Applying phytoliths to the reconstruction of rice agriculture: From wet to dry and back again in the Neolithic Lower Yangtze

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Introduction

More than half of the world's population today relies on rice as its main staple food, and the expansion of rice farming has had a major impact on Asian environments. The trajectories from wild to cultivated to domesticated rice and the development of more intensive arable systems, provided a basis for the development of social complexity in China, mainland Southeast Asia and parts of India (Glover and Higham 1996; Fuller and Qin 2009; 2010). The spread of wet rice agriculture has also been linked to methane expansion and global warming (Ruddiman *et al.* 2008; Ruddiman 2013; Fuller *et al.* 2011). Distinguishing between wet and dry farmed rice in archaeological contexts is key to understanding developing rice systems and their role in both socioeconomic change and environmental impacts. One method of determining changes in arable system is to analyse ecological community groupings in the weed assemblages, which has long been applied in Europe (e.g. Jones 1995; Charles *et al.* 2003), and more recently to rice cultivation (Fuller & Qin 2009; Weisskopf *et al.* 2014). In the present contribution we present a new method and illustrate it by application to sites from a sequence in the Lower Yangtze region of China.

In this paper we use differing ratios of phytolith morphotypes that are divided into those that are genetically predisposed to produce silica bodies in grasses (fixed) and those morphotypes

that are formed only when there is sufficient uptake of water (sensitive). Madella *et al*. (2009) developed this model using ratios of short to long cell phytoliths from the leaves of grasses from the Triticaceae family to understand winter cereal irrigation (of wheat or barley) in arid zones in the Near East. Jenkins *et al*. (2011) expanded this, also using Triticaceae, with experimental work in Jordan to further interpret Near Eastern water management. Here, this model is taken a step further and, using ratios of fixed and sensitive cells from all available Poaceae in the phytolith assemblages, applied to ethnographic rice field samples from India and Chinese archaeological sites that provide a sequence of change from ca. 5000 BC to 2300 BC (Figure 1

Methodology

This approach is based on phytoliths extracted from sediment samples from early rice cultivating sites, including both typical settlement waste samples and some palaeosols from rice cultivation areas. First it was determined that phytolith samples contained substantial proportions of rice (between 6900 rice phytoliths per gram to 6,000,000 rice phytoliths per gram), and thus it is assumed that a substantial contribution of the phytolith inputs come from rice fields, including rice crop-processing waste and weeds co-harvested with rice. The use of phytolith assemblages to identify rice crop-processing has been demonstrated elsewhere (Harvey & Fuller 2005; Zheng *et al.* 2009; Weisskopf *et al*. 2014; Weisskopf, 2014). In the case of the three sites considered here, each has also had macro-botanical analyses of archaeological flotation samples that indicate the prominence or dominance of rice in subsistence (Fuller & Qin 2010; Fuller & Weisskopf 2012; Gao, 2012). Thus the presence of rice cultivation is taken as a given and instead the relative signal for wetter or drier grass ecology is assessed.

Samples are processed and counted following standard procedures for phytolith analysis. For this study phytoliths were extracted from 800 mg of sediment per samples following the protocol of Rosen (1999). Between 300 and 400 single cells were counted at 400x magnification for each slide. Then counts are grouped for morphotypes based on whether these are defined as sensitive versus fixed cell types following the definitions of Madella *et al*. (2009): Table 1.

Table 1. Phytolith morphotypes from grasses classified into fixed and sensitive morphotypes.

Dry or fixed, passive (Short grass cells)	Wet or sensitive, active (Long grass cells and stomata)
Rondel	Long smooth
Round rondel (Stipa type)	Long sinuate
Saddle	Long polyhedral
Bilobate	Long echinate
Scooped bilobate	Stomata
Square bilobate (Setaria type)	
Cross	
Collapsed saddle	

Phytolith production and the sensitive versus fixed model

Phytoliths are bio-mineralised particles formed within the intra and extra-cellular space of living cells in the culms, leaves, roots and inflorescences of higher plants (Figure 2). Silica is an abundant element and a constituent of many mineral soils (Hodson & Evans 1995: Prychid *et al*, 2004). Soluble silica is released into sediments and soils by the weathering of silicate minerals (Piperno 1988, Prychid *et al*, 2004). Monosilicic acid (H_4SiO_4) is soluble in water and is absorbed into the plant with other minerals in the groundwater through the roots and carried in the xylem sap (Hodson & Evans, 1995, Prychid *et al*. 2004, Piperno 2006). As the monosilicic acid is transported in the transpiration stream it moves through the permeable plant membranes becoming polymerised as solid amorphous silicon dioxide (SiO_2) in the plant tissues where it is deposited within the cell lumen and intercellular spaces, often taking on their form, as well as forming external layers on the cell walls (Piperno 2006; Carnelli *et al*. 2001). Silica may be found in all plant parts, including the roots, but most of the silica is laid down in the aerial structures both vegetative and reproductive (Piperno 2006; Prychid *et al*. 2004). In grasses most phytoliths are commonly found in the epidermis. Among these many mechanisms affecting phytolith formation are two principal factors; genetically and environmentally controlled silicification. The first originates in the plant's own genetic and physiological mechanisms and relates to phytolith production in designated cells and tissues. Some cells actively accumulate silica and will produce phytoliths under any hydrological conditions (Madella *et al*. 2009; Hodson *et al*. 2005). The second is associated with outside

factors of the local environment, including climate, soil type, soil hydration, age and type of plant (Piperno 2006; Madella *et al*. 2011).

Grasses have high production rates of silica bodies (phytoliths) both in and between the cell walls (Madella *et al.* 2009; Piperno 2006; Metcalfe 1960). There is variation between silicification in specific cells in different parts of the plant (Webb & Longstaffe 2000; Perry *et al*. 1984). More importantly for the purposes of this study there is variation according to the environment where the plant is grown (Tsartsidou *et al*. 2007; Epstein 1999). Blackman and Parry (1968) suggest short cells have a genetic control over silica deposition in their lumen so produce silica bodies regardless of water availability. Others, such as epidermal long cells, have no genetic control so silica deposition is influenced by external factors such as local environment and water availability (Piperno 1988; Blackman & Parry 1968). Greater transpiration through the plant can mean more silica deposited in cells that are not designed for this purpose. Looking at these cells is particularly appropriate for understanding rice agriculture as wild rice is a wetland plant growing in warm marshy areas so high transpiration should be expected. When people started cultivating rice it is likely they husbanded wild rice stands at lake and river edges, as reconstructed at Tianluoshan (Fuller & Qin 2010; Fuller *et al*. 2011). However, once farming rice in small fields, such as those at Caoxieshan (4000-3800 BC) developed, the fields may have been drier than the wild and early cultivated rice stands. After the development of paddy fields with irrigation systems, we would expect to see a return to higher ratios of phytoliths from environmentally controlled silicification. However, there are several potential issues; one is that rice generally grows in much more humid conditions than the Southwest Asian winter cereals previous considered (Madella et al 2009; Jenkins et al 2010). More water and greater transvaporation are likely to cause higher phytolith production overall. This means the grasses in the rice fields may produce too many environmentally sensitive morphotypes (Table 1) to make changes in arable systems definable. As we demonstrate, this is not the case and our results show the applicability of this method outside arid and semi-arid regions. Another potential problem is that while the model may be applicable to phytolith assemblages collected from sediments from specific fields, the phytoliths from the archaeological samples analysed here derive from a variety of contexts and have mostly been deposited as part of crop processing activities. This may skew the results somewhat. However, the crop processing residues should reflect the plants in the field system from which they were harvested, and this is suggested by patterns in previous

analyses (Weisskopf *et al.* 2014; Weisskopf 2014). It should also be noted the modern fields are in India while the archaeological samples come from the Lower Yangtze Valley in China so biogeographical factors may come into play when comparing modern and ancient samples, but the responses of plant physiology to local environmental conditions, such as the silica deposition in relation to water availability, are expected to outweigh biogeography. The modern fields we sampled in China unfortunately produced few weeds or phytoliths, which we attribute to treatment with herbicides. Nevertheless, we find interpretable contrasts in both ancient and modern samples that reflect relative wetness of fields.

The modern rice fields

Sediment samples for phytoliths were collected from traditionally farmed modern rice fields in the Western Ghats and Orissa, India in order to create modern analogues to test the archaeological samples (Weisskopf *et al.* 2014; Fuller & Weisskopf 2012).   Fields represented a range of arable field types; lowland rain-fed, upland rain-fed and decrue, as well as wild rice (Figure 3). Wild rice was further divided into perennial (*O.rufipogon*) and annual (*O.nivara*). Soil samples were processed for phytoliths as a representation of the diversity of the weed flora. For the purposes of the present study these analogue fields were grouped based on broad variation of soil moisture level inferred throughout the growing season, as dry (rainfed and margin of wetlands), very wet (in standing water throughout most of the growing season, as typical of either deep water rices, irrigated paddies or wild rices), or intermediate (Table 2).

Table 2. Modern rice stands in India (I#) sampled for phytoliths and grouped based on relative degrees of wetness (further details of sites in Weisskopf et al 2014)

	Dry rice	Intermediate	Wet rice
Wild			I5 (O. nivara I10 (O. rufipogon)
Cultivated	I2 & I3 (upland rainfed)	I1,I4 & I6 (lowland rainfed), I7 & I8 (decrue)	

The archaeological rice and weeds

The archaeological samples come from three Neolithic sites in the Lower Yangtze, Tianluoshan (4800-4300BC), Caoxieshan (3950-3700BC) and Maoshan (3000-2300BC) (Figure 4). Tianluoshan (Fig. 4A), Zhejiang province, is a Neolithic Hemudu culture site with evidence for pre-domestication rice cultivation as well as later levels producing the remains of more domesticated rice (Fuller *et al*. 2009). Excavations between 2004 and 2007 by the Zhejiang Province Institute of Archaeology, have produced important archaeobotanical and dating evidence on the Hemudu Neolithic culture (Sun 2013). Direct AMS radiocarbon dates on nuts and grains show a sequence between ~ 6900 and 6300 years BP covering three distinct phases; K3 midden, layers 8 and 7, and layers 6 and 5, layers 4 and 3 (Fuller *et al.* 2009). The 14 phytolith samples analysed here are from the second (Layers 8-7) and third (Layers 6-5) phase as well as a later fourth phase (Layers 4-3). All samples are from cultural contexts within the settlement area, although in Layer 8 these are at the edge of stream the settlement abuts, while the others are from within and around areas of buildings (houses) indicated by preserved wooden posts. The data from the macro-remains suggest a growing dependence on rice over time (Fuller *et al*. 2009; Fuller & Qin 2010). The phytolith samples from the ancient river's edge and those from the cultural contexts yielded rice remains suggesting an important input into the phytolith assemblage from rice cultivation and rice processing.

Caoxieshan, Jiangsu province (4000-3800BC) is a later Lower Yangtze site. Excavations in the later 1990s revealed small shallow fields often 20-50 cm deep, all less than 10 square meters (Zou *et al.* 2000), and more recently in 2008, such fields and associated cultural layers and house-related midden were sampled for flotation and phytoliths (Figure 4B, 4C). Our working hypothesis is that these fields functioned to allow tight control of water and especially the draining of water to drought-stress the rice plants (Fuller & Qin 2009). These small fields would have also allowed fertilization of the soil, likely through the addition of settlement midden material, judging by the presence of ceramics and charred plant remains. Although the rice here is domesticated in terms of non-shattering spikelet bases (Fuller et al. 2014), it is likely to have still possessed some wild-type traits, including pereniality, which means that under consistent water conditions vegetative growth would have been emphasized, thus reducing grain yield. These small fields would have allowed easy drainage to induce water stress and produce more flowers and grains (Fuller & Qin 2009; Fuller 2011).

In any case these fields imply small, scale and intensive cultivation rather than complex and extensive systems. Sixteen samples were analysed from a range of contexts at Caoxieshan.

Maoshan is located on an alluvial plain, dissected by streams and spans 3000-2300BC, including three sub phases of the Liangzhu culture. In the Late Liangzhu period (2600-2300BC) there is evidence here for large intensively irrigated farming (Figures 4D, 4E) with irrigation streams running through fields of ca. 0.2 hectares (Zhuang *et al.* 2014), while Early Liangzhu levels include small ovoid field units similar to those from Caoxieshan. The intensification of rice farming over the course of the Liangzhu period supported major specialized craft production and social differentiation on the level of early urban societies (Qin 2013). Eighteen samples were analysed from Maoshan including cultural midden deposits as well as rice field palaeosols.

The evidence for rice cultivation at these sites thus suggests a range of practices, some early cultivation through wetland margin management (Tianluoshan) to small, highly controlled and regularly flooded and drained fields (Caoxieshan and early Maoshan) to large intensive and irrigated paddies (later Maoshan). As rice was being farmed very differently at these sites it should be possible to see changing agricultural practices over time, thus providing an ideal test case of the utility of our proposed phytolith index for rice field wetness. All three sites have samples from the river's edge or fields, and also from cultural contexts so it is possible to test whether the arable system can be reflected in the phytolith assemblages from the typical midden material on habitation sites as well as from the fields themselves.

Results

The percentage of fixed morphotypes versus the percentage of sensitive forms demonstrate distinctive patterns in modern analogue rice fields as do the wild rice stands (Figure 5). The wild rice stands are wetter than the cultivated rice fields, and annual rice (*O. nivara*) stands are wetter than perennial rice (*O. rufipogon*). At first it might seem counterintuitive that annual wild rice has a wetter signature than perennial rice, since annual wild rice grows in climatically drier conditions. However, these regions are only seasonally dry and during the months when wild *O. nivara* is growing it grows under very wet conditions brought on by the rainy season. The rice from the temporarily inundated decrue fields has higher levels of sensitive forms and lower levels of fixed forms than the lowland rainfed rice, again reflecting the environments in the sampled fields, while in contrast the upland rainfed rice has higher

percentages of fixed and the lowest level of sensitive. Overall ratios decrease according to the decrease in water abundance in each arable system and they are wettest in conjunction with wild rice stands.

For the three sites in the Lower Yangtze, Tianluoshan, Caoxieshan and Maoshan, there are two questions to address. The first is can the samples from the fields be related to specific agricultural systems. The second is whether the remains from the cultural contexts (more typical settlement waste, including household rubbish (midden) and crop-processing waste) reflect the fields.

First, we can compare all three sites on the basis of phytoliths from river edge and/or paddy field contexts (Figure 7). The riverside samples from Tianluoshan show high proportions of sensitive morphotypes, consistent with a wetland setting, like those settings where wild rice occurs. This is not to say the rice of the Hemudu period is wild, as it is clearly undergoing domestication and in the pre-domestication cultivation stage (Fuller et al. 2007; 2009), but that the ecology under which early cultivated rice was managed here is close to the habitat of wild rices. The comparatively high ratio should be expected, as early cultivated rice was managed in habitats like those of wild populations, but probably closer to the annual end of that spectrum (Fuller and Qin 2010; Fuller 2011). In contrast, the phytoliths from small fields at Caoxieshan have many more fixed morphotypes, keeping with the drier signatures in cultivated rainfed or decrue fields among the analogues. This also supports the notion that these fields were kept drier than wild rice stands in order to force the rice to produce seed. Early water control was about drainage rather than irrigation. Later at Maoshan there is a return to domination by sensitive forms but to a slightly lesser extent than in the earlier phase at Tianluoshan. This suggests much wetter conditions, wetter than our Indian cultivated analogues, which may be expected in highly irrigated paddy systems.

Archaeological samples from typical cultural contexts, associated with occupation debris or middens, show a similar picture in terms of contrasts between sites (Figure 8). The Tianluoshan samples are dominated by high percentages of sensitive forms. Caoxieshan presents a contrast with more than 50% fixed forms. Maoshan shows a return to higher levels of sensitive morphotypes but not as high as the field samples, with a much lower sensitive to fixed ratio than the paddy field samples. This may be because a greater proportion of the grass leaves from Maoshan may not necessarily be from crop processing than at the other sites, and harvesting methods may have targeted the higher portion of plants (mainly

panicles), suggested by the widespread occurrence of hand harvest knives (sickles) in the Liangzhu period. It is also possible that other non-crop weed grasses entered assemblages regularly, such as those used in roofing or matting. Nevertheless the contrasts with earlier Majiabang samples indicate wetter conditions, suggesting that a signal from the arable rice environment is present. Thus phytolith assemblages from both kinds of contexts appear to reflect the same underlying patterns of phytolith input from rice habitats.

The general trend is the same from both sample types, and these agree on the chronological changes, but there are still some contrasts between sample types within Maoshan. At Maoshan the field samples have higher percentages of sensitive forms and the sensitive to fixed ratio is lower in the assemblages from the cultural contexts. This indicates some of wet indicator taxa or plant parts are remaining in field rather than being harvested. This is expected as these morphotypes occur in grass leaves, only a fraction of which enter the harvest. When both sets of results are shown together (Figure 9), it is seen that the wet field samples from Maoshan and the pre-domestication cultivation samples from Tianluoshan have high ratios like our modern wild rice stands (Figure 9).

Conclusions

The samples from the cultural contexts show similar patterns to the archaeological field systems although contrasts are not as strong. We suggest that this relates to harvesting practices with the harvest including a smaller proportion of the overall grass leaves (from the crop or weeds) that were in the field. At Tianluoshan the percentage of sensitive to fixed is almost the same as the fields suggesting the grass leaves from the site are predominantly crop processing waste. At Caoxieshan, as Tianluoshan, there are more fixed forms in the cultural contexts than from the fields but the difference is slight. The phytolith assemblage from the Maoshan site has a lower sensitive to fixed ratio than the paddy field samples. This may be because a greater proportion of the grass leaves from Maoshan came from different sources, other than crop-processing. Non-crop weed grasses may have been used in roofing, matting, or basketry, etc. However, the differentiation mostly reflects the samples from the fields supporting the theory that most of the plant remains in the samples from these sites come from crop-processing residues which contain a signal about past field conditions. This means that this method is applicable to archaeological samples from cultural contexts as well as those from ancient field systems

The results of applying this model to the phytoliths from Tianluoshan, Caoxieshan and Maoshan demonstrate a good method for differentiating between arable field systems. It is possible to see early rice cultivation in the river at Tianluoshan. This method provides a similar environment to the stands of wild rice growing in India and it is easy to picture the development of rice husbandry here by seeding and managing a wetland margin. At Caoxieshan the fields are drier, and it seems likely that the small fields at Caoxieshan were rainfed, and that water control efforts were directing at drying out the fields strategically. The development of large paddy fields at Maoshan can be seen in the increase in sensitive forms in the phytolith assemblage. This method is a useful tool for exploring and understanding developments in early rice farming.

Acknowledgements

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Tables

Table 1. Phytolith morphotypes from grasses classified into fixed and sensitive morphotypes.

Table 2. Modern rice stands in India sampled for phytoliths and grouped based on relative degrees of wetness (further details of sites in Weisskopf et al 2014)

Figure Captions

Figure 1. Map of modern analogue study sites, in India, and archaeological sites, in China, referred to in this paper.

Figure 2. Example of phytolith morphotypes included in this study, from modern reference material. A. *Avena* leaf long sinuate; B. Chloris virgata leaf saddles; C. *Setaria faberii* leaf square bilobate D. *Bromus catharticus* leaves long smooth and rondels; E. *Oryza rufipogon* leaf scooped bilobes; F. wild *Setaria* sp. leaf bilobate; G. *Panicum miliceum* leaf long cells and bilobes; H. *Coix lachrymajobi* leaf crosses I. *Ischaemum rugosum* leaf bilobes; J. *Stipa tirsa* leaf round rondels; K. *Bambusa* sp. leaf collapsed saddles; L. *Dactylis glomerata* leaf long smoooth

Figure 3. Example of modern rice stands in India sampled for phytoliths in this study. A. Upland rainfed rice, Penchant Ghat, Maharashtra (I2); B. Lowland rainfed rice, central Odisha (I4); C. Lolwand rainfed rice, Maharashtra (I1); D. Decrue field in Munda zone of northern Odisha, ranging from dry to deepwater (I7); E. *Oryza rufipogon,* perennial wild rice, northeastern Odisha (I10); F. *Oryza nivara,* anuual wild rice, northeastern Odisha (I5).

Figure 4. The archaeological sites sampled for this study. A. Tianluoshan Site, main part of ancient river (center) and western river bank, with posts aligned along the bank (left); B Caoxieshan site, plan of trench T0422 plan (F1: House platform with postholes; S:paddy fields); C. Caoxieshan site trench during excavations showing paddyfield units (trench is 5 m. wide); D. Maoshan site, overview of whole paddy area (orange lines drawn over paths/embankments between paddy fields; archaeological trenches are 15 meters square; E. Part of Maoshan excavations showing a view of pathways L2, the eastern most field boundary uncovered, running north to south.

Figure 5: Percentage of fixed versus sensitive phytolith morphotypes in wild rice stands and modern Indian rice fields. Percentages exclude all phytoliths types not within the sensitive/fixed classification.

Figure 6. Comparison of the proportion of sensitive versus fixed phytolith morphotypes across three archaeological sites of different phases in the Lower Yangtze. A. Comparison of river edge or field palaeosol assemblages. B. Comparison of cultural layer/midden context assemblages.
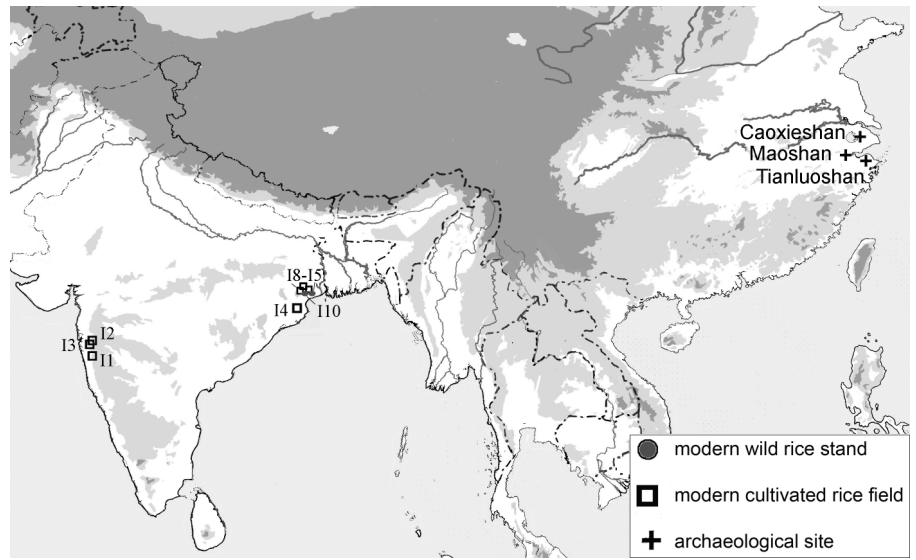
Figure 1. Map of modern analogue study sites, in India, and archaeological sites, in China, referred to in this paper.
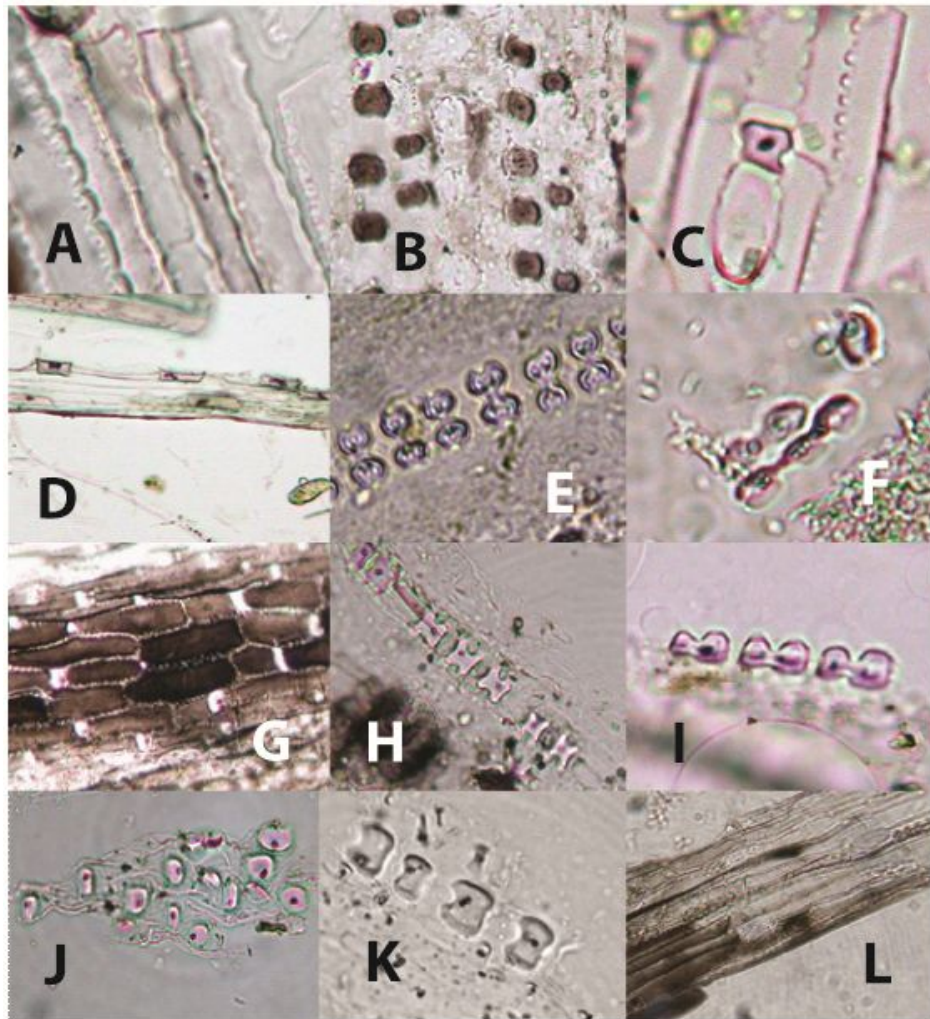
Figure 2. Example of phytolith morphotypes included in this study, from modern reference material. A. *Avena* leaf long sinuate; B. Chloris virgata leaf saddles; C. *Setaria faberii* leaf square bilobate D. *Bromus catharticus* leaves long smooth and rondels; E. *Oryza rufipogon* leaf scooped bilobes; F. wild *Setaria* sp. leaf bilobate; G. *Panicum miliceum* leaf long cells and bilobes; H. *Coix lachrymajobi* leaf crosses I. *Ischaemum rugosum* leaf bilobes; J. *Stipa tirsa* leaf round rondels; K. *Bambusa* sp. leaf collapsed saddles; L. *Dactylis glomerata* leaf long smoooth
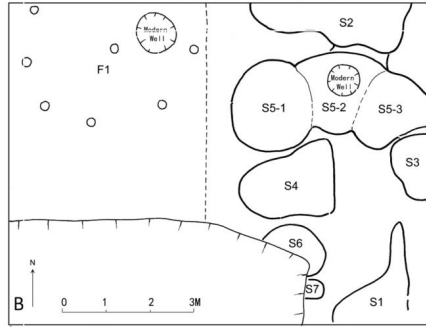
Figure 3. Example of modern rice stands in India sampled for phytoliths in this study. A. Upland rainfed rice, Penchant Ghat, Maharashtra (I2); B. Lowland rainfed rice, central Odisha (I4); C. Lolwand rainfed rice, Maharashtra (I1); D. Decrue field in Munda zone of northern Odisha, ranging from dry to deepwater (I7); E. *Oryza rufipogon,* perennial wild rice, northeastern Odisha (I10); F. *Oryza nivara,* anuual wild rice, northeastern Odisha (I5).
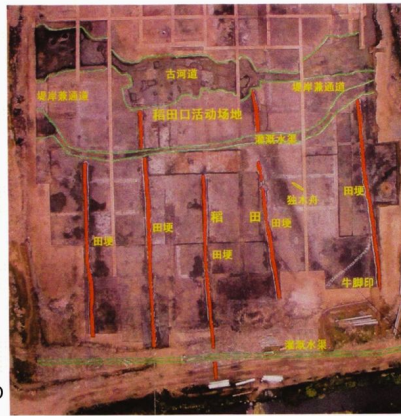
A

B

C

D

E

Figure 4. The archaeological sites sampled for this study. A. Tianluoshan Site, main part of ancient river (center) and western river bank, with posts aligned along the bank (left); B Caoxieshan site, plan of trench T0422 plan (F1: House platform with postholes; S:paddy fields); C. Caoxieshan site trench during excavations showing paddyfield units (trench is 5 m. wide); D. Maoshan site, overview of whole paddy area (orange lines drawn over paths/embankments between paddy fields; archaeological trenches are 15 meters square; E. Part of Maoshan excavations showing a view of pathways L2, the eastern most field boundary uncovered, running north to south.
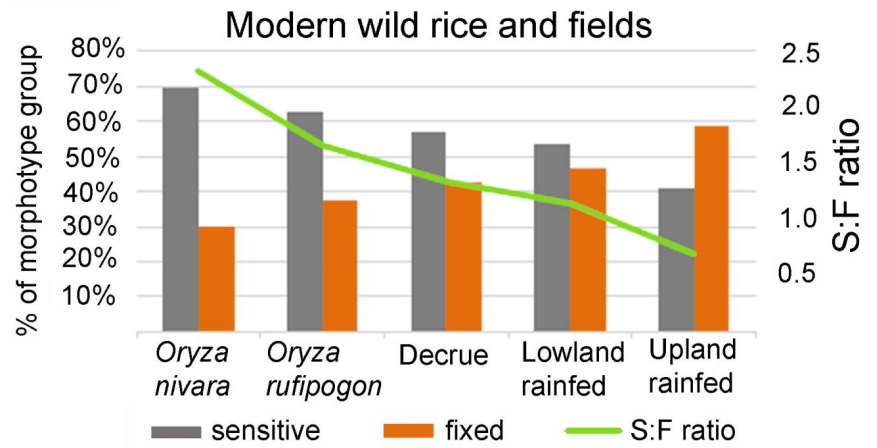

Figure 5: Percentage of fixed versus sensitive phytolith morphotypes in wild rice stands and modern Indian rice fields. Percentages exclude all phytoliths types not within the sensitive/fixed classification.
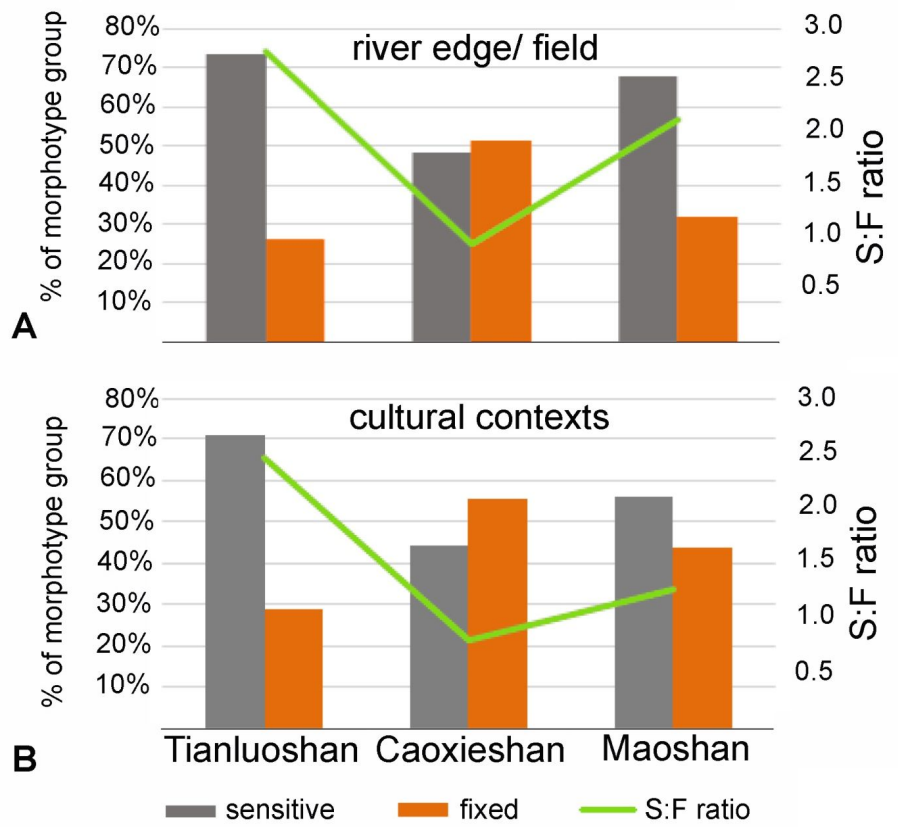
Figure 6. Comparison of the proportion of sensitive versus fixed phytolith morphotypes across three archaeological sites of different phases in the Lower Yangtze. A. Comparison of river edge or field palaeosol assemblages. B. Comparison of cultural layer/midden context assemblages.

Table 1. Phytolith morphotypes from grasses classified into fixed and sensitive morphotypes.

Dry or fixed, passive (Short grass cells)	Wet or sensitive, active (Long grass cells and stomata)
Rondel	Long smooth
Round rondel (Stipa type)	Long sinuate
Saddle	Long polyhedral
Bilobate	Long echinate
Scooped bilobate	Stomata
Square bilobate (Setaria type)	
Cross	
Collapsed saddle	

Table 2. Modern rice stands in India (I#) sampled for phytoliths and grouped based on relative degrees of wetness (further details of sites in Weisskopf et al 2013)

	Dry rice	Intermediate	Wet rice
Wild			I5 (O. nivara
			I10 (O. rufipogon)
Cultivated	I2 & I3 (upland rainfed)	I1,I4 & I6 (lowland rainfed), I7 & I8 (decrue)	

Supplementary Table. Archaeological sediment samples included in the phytolith analysis reported in the present paper

Site	Sample number	Period	est. date	Context type
Tianluoshan	T105 (8) S2	Hemudu	4900-4700 BC	river edge, (waterlogged)
Tianluoshan	T105 (8) SI	Hemudu	4900-4700 BC	river edge, (waterlogged)
Tianluoshan	T302 (6) SI	Hemudu	4700-4500 BC	general habitation fill
Tianluoshan	T003 (6) SI	Hemudu	4700-4500 BC	general habitation fill
Tianluoshan	T302 (6) I SI	Hemudu	4700-4500 BC	general habitation fill
Tianluoshan	T302 (5) SI	Hemudu	4700-4500 BC	general habitation fill
Tianluoshan	T302 (5)	Hemudu	4700-4500 BC	general habitation fill
Tianluoshan	T003 (5) SI	Hemudu	4700-4500 BC	general habitation fill
Tianluoshan	T302 (5) T [=lower] S1	Hemudu	4700-4500 BC	general habitation fill
Tianluoshan	T302 (5) tns	Hemudu	4700-4500 BC	general habitation fill
Tianluoshan	T302 (4) SI	Hemudu	4500-4300 BC	general habitation fill
Tianluoshan	T302 (4) SI	Hemudu	4500-4300 BC	general habitation fill
Tianluoshan	T302 (3) SI	Hemudu	4300-3800 BC	general habitation fill
Tianluoshan	T302 (3) T [=lower] S1	Hemudu	4300-3800 BC	general habitation fill
Caoxieshan	CXS TO422 (1) E. Section	Majiabang	4000BC	cultural layer
Caoxieshan	CXS TO422 (3) E. Section	Majiabang	4000BC	cultural layer
Caoxieshan	CXS TO422 (4) E. Section	Majiabang	4000BC	cultural layer
Caoxieshan	CXS TO422 (6)E. Section	Majiabang	4000BC	natural
Caoxieshan	CXS TO422 H15	Majiabang	4000BC	Platform
Caoxieshan	CXS TO422 F1 (1)-C	Majiabang	4000BC	Floor
Caoxieshan	CXS TO422 F1 Found.	Majiabang	4000BC	Floor Foundation
Caoxieshan	CXS TO422 S1	Majiabang	4000BC	Field palaeosol
Caoxieshan	CXS TO422 S4	Majiabang	4000BC	Field palaeosol
Caoxieshan	CXS TO422 S5	Majiabang	4000BC	Field palaeosol
Caoxieshan	CXS TO422 S6	Majiabang	4000BC	Field palaeosol
Caoxieshan	CXS S21	Majiabang	4000BC	Field palaeosol
Caoxieshan	CXS S23-1	Majiabang	4000BC	Field palaeosol
Caoxieshan	CXS S24	Majiabang	4000BC	Field palaeosol
Caoxieshan	CXS S27	Majiabang	4000BC	Field palaeosol
Caoxieshan	CXS S29	Majiabang	4000BC	Field palaeosol
Maoshan	09YMTN 12E12 - 12	Majiabang	?4500-4000 BC	general habitation fill
Maoshan	09YLM TN9E12 -11	Majiabang	?4500-4000 BC	general habitation fill
Maoshan	09YLMTN10-11E12G4-1-a	Liangzhu	3300-2300 BC	general habitation fill
Maoshan	09YLMTN10-11E12G4-1-b	Liangzhu	3300-2300 BC	general habitation fill
Maoshan	09YLMTN10-11E12G4-1-d	Liangzhu	3300-2300 BC	general habitation fill
Maoshan	09YLMTN10-11E12G4-1-e	Liangzhu	3300-2300 BC	general habitation fill
Maoshan	09YLMTN10-11E12G4 -1-f	Liangzhu	3300-2300 BC	general habitation fill
Maoshan	09YLMTN10-11E12G4 -3	Liangzhu	3300-2300 BC	general habitation fill
Maoshan	09YMTN 12E12 - 10	Liangzhu	3300-2300 BC	general habitation fill
Maoshan	09YMTN 12E12 - 9	Liangzhu	3300-2300 BC	general habitation fill
Maoshan	09YLMTN4E9-7	Liangzhu	3300-2300 BC	Field palaeosol
Maoshan	09YLMTN4E9-8	Liangzhu	3300-2300 BC	Field palaeosol
Maoshan	09YLMTN5E13-14-8	Liangzhu	3300-2300 BC	Field palaeosol
Maoshan	09YLM I Paddy II	Liangzhu	3300-2300 BC	Field palaeosol
Maoshan	09YLM.paddy. III	Liangzhu	3300-2300 BC	Field palaeosol
Maoshan	09YLM River	Liangzhu	3300-2300 BC	ancient river fill