation infrastructure were also related; the growing of wheat, a water-intensive crop, required the construction of irrigation facilities, which allowed farmers to cultivate this crop during the arid winter of the East Asian monsoon climatic zone.

Social factors: smallholder farming in the great empire

Large-scale, specialised economic production is often argued to be essential for increasing agricultural productivity because it leads to resource optimisation. Netting's (1993) ethnographic case studies, however, indicate that a self-sufficient 'smallholder economy' is more productive and sustainable than other agricultural modes, such as hired labour and collective farming. Netting (1993) attributes the success of agriculture during dynastic China to this smallholder economy.

The Western Han Dynasty witnessed the emergence of new political, social and economic institutions and the transformation of agrarian traditions (Hsu 1978, 1980). Historical sources suggest that the smallholder mode of agriculture that emerged during the Western Han Dynasty challenged the established manorial tradition (Bray 1980; Hsu 1980). This text-based argument, however, has never been evaluated using archaeological evidence, and many details of this economic model, such as when and where people adopted it, remain unclear. Our observations from various lines of scientific inquiry indicate that agricultural production at Sanyangzhuang was based predominantly on a smallholder economy. Within a single rural compound, we found iron implements for cultivation, stone tools such as trip hammer heads, grinding stones and stone mortars for food processing, and starch grains from various crops on the stone tools. These finds suggest that the residents of these compounds participated in all aspects of farming, from cultivating to harvesting and grain processing. The distribution of the compounds and farming fields reinforces the complexity and intensity of Sanyangzhuang's smallholder economy. Fourteen compounds of similar size and layout are randomly distributed over a 1km^2 area, indicating a lack of formal planning and hierarchy at this rural settlement. In addition, the layout of the village—agricultural fields surrounding each individual compound with large spaces in between—differs from the concentrated pattern of residential houses observed at most modern rural communities in China (Figure 2). We suggest that this pattern at Sanyangzhuang indicates that land ownership was closely associated with the compounds, rather than being allocated by a higher administration.

Contrary to the traditional view that a smallholder economy equates to isolation and complete self-sufficiency (e.g. Chayanov 1986), the full complement of production equipment at Sanyangzhuang indicates that the inhabitants were well incorporated into the broader Han Empire economy. While farmers produced food at a household level, they did so as participants in a wider state economy. Iron tools, stone bowls, trip hammer heads and traction animals were brought into the village from external sources, and local irrigation features and canals were probably constructed through the deployment of communal labour. Furthermore, the crisscrossing road system suggests the existence of strong ties between the rural village and the outside world (Figure 2). These are clear signs of a complex, flourishing economy that required the integration of many parts to create a functioning whole.

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In this new economic form, smallholder farmers were no longer bound labourers of feudal lords, but rather free proprietors integrated into a dynastic economy that extracted taxes and labour in the form of in-kind and corvée payments (Pan 1950). Farmers had to make every endeavour to increase grain yields to obtain a surplus and pay taxes. This newly established smallholder economy therefore stimulated and accelerated the changes of productivity factors—cereals, soils and iron—which supported the rapid intensification of agricultural production during the Western Han Dynasty.

Conclusion

Our case study at Sanyangzhuang goes beyond the historical literature on agricultural traditions and explores the agrarian economy of the Western Han Dynasty from an archaeological perspective. Our data suggest that this village consisted of the small, widely scattered compounds of smallholder farmers who were integrated into the wider Western Han economy. Through the manipulation of local microenvironments, they were able to cultivate millet and wheat, along with a diverse range of other crops. They managed and maintained their fields through deep tillage, manuring and irrigation, and their skilful combination of iron tools and animal traction indicates the early mechanisation of agriculture. The synergy of all these technological, social and economic developments brought about an unprecedented increase in agricultural productivity during the Western Han Dynasty. The resulting agrarian prosperity had far-reaching ramifications, including population growth, territorial expansion and the formation and consolidation of mainstream ideology and national identity.

Acknowledgements

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Supplementary material

To view supplementary material for this article, please visit https://doi.org/10.15184/aqy.2019.74

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