

RESEARCH PAPER

Archaeobotanical Investigations into Golbai Sasan and Gopalpur, Two Neolithic-Chalcolithic Settlements of Odisha

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This paper presents the results of plant macro-remain and phytolith analyses from two Neolithic-Early Historic mounded settlement sites in Odisha, eastern India: Gopalpur and Golbai Sasan. Macrobotanical and phytolith samples were taken throughout the stratigraphy and the results are presented here. The plant remains confirm the presence of a distinct agricultural economy in Neolithic-Chalcolithic Odisha based on rice (*Oryza sativa*), pulses (*Vigna* spp., *Macrotyloma uniflorum* and *Cajanus cajan*) and millets (*Bracharia ramosa*, *Panicum* spp., *Setaria* spp. and possibly *Paspalum* sp.). Crop processing activities have been reconstructed using both phytoliths and macro-remains, and suggest that threshing occurred off site as part of a communal harvesting strategy. Potential differences between the economies of Golbai Sasan and Gopalpur are suggested, with a broader range of pulses present at Gopalpur. Radiocarbon dates from individual rice grains and legumes provide a secure chronology for the sites. This paper therefore provides the first published details for the agricultural base of the Neolithic-Chalcolithic coastal lowlands in Odisha, as well as new AMS radiocarbon dates for the Odishan Neolithic-Chalcolithic period.

Introduction

Gopalpur and Golbai Sasan are situated in the coastal lowlands of Odisha, close to Chilka Lake (**Figure 1**). They are large, highly stratified settlement mounds, situated close to rivers within the zone of transition from hilly escarpments to the west and the flat alluvial coastal plains to the east. Pottery recovered from both sites include red and grey ware, and hand made pottery at the lower levels (Mohanty et al 2012), indicating that the earliest levels are Neolithic, often dated to c. 4500–3200 BP based on comparative ceramic typologies (predominantly of Bihar, West Bengal, Madhya Pradesh and Uttar Pradesh) (e.g. Dash 2008, Behera 2000a). The latest levels have been dated to the Iron Age (c.2500 BP–1500 BP) on the basis of small finds typology, including pottery and a few iron objects (Kar and Joglekar 2000, Sinha 2000, Kar et al 1998, Mohanty 1994). Section scrapings at Golbai Sasan and Gopalpur took place in 2003 and archaeobotanical analysis was carried out by Harvey (2006). Based on the results of this excavation and questions surrounding the site's relationship to the development of Sisupalgarh (a large Early Historic fortified settlement located nearby (Mohanty and Smith 2008, Smith and Mohanty 2010, Mohanty et al 2013) two large

stepped trenches were opened at Golbai Sasan in 2011 (Mohanty et al 2012) (**Figure 2**).

Sites of the coastal lowlands represent the earliest permanent settlement sites in the region and have long been presumed to also represent the earliest agricultural societies. These sites are contemporary, however, with more ephemeral upland sites such as Bajpur and Kuchai (Basa et al 2000, Harvey 2006). Such ephemeral sites have short stratigraphic sequences and reveal little (in some cases, no) archaeobotanical remains, even after targeted archaeobotanical sampling (Harvey 2006).



Figure 1: Map showing the location of Gopalpur and Golbai Sasan in relation to key archaeological sites in the area. Deltihuda, Harirajpur, Khambeswaripali and Suabarei are Neolithic-Chalcolithic settlement mounds. Talapada and Sisupalgarh are Early Historic fortified settlements.

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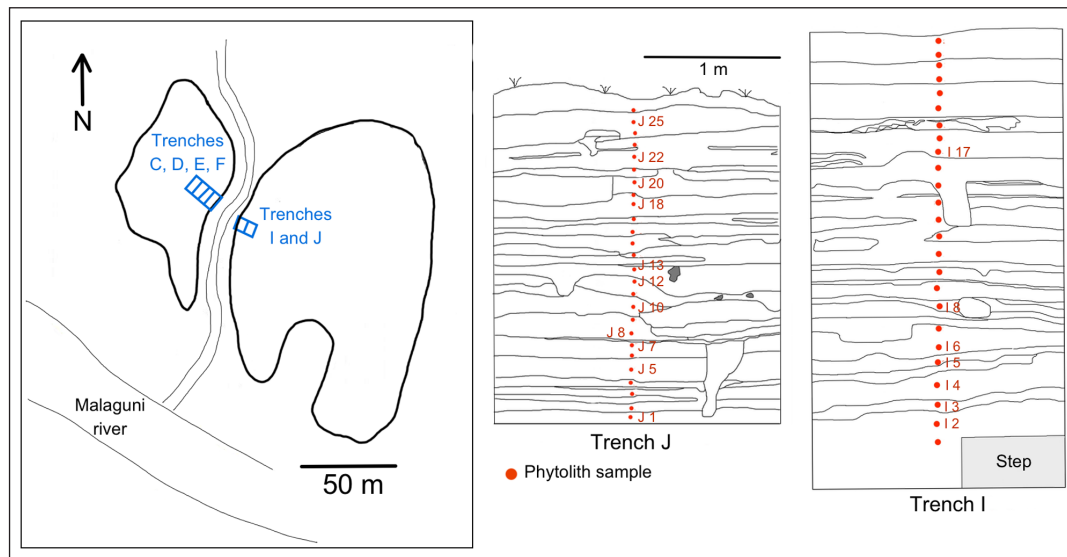


Figure 2: Site plan and trench sections showing location of phytolith samples for Golbai Sasan 2011 excavations.

The sites are often classified as Mesolithic on the basis of stone tool technology, with many of the upland sites (or “open air sites”, as described in much of the literature) in the region initially identified through microlithic scatters (e.g. Mohanty 2000). A radiocarbon sequence is not available for this period, however it appears that these sites were used for a long period of time, albeit un-intensively, as Neolithic ceramics appear in the upper stratigraphy at several sites (e.g. Basa et al 2000, Harvey 2006). There is a clear demarcation within the landscape created by the distribution of these sites, which occur in the uplands, and the agricultural mounded settlements of the coastal lowland areas. This indicates that at least two different cultural groups occupied Odisha in the Neolithic-Chalcolithic period, yet it is not currently clear how these groups interacted. Further intensive investigations into both regions would provide good evidence with which to examine this. One of the objectives of this present research was to examine any evidence within the archaeobotanical remains for economic interaction between these groups.

The archaeobotanical samples from Golbai Sasan and Gopalpur derive from continuously occupied sites spanning the period of early rice cultivation, through to established rice-based economies. These two sites, along with sites such as Kuchai (Thapar 1961–1962), Harirajpur (Behera 2013), Suabarei (Joglekar and Patnaik 2016) and Ostapur (R.K. Mohanty and M. Smith, unpublished) represent some of the few excavated, yet numerous, sites of the “Eastern Wetlands Tradition” (sensu Fuller 2006). Based on the initial archaeobotanical analysis of Gopalpur and Golbai Sasan by Harvey (2006), Odisha appears to be home to a distinct Neolithic-Chalcolithic culture based on rice and pulse cultivation. This includes a possible independent domestication of pigeon pea (*Cajanus cajan*) within Odisha, perhaps as early as c.4500–4000 BP (Fuller and Harvey 2006). Initial analyses of the faunal remains from Gopalpur and Golbai Sasan have shown that domestic cattle and buffalo rearing occurred alongside wild animal hunting (Kar et al 1998, Sinha 2000, Mohanty et al 2010–2011). This matches the pattern from other sites

including Chalcolithic Suabarei, at which a broad range of wild fauna (including hunted game mammals, birds, fish and small turtles) and domesticated cattle, buffalo, pig and sheep/goat were identified (Joglekar and Patnaik 2016).

Early plant agriculture in Odisha; research background and questions

Golbai Sasan was chosen for targeted archaeobotanical sampling in 2011 in order to target secure Neolithic samples, identify its agricultural base during the Neolithic and Chalcolithic, investigate any possible developments in domestic crop cultivation in this region (including changes in cultivation techniques, crop processing and the types of crops grown) and to get a complete AMS C14 sequence from earliest Neolithic to the most recent deposits.

East India has long been posited as an early centre of plant domestication within the subcontinent. The presence of large stands of wild rice throughout the region, as well as a host of other sub-tropical genera including several wild pulses and fruit trees within the forests and forest margins of the Eastern Ghats, has been used to support the hypothesis. However, archaeobotanical evidence for early (i.e. Mesolithic and Neolithic) exploitation of wild or domestic rice is sparse. Reasons for this include infrequent archaeobotanical sampling of archaeological sites, the limited identification and excavation of sites from this period, the apparent longevity of wild rice collecting and shifting cultivation (as indicated by the persistence of un-intensive occupation sites and nomadic populations) and difficulties in distinguishing between wild and domestic species (Kingwell-Banham 2015, Kingwell-Banham and Fuller 2012, Harvey 2006, Fuller 2003, 2006, 2011, Morrison and Junker 2002). The apparent sudden arrival of rice agriculture into Odisha indicated by the sudden appearance of Neolithic mounded settlement sites in the archaeological record, where no agriculture had been practiced previously, has also lent support to the suggestion that rice may have undergone, or began, a domestication process here. Equally it has also been suggested that this represents the movement of people and/or agricultural

Table 1: Previously published radiocarbon dates for Golbai Sasan and Gopalpur, calibrated using OxCal 4.2.

Site and reference	Lab Code	Ascribed Period	Layer	Material	BP	Cal BP 2σ
Golbai Sasan (Bisht et al 1993–94)	PRL 1641	Chalcolithic	15	Charcoal	2600 +/- 90	2871–2380
	PRL 1637	Chalcolithic	13	Charcoal	4100 +/- 100	4859–4300
	PRL 1642	Chalcolithic	4	Charcoal	4310 +/- 100	5284–4580
	PRL 1646	Neolithic	18	Charcoal	2710 +/- 90	3072–2540
Golbai Sasan (Harvey 2006)	OxA-14132	Chalcolithic	3	<i>Oryza sativa</i> grain	2927 +/- 28	3165–2960
	OxA-14133	Chalcolithic	9	<i>Oryza sativa</i> grain	2943 +/- 28	3170–2990
	OxA-14134	Neolithic-Chalcolithic	13D	<i>Oryza sativa</i> grain	2966 +/- 32	3215–3000
	OxA-14135	Neolithic-Chalcolithic	13D	<i>Vigna radiata</i> seed	2920 +/- 29	3165–2955
Gopalpur (Harvey 2006)	OxA-14131	Chalcolithic	13	<i>Oryza sativa</i> grain	2874 +/- 45	3120–2865
	OxA-14130	Chalcolithic	8	<i>Oryza sativa</i> grain	2983 +/- 32	3270–3060
	OxA-14129	Chalcolithic	6	<i>Oryza sativa</i> grain	2964 +/- 30	3315–2995
	OxA-14128	Neolithic-Chalcolithic	2	<i>Cajanus cajan</i> seed	3035 +/- 31	3345–3160

technology into this area from the Ganges Plains (Harvey 2006, Sinha 2000).

Archaeobotanical sampling of Gopalpur and Golbai Sasan by Harvey (2006) did not produce a sequence of rice development from morphologically wild to morphologically domestic. However, the layers that she sampled did not include those from the earliest Neolithic levels. One of the objectives of the 2011 sampling at Golbai Sasan was therefore to recover archaeobotanical remains from the earliest levels in order to examine the possible domestication or introduction of rice into the area. Direct radiocarbon dating of the archaeobotanical remains from Golbai Sasan has allowed for these issues to be examined within a secure chronological time frame.

In addition, archaeobotanical results from the sites shed light on the agricultural base of Chalcolithic Odisha, which preceded the construction of Early Historic fortified cities such as Sisupulgarh and Talapada. The construction of these cities, especially the largest, Sisupulgarh, would have required a significant labour input from, presumably, the local population. This labour force would have had to have been supported by agriculturalists within the hinterland, however we know very little about the type of agriculture practiced at this period. Specifically, there are large questions relating to where the population of these new cities came from, including the mystery of why Sisupulgarh was so densely occupied whilst Talapada was sparsely occupied. Again, our radiocarbon dating and archaeobotanical analysis has allowed us to begin to answer these questions and suggest models which can be tested by future archaeological work.

Previous archaeological work and radiocarbon dating at Golbai Sasan and Gopalpur

Of the two sites, Golbai Sasan has been excavated more fully, although by no means exhaustively. Postholes, possible clay floors, Red Ware, Grey Ware, pieces of antler and worked bone tools have been identified within the Neolithic layers of the site during previous excavations (Mohanty 1994, Sinha 2000). Following the Neolithic

levels, a Chalcolithic period began which is characterised by bone, antler and copper tools, including bone harpoons and digging sticks, plus pottery with red, black and chocolate slips. 13 circular huts with reported diameters of between 3.9 m and 7.9 m, and with central partitions marked by small postholes, were identified within this period by Sinha (2000). Other notable finds include earrings made from fish vertebrae and human-like terracotta figurines (*ibid.*). Faunal remains included domestic cattle and buffalo, plus wild pig and deer. During the Early Iron Age (c.2500 BP) the settlement appears to have entered a decline. Pottery becomes poorly manufactured and the number of finds reduces. Post holes were identified but no hut plans were recovered by Sinha (*ibid.*). The tool assemblage remained the same, with significant numbers of bone, antler and stone tools, but one iron celt was found by Sinha (*ibid.*) that appears to have been made fairly crudely, leading to the suggestion that the maker was not familiar with iron technologies. Excavations conducted in 2011 were the most extensive to have been conducted at this site thus far. They revealed a 9–10 m deep habitation sequence, from c.2 m below the surface level upwards to 7 m above (**Figure 2**) (Mohanty et al 2012–2013).

The site has been radiocarbon dated by previous excavators, however initial dates were all taken from wood charcoal (charcoal is particularly vulnerable to the “old wood effect”) (Bisht et al 1993–1994). Subsequent dating has also produced an unclear sequence thought to be related to the fact that excavations were shallow, possibly from mixed deposits of slumped soils, and that the sampled contexts were all from the Chalcolithic period (Harvey 2006) (**Table 1**). It should be noted that apart from two charcoal samples from Chalcolithic levels (Bisht et al 1993–94) none of these dates are as old as 4500 BP (Dash 2000). The anomalously old dates from Chalcolithic charcoal suggests that these were taken from old wood. Older trees are often used for construction and old growth forests were frequently cleared and used by early farmers.

Gopalpur is situated on the Khatiari stream, which has eroded part of the mound revealing the stratified

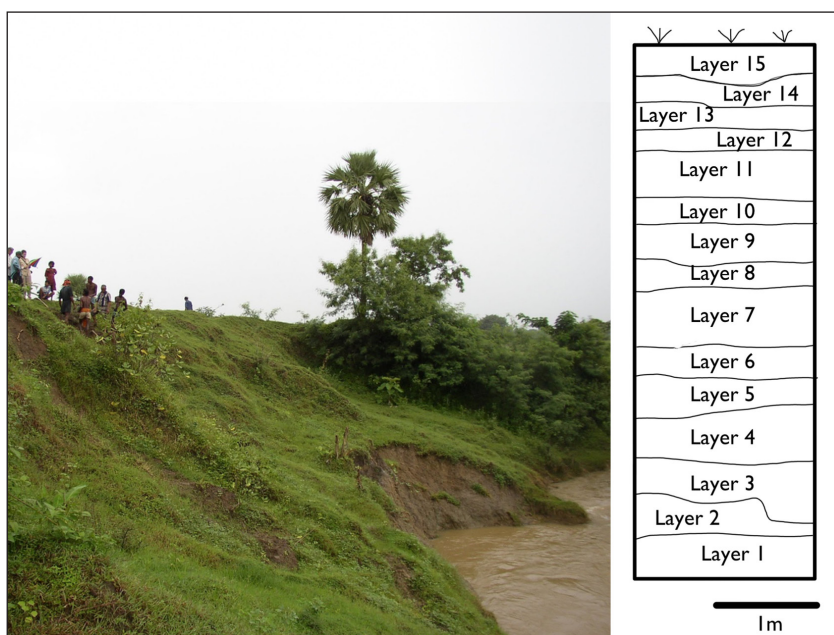


Figure 3: The trench section at Gopalpur 2003. Phytolith and macrobotanical samples were taken from each layer.

deposits in the cliff edge (**Figure 3**). Unlike Golbai Sasan, Gopalpur has never been subject to extensive excavations, but was surveyed in 1995–1996 (Kar 1995–1996). Surface finds have been reported which show much similarity with Golbai Sasan, including the presence of Neolithic Red Wares and Chalcolithic Black and Red Wares (Kar and Joglekar 2000, Kar et al 1998). Lithics, ceramics and faunal remains all correspond with those from Golbai Sasan, however no bone tools or iron artefacts have been reported from Gopalpur (Kar et al 1998). A section scraping was carried out in 2003 by Mohanty, and Harvey analysed the plant remains (reported below) (Harvey 2006). Radiocarbon dates were also taken, but again are suggested to relate to mixed deposits of slumped soils (**Table 1**) (Harvey 2006).

Methods

For each of the excavations/diggings reported here bulk soil samples of between 5 and 50 litres were taken and charred plant remains were recovered via bucket floatation. These were collected on a 0.25 mm mesh at Golbai Sasan 2011 to ensure the recovery of small weeds and rice spikelet bases, which can be used to differentiate between wild and domestic rice (Fuller et al 2009), whilst a 0.5 mm mesh was used at the earlier 2003/2004 work at Gopalpur and Golbai Sasan. Samples were dried on-site, packed into zip lock bags and were studied by Kingwell-Banham from UCL Institute of Archaeology, London. The samples were dry sieved to 4 mm, 2 mm, 1 mm, 0.5 mm and 0.25 mm and were examined under an optical microscope at 8× to 35× magnification. Each seed (whole or fragmented) was given a count of 1, with the exception of rice grains and pulses. Rice grains were given a count of 1 where either over 50% of the grain was present or the embryo was visible. Rice grain fragments were only recorded from the >0.5 mm fractions. Pulses were recorded as either whole, half or fragmented. Identifications of cereals, chaff, pulses, millets, weeds, nuts and fruits were made using the reference collection at UCL Institute of Archaeology and a variety of literature (e.g.

Castillo 2013 (especially for *Citrus* sp.), Cappers et al 2009, Fuller and Harvey 2006, Tropicos.org 2018).

All rice grains recovered in a reasonable state of preservation from Golbai Sasan 2011 (i.e. with a preservation value of 1 or 2 (following Hubbard and al Azm (1990)) were measured using a microscope graticule. Length, breadth and width were recorded following the published method for differentiating between *Oryza sativa* ssp. *indica* and *Oryza sativa* ssp. *japonica* using length/width ratios (Castillo et al 2016).

Phytolith samples were taken from trench sections (**Figures 2** and **3**) directly into zip lock bags using a trowel cleaned with bottled water and Kimwipes®. Approximately 100 g of sediment was taken per sample and 0.8 g of this was processed by heavy liquid flotation using Sodium Polytungstate (Albert and Weiner 2001, Piperno 2006, Rosen 1995). The weight of sediment processed was recorded, as was the weight of phytoliths extracted and the weight of phytoliths mounted (Albert and Weiner 2001). Phytoliths were counted using a biological microscope at ×400 magnification. A minimum of 300 single cell phytoliths and 100 multi-cell phytolith panels were counted per slide. Identifications were made using reference slides housed at UCL Institute of Archaeology and relevant literature (for example, Eichhorn et al 2010, Lu et al 2009, Piperno 2006, Weisskopf and Lee 2016).

Fourteen single rice grains and one *Vigna* sp. bean from Golbai Sasan 2011 were sent to the Oxford Radiocarbon Accelerator Unit (ORAU) for radiocarbon dating, however seven of these had a low carbon content and could not be dated. Results were calibrated and modelled using OxCal 4.5.

Results

Radiocarbon dates

The new radiocarbon dates from Golbai Sasan 2011 place the site at between c.3450 and c.2850 cal BP (**Table 2**, **Figure 4**). The transition from Neolithic to Chalcolithic has been modelled at 3115–3065 BP.

Table 2: New radiocarbon dates from Golbai Sasan 2011.

Lab code	Trench/Layer	Depth	Period	Material	BP	Cal BP 2σ
OxA-27533	D/1	45–86 cm	Chalcolithic	<i>Oryza sativa</i>	2946 +/- 32	3210–2997
OxA-30014	E/4	347–363 cm	Chalcolithic	<i>Oryza sativa</i>	2834 +/- 29	3035–2860
OxA-29898	F/2	468–494 cm	Chalcolithic	<i>Oryza sativa</i>	2943 +/- 26	3174–3002
OxA-29899	F/8	502–532 cm	Chalcolithic	<i>Oryza sativa</i>	2946 +/- 25	3177–3002
OxA-27496	J/17	249–275 cm	Chalcolithic	<i>Oryza sativa</i>	2963 +/- 28	3215–3007
OxA-29901	J/18	275–290 cm	Chalcolithic	<i>Oryza sativa</i>	2943 +/- 26	3176–3000
OxA-27534	I/15	450–457 cm	Neolithic	<i>Vigna</i> sp.	3005 +/- 45	3326–3063
OxA-29900	I/18	485–530 cm	Neolithic	<i>Oryza sativa</i>	3164 +/- 26	3450–3350

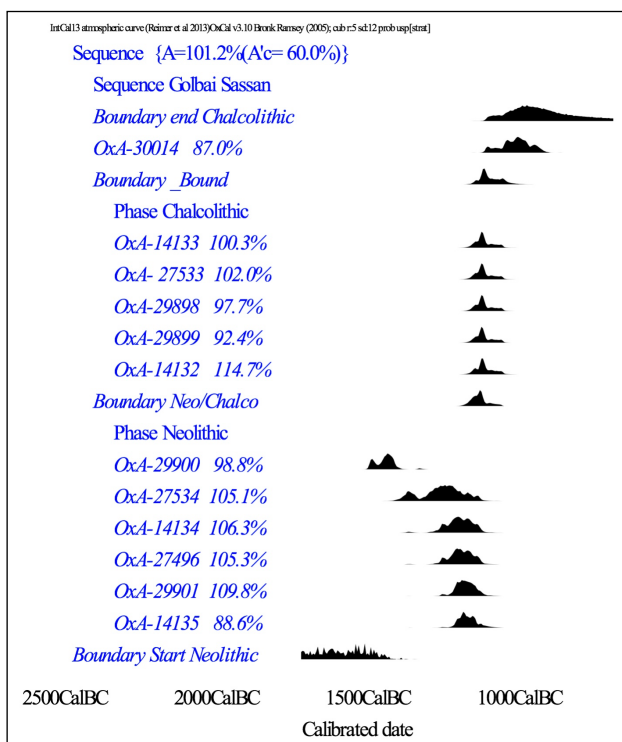


Figure 4: Modelled radiocarbon dates and boundaries for Golbai Sasan.

Macrobotanical remains

15 macrobotanical samples from Golbai Sasan 2003 and 31 from the 2011 excavations were fully sorted and analysed for macro remains (Table 3). 25 samples from Gopalpur 2003/2004 were sorted and analysed (Table 4). Preservation was generally poor across both sites and assigning lower taxonomic ranks to certain finds was not possible. The samples from Golbai Sasan 2011 trenches I and J provide a complete sequence from the earliest Neolithic to Chalcolithic levels of the site, whereas only Chalcolithic samples are available from Gopalpur.

The macro remains contain a large component of rice remains, both grains and spikelet bases (Figures 5, 6 and 7). Of the total spikelet base assemblage 70% were unfortunately unidentifiable to type, representing 56 of 80 individuals. The spikelet bases that were preserved in an identifiable condition are predominantly of domestic type (74% of the identifiable fraction), with 21% of the identifiable sample identified as wild type and 5% as

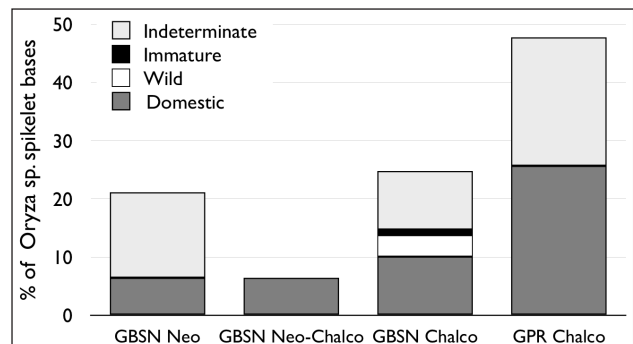


Figure 5: Wild, domestic and immature spikelet bases from Golbai Sasan (GBSN) and Gopalpur (GPR).

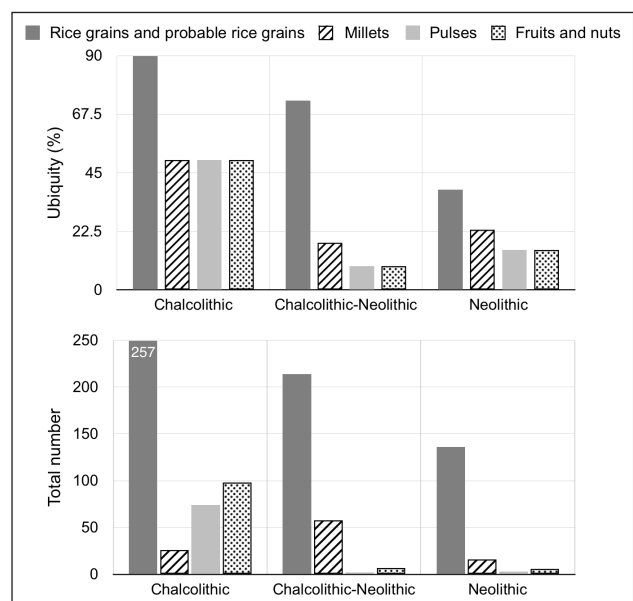


Figure 6: Frequency and ubiquity of the main crops present at Golbai Sasan.

immature. This is consistent with a domestic crop of cultivated rice, with wild types representing weedy rices (Fuller et al 2009, 2016). Rice is consistently present throughout the sequence from the earliest Neolithic onwards, however there is no chronological difference in grain morphology or the relative proportions of wild:domestic:immature spikelet bases (Figure 5).

At Golbai Sasan several pulses, in the form of *Cajanus* sp., *Macrotyloma* sp., *Vigna* sp. and *Vigna radiata*, were recovered, as were several grasses, including

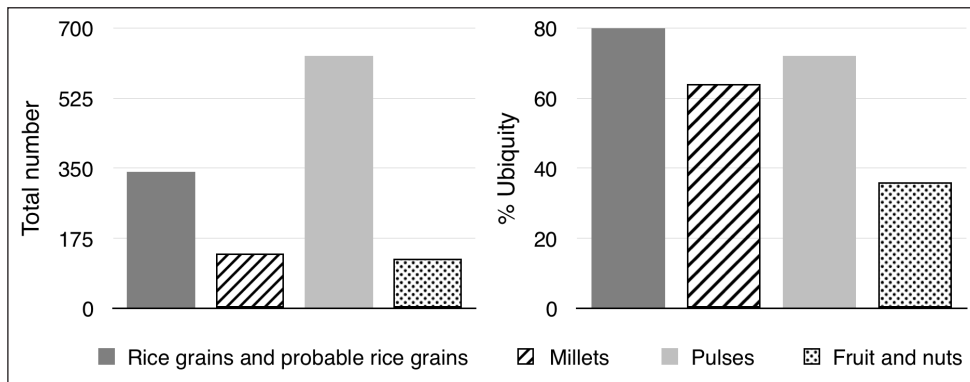


Figure 7: Frequency and ubiquity of the main crops present at Gopalpur.

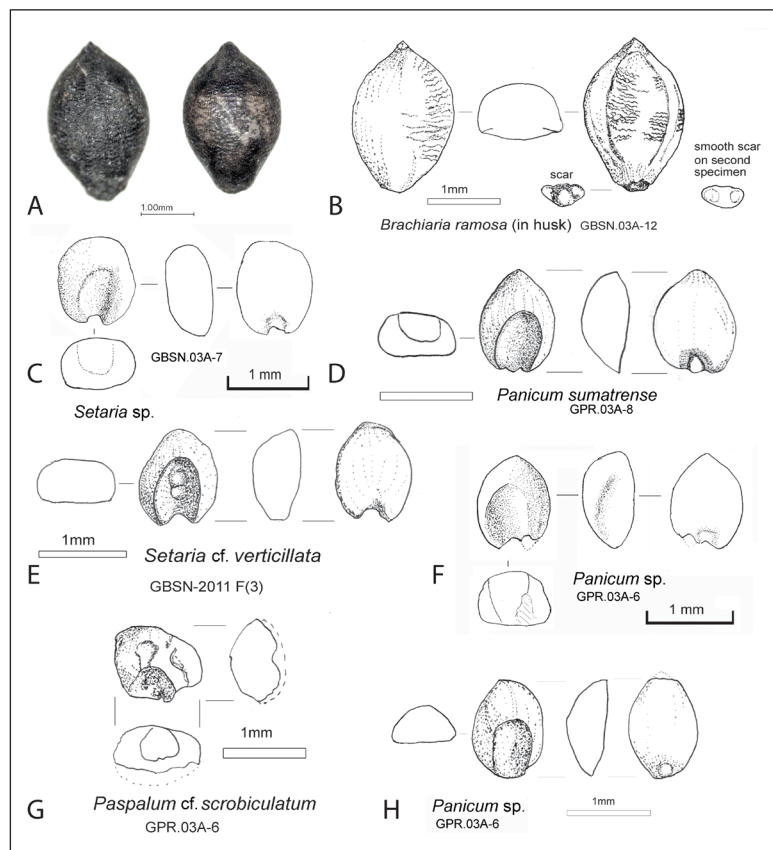


Figure 8: Examples of millets and millet grasses from Gopalpur and Golbai Sasan. **A, B.** *Brachiaria ramosa* in the husk. **C.** *Setaria* sp. (after Harvey et al 2006). **D.** *Panicum sumatrense*, **E.** *Setaria* cf. *verticillata* type millet, **F, H.** Small, wild *Panicum* sp., **G.** *Paspalum* cf. *scrobiculatum*. All drawings by DQF.

likely weeds (*Paspalum scrobiculatum*, *Echinochloa* sp., small *Panicum* sp.) as well as possible millet crops, including possible proso millet (*Panicum sumatrense*), browntop millet (*Brachiaria ramosa*), possible bristly foxtail (*Setaria* cf. *verticillata*) and another *Setaria* sp. (**Figure 8**). Millets and pulses appear together in the assemblage from the Chalcolithic period onwards (Sample I13, c.3000 BP), but this may be a reflection of preservation rather than agricultural economy. Of the pulses, *Vigna* sp. is most common both in terms of ubiquity and total numbers retrieved.

The fruit peel and nut shell fragments that were recovered were very small and poorly preserved and therefore it was not possible to identify the majority of them, however *Ziziphus* sp. has been identified.

Several different wild weeds were identified, however these occurred in low numbers and were all low in ubiquity. Apart from *Cyperaceae* and *Commelina* sp., weed species are represented by only one or two individual finds.

At Gopalpur rice (*Oryza sativa*) was recovered alongside *Macrotyloma uniflorum* (horsegram) and *Cajanus cajan* (pigeon pea) as well as millets (*Setaria* spp., *Panicum sumatrense* (little millet)). Two *Brachiaria ramosa* specimens preserved in the husk (**Figure 8a, b**) also preserve spikelet disarticulation scars, one of which appears torn and the other smoothly dehisced. The presence of a torn example could imply the presence of some domestication *Brachiaria* or a population undergoing domestication. *Paspalum* and *Echinochloa* likely represents weeds, as these are among the most common weedy taxa in rice

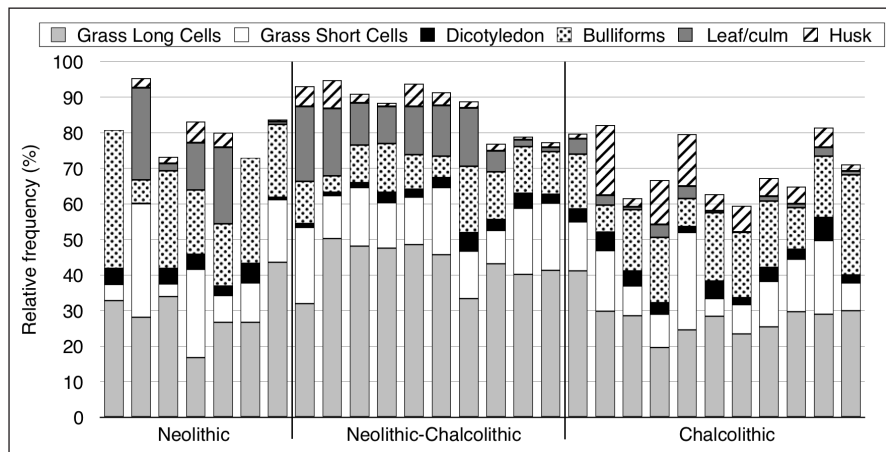


Figure 9: Relative frequency of main phytolith morphotypes identified at Golbai Sasan.

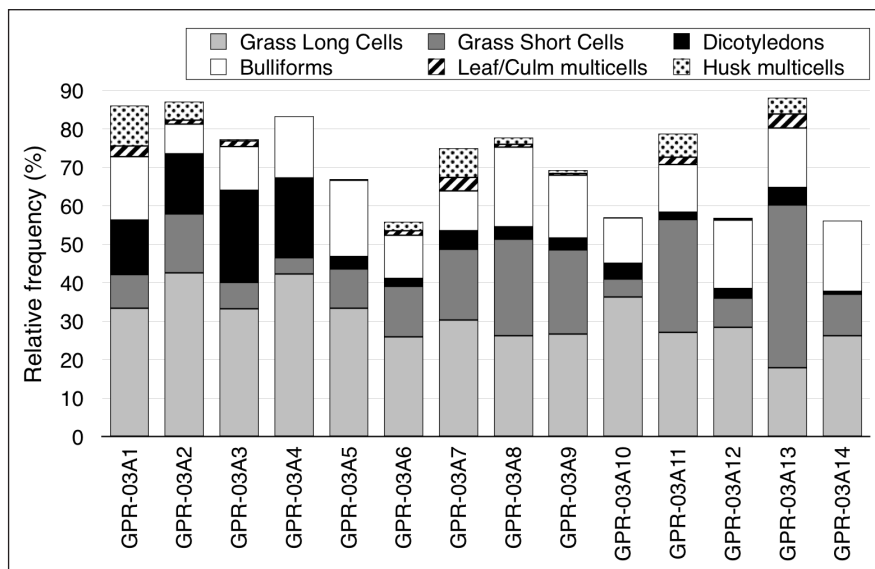


Figure 10: Relative frequency of main phytolith morphotypes identified at Gopalpur.

(Holm et al 1977). Examining the raw count data shows that rice is prevalent at the site with 328 grains identified, however pulses also have a high count of 631 fragments in total, showing that they were a very important food source. 19 whole pulses and 32 pulse halves are identified as *Macrotyloma uniflorum*, and 2 pulse halves are identified as *Cajanus cajan*, but there is a high quantity of unidentifiable pulse fragments within the samples.

The wild weed assemblage is small, with only 97 seeds recovered. In addition, preservation is very poor, hampering species or even genus level identifications. In general, the weed flora is represented by grasses, some sedges and Polygonaceae.

Of note is the high occurrence of fruit peel recovered in the 2004 samples. Sample GPR-04-14 in particular contained 149 pieces of peel. Identification to species of fruit peel can be difficult, as its rare recovery means that there are few resources to aid identification and a lack of reference material (Fuller et al 2018). Using the reference material in the Institute of Archaeology, in particular work by Castillo (2013), an identification of *Citrus* spp. was given to 100 fragments (see also, Fuller et al 2018). At least some of the larger pieces resemble citron (*Citrus medica*). As no

citrus species are regarded as being wild in Odisha, these finds suggest that citrus fruits (probably an early citron) were cultivated in Chalcolithic Odisha (Fuller et al 2018, Weisskopf and Fuller 2014).

The phytolith results

Offsite samples were taken at both sites and examined in comparison with the archaeological material in order to identify possible contamination of the archaeological samples with modern elements. None was noted.

In general, the phytolith remains from Gopalpur are very similar to those from Golbai Sasan, however *Oryza*-type leaf/stem multi-cell panels were less frequently recovered, suggesting possible differences in rice crop processing strategies between the two sites. The most common morphotypes from Golbai Sasan and Gopalpur are long cells, bulliforms and keystone (Figures 9 and 10). Rondels are also recorded in high numbers from several contexts, as are *Oryza*-type double peaked glume cells. The multi cell panels are dominated by unidentifiable leaf/stem and rice husk. Other single cells (including *Oryza*-type bulliforms and all other grass short cells) and multi cell panels identifiable to family, genus or species are only rarely

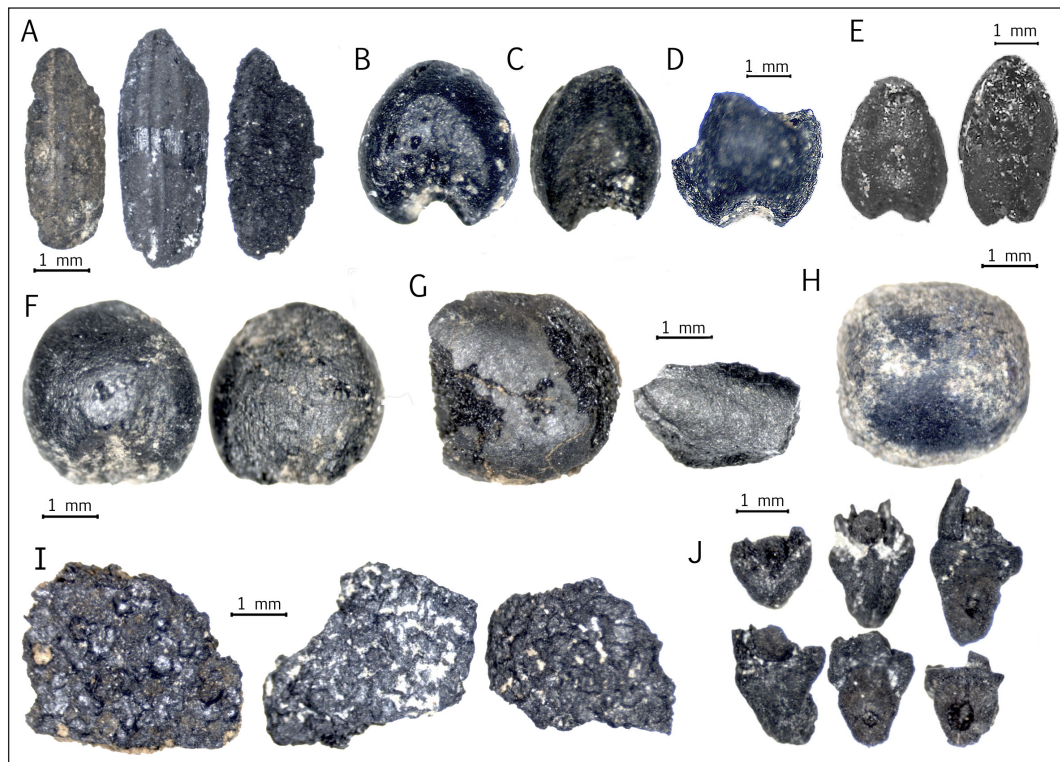


Figure 11: Selected macrobotanical remains of crops from Golbai Sasan and Gopalpur. **A)** *Oryza sativa* **B)** *Setaria* sp. **C)** *Panicum sumatrense* **D)** *Paspalum* sp. **E)** *Setaria* cf. *verticillata* **F)** *Paspalum scrobiculatum* **G)** *Macrotyloma uniflorum* **H)** *Vigna radiata* **I)** *Citrus* sp. peel **J)** Domesticated *Oryza* sp. spikelet bases.

recorded i.e. at relative frequencies of <5%. *Oryza* (including *Oryza* type bilobes, keystones and multi cell panels) was identified in all but one sample from Golbai Sasan (I17, corresponding to the archaeologically sterile sub-soil), and two samples from Gopalpur (3 and 10). 'Husk cf. *Oryza*' positively correlates with 'Husk unidentifiable.' in most samples, suggesting that a proportion of the 'Husk unidentifiable' morphotypes derive from rice. Rice husk is more frequent than rice leaf/culm at both sites. Husk multi-cell panels (including rice husk panels) increase in relative frequency at Golbai Sasan during the Chalcolithic period. Millet husk multi cell panels are only recovered in trace amounts (relative frequency of <0.54%), at a ubiquity of 21% from both Golbai Sasan and Gopalpur.

The phytolith assemblage from both sites corresponds with the macro botanical remains, and demonstrates the presence of rice cultivation and supplementary small-scale small millet agriculture at both sites.

Discussion

Plant based subsistence during the Neolithic to Chalcolithic of the coastal lowlands of Odisha

Archaeobotanical analysis has revealed a distinct agricultural economy based on rice (*Oryza sativa* cf. subspecies *indica*), pulses (*Cajanus cajan*, *Macrotyloma uniflorum* and *Vigna* cf. *radiata*) and possible supplementary millets (*Panicum Sumatrense*, and *Setaria* spp.) (Figure 11). This is in contrast to contemporary Neolithic-Chalcolithic sites in the Ganges Basin, which grew both summer (primarily of South Asian origin, like rice) and winter crops (primarily crops of Southwest Asian origin, like wheat and barley), or the contemporary sites of South India and the Deccan where the small South Asian millets and Southwest Asian

crops were cultivated (Kingwell-Banham et al 2015, Fuller 2006, 2011).

In Odisha rice appears to have been the dominant crop since the first farming settlements were established. 50% of the macrobotanical crop remains recovered and analysed from lowland coastal sites have been rice grains. Other crops include three pulses which, by themselves, make up the majority of the remaining 50%. These are mungbean (*Vigna radiata* and possibly another *Vigna* sp.), horsegram (*Macrotyloma uniflorum*) and pigeon pea (*Cajanus cajan*). Pulse cultivation was an important agricultural occupation in this area, providing valuable plant based protein to the human diet, but also acting as a nitrogen fixer in agricultural soils. Millets were likely grown at Golbai Sasan but the data from Gopalpur suggests that millets were more important at that site during the Chalcolithic period than at Chalcolithic Golbai Sasan. Millet crops are of relatively low yield, but require less water to grow. They may have been cultivated in part as an insurance crop, becoming a staple food during periods of low rainfall. Alternatively, a millet crop may have been grown in order to provide fodder for livestock. Cattle and buffalo have previously been identified through undated surface collections and excavations at Golbai Sasan, Gopalpur and Khameswaripali (Behera 2000b, Kar and Joglekar 2000, Kar et al 1998, Sinha 2000). Despite this, it is worth noting that any of these millets could have been incorporated into the assemblage as weeds of rice. In the absence of morphological domestication indicators, small millets elsewhere in India have been inferred as crops based on high ubiquities and/or frequencies of occurrence (e.g. Fuller 2003) and the recovered quantities of millets from these sites is relatively low. Thus a challenge

Table 3: Macrobotanical remains recovered from Golbai Sasan.

Period	Neolithic Total count (Ubiquity %)	Chalcolithic-Neolithic Total count (Ubiquity %)	Chalcolithic Total count (Ubiquity %)
# Samples (Volume L)	13 (225)	11 (114)	20 (358)
<i>Oryza sativa</i>	38 (30.77%)	79 (63.64%)	217 (85%)
cf <i>Oryza</i> spp.	15 (23.08%)	26 (36.36%)	40 (45%)
Cereal indet.	83 (23.08%)	109 (54.55%)	149 (60%)
<i>Oryza sativa</i> spikelet bases domestic type	7 (23.08%)	7 (36.36%)	11 (10%)
<i>Oryza</i> sp. spikelet bases immature	0	0	1 (5%)
<i>Oryza</i> sp. spikelet bases wild type	0	0	4 (5%)
<i>Oryza</i> sp. spikelet bases indeterminate	16 (7.69%)	0	11 (5%)
<i>Bracharia ramosa</i>	0	0	3 (10%)
<i>Echinochloa</i> sp.	4 (15.38%)	3 (9.09%)	0
<i>Panicum</i> sp.	0	10 (18.18%)	0
<i>Panicum</i> cf. <i>sumatrense</i>	1 (7.69%)	0	0
<i>Paspalum scrobiculatum</i>	0	4 (9.09%)	7 (35%)
<i>Setaria</i> spp.	3 (15.38%)	26 (18.18%)	16 (30%)
<i>Setaria</i> cf. <i>verticillata</i>	1 (7.69%)	0	4 (15%)
Millet indet.	6 (15.38%)	15 (18.18%)	12 (30%)
<i>Cajanus</i> sp.	0	0	4 (15%)
<i>Macrotyloma</i> sp.	0	2 (9.09%)	12 (30%)
<i>Vigna</i> spp.	1 (7.69%)	2 (9.09%)	0
<i>Vigna radiata</i>	0	0	2 (10%)
cf. <i>Vigna</i>	2 (7.69%)	0	0
cf. Araliaceae	1 (7.69%)	1 (9.09%)	1 (5%)
Asteraceae	1 (7.69%)	0	2 (10%)
Cyperaceae	2 (15.38%)	3 (18.18%)	1 (5%)
cf. <i>Scheonoplectus</i> sp.	0	4 (9.09%)	1 (5%)
Lamiaceae	1 (7.69%)	0	1 (5%)
Malvaceae	0	0	3 (5%)
Rubiaceae	0	0	2 (10%)
Scrophulariaceae cf. <i>Lindernia/Scropia</i> type	0	0	4 (15%)
<i>Sisyrinchium</i> sp.	1 (7.69%)	4 (18.18%)	0
cf. <i>Scirpus</i>	2 (7.69%)	0	0
Indeterminate seeds	13 (23.08%)	0	0
cf. Peel fragments	0	7 (9.09%)	2 (5%)
<i>Ziziphus</i> sp.	0	0	9 (15%)
cf. nut shell fragments	6 (15.38%)	0	87 (40%)

for future work is determine whether millets were minor food grains or persistent weeds in economies that were focused on rice.

The fruit peel and nut shell fragments recovered from Golbai Sasan provide some limited evidence for arboriculture in Odisha. Many valuable fruit tree species, such as mango, jackfruit and citrus, are native to the dry-moist-deciduous zones of South Asia, which is the potential climax forest covering much of the state of Odisha (Asouti

and Fuller 2008). These areas are thus the possible source of many domesticates, including the above. Whilst the current evidence does not provide concrete data of any kind, it is a tantalising indication of an often unexamined aspect of subsistence economies, the development of cash crops and the domestication of trees, where they are likely first managed by shifting cultivators in the forested hills and then transferred to sedentary farmers in the plains (Kingwell-Banham and Fuller 2012). The *Citrus* sp. peel

Table 4: Macrobotanical remains recovered from Gopalpur.

Period # Samples (volume L)	Chalcolithic	
	24 (480)	
	Ubiquity (%)	Total count
<i>Oryzasativa</i> grains	80	328
cf <i>Oryza</i> spp. Grain fragments	12	13
<i>Oryza sativa</i> spikelet bases domestic type	28	50
<i>Oryza</i> spp. spikelet bases indet type	24	83
Cereal grain fragments	36	312
cf. <i>Macrotylomas</i> p.	4	1
<i>Macrotyloma uniflorum</i> whole bean	20	19
<i>Macrotyloma uniflorum</i> cotyledon	16	32
<i>Macrotyloma uniflorum</i> bean fragment	24	132
<i>Cajanus cajan</i> cotyledon	4	2
Pulse fragments	68	445
cf. <i>Setaria</i> spp.	4	1
<i>Setaria</i> spp.	32	19
cf. <i>Panicum</i> spp.	8	4
<i>Panicum</i> spp.	12	16
<i>Panicum sumantrense</i>	8	3
<i>Paspalum</i> sp.	4	1
cf. <i>Echinochloa</i> spp.	8	6
<i>Echinochloa</i> spp.	16	13
Small millets indeterminate	44	74
<i>Celtis</i> sp.	8	2
Citrus peel	24	100
Peel fragments indeterminate	20	89
<i>Cyperaceae</i> type	28	15
cf. <i>Cyperus</i> sp.	4	3
cf. <i>Andropogonal</i> sp.	4	1
<i>Cenchrus</i> type	4	1
cf. <i>Eragrostis</i> sp.	4	2
<i>Ischaemum rugosum</i>	16	9
Large grass type 1	16	30
Small grass	8	9
<i>Polygonaceae</i> type	24	24
<i>Rubiaceae</i> fruit fragment	4	3
Indeterminate seeds	92	464

recovered from Gopalpur is one of the most interesting finds from the sites and the fragments from Gopalpur represent the second reported find of *Citrus* sp. from South Asia. They also come with an associated radiocarbon date of 3250–3050 BP, so we now have tentative evidence for the presence of *Citrus* sp. cultivation across India by c.3150 BP (Fuller et al 2018).

The phytolith evidence from Golbai Sasan and Gopalpur suggests that the latter stages of crop processing (winnowing and dehusking (Harvey and Fuller 2005)) were occurring onsite. The dominance of rice husk multi-cells panels over rice leaf/culm panels indicates that the majority of crop waste was from the spikelet and not from the rest

of the plant. It is likely that the majority of the straw was removed either during harvesting or during early stages of crop processing away from the settlement. At Golbai Sasan there appears to be an increase in these activities during the Chalcolithic period seen in the increase in the relative proportions of husk multi-cell phytoliths.

Domesticated rice, mungbean and a possible local domestication of pigeon pea

The recovery of spikelet bases from both sites allows us to assess direct evidence for rice domestication in Odisha. At Golbai Sasan and Gopalpur the majority of spikelet bases were of domestic type, corresponding with evidence from

across South Asia that both morphological and genetic domestication (i.e. the development of non-shattering heads) had taken place by c.4000 BP (Fuller et al 2010, 2016). Few wild spikelet bases were identified, suggesting that the rice cultivated had little genetic input from wild types or weedy rice cross breeding with domesticated cultivars. Domestic-type spikelet bases are found from the Neolithic levels onwards at Golbai Sasan, and there is no evidence for the domestication process from either site (i.e. a change in proportion from predominantly wild to predominantly domesticated spikelet bases), indicating that cultivated rice came into Odisha in a fully domesticated form.

One *Cajanus cajan* (pigeon pea) bean recovered from Gopalpur has been directly dated to 3345–3160 BP, the earliest recorded direct date for pigeon pea. The *Cajanus cajan* from both Gopalpur and Golbai Sasan are among earliest occurrences of this species within the archaeological record, however those reported (but not directly dated) from Piklihal (c.3850–3650 BP) and Sanaganakallu (c.3700–3450 BP) appear earlier (Fuller and Harvey 2006). The wild progenitor grows within the Eastern Ghats and so it has been suggested that this pea was independently domesticated within Odisha, perhaps as early as c.4500–4000 BP (Fuller and Harvey 2006, Harvey 2006). This is, as yet, still largely supposition, but concentrated archaeobotanical sampling of sites within the higher forested uplands of Odisha should elucidate this.

The mungbean recovered and dated from Golbai Sasan to 3349–3063 BP is the earliest *Vigna radiata* to be dated in Odisha. Other dates on *Vigna radiata* come from the Southern Peninsula (early *Vigna radiata* from Hanumantaraopeta, Sanyasula Gavi and Tekkalokota dated to c.3650 BP) and the Neolithic Ganges (early *Vigna radiata* from Mahagara is dated to 3575–3435 BP) (Fuller and Harvey 2006). It has been suggested that *Vigna radiata* may have been domesticated twice, once in South India and once in the western Himalayan foothills (ibid.; Fuller 2007), and size change data tend to support separate northwestern and southern processes. The dated bean from Golbai Sasan shows that *V. radiata/mungo*

cultivation had spread beyond its sphere of domestication to other parts of the Indian subcontinent by c.3150 BP, but whether this had arrived from the Deccan or from western India, e.g. via the Ganges, remains unclear.

The Neolithic transition in lowland Odisha

The archaeobotanical assemblages from Gopalpur and Golbai Sasan have provided a good data set from which to start exploring issues associated with the development of Neolithic societies in coastal lowland Odisha. Using parallels from other areas of the world, we can make the suggestion that the adoption of agriculture by hunter-gatherer groups already present in Odisha is very unlikely (see e.g. Bellwood 2004). The radiocarbon dates, which place the beginning of the Neolithic in Odisha at around 3500 BP, suggests that any movement by farmers/pastoralists to come into the east would have been a protracted process, taking around 1000 years. These agriculturalists may have come from the Gangetic Plains (who from c.4150 BP practised both summer and winter crop cultivation and reared domestic cattle, buffalo, sheep/goat and pig (Joglekar 2007–2008), or from the Vindhyan Region, as has been suggested based on the similarities in Black and Red Ware recovered from Chalcolithic sites (Mishra 2012). Examining archaeobotanical data for the presence of rice in South Asia prior to 3450 BP shows that the crop does not spread far outside of the Indo-Gangetic zone until 3949–3450 BP, and that the initial spread outside of this areas also occurs in environments with high water availability (either provided by monsoon rains or rivers, existing and ancient) (Figure 12). Taking this into account, it is more likely that domesticated rice moved into East India following the Ganges and within wetter environments. As in other regions of the world (e.g. Cyprus: Lucas (2014), Ireland: McClatchie et al (2014) and the Balkans: de Vareilles (2018)), species were dropped from the crop package as it moved into a different environmental and cultural area. In the case of Odisha, winter crops were dropped. Which mechanisms pushed and enabled rice agriculturalists to move into eastern

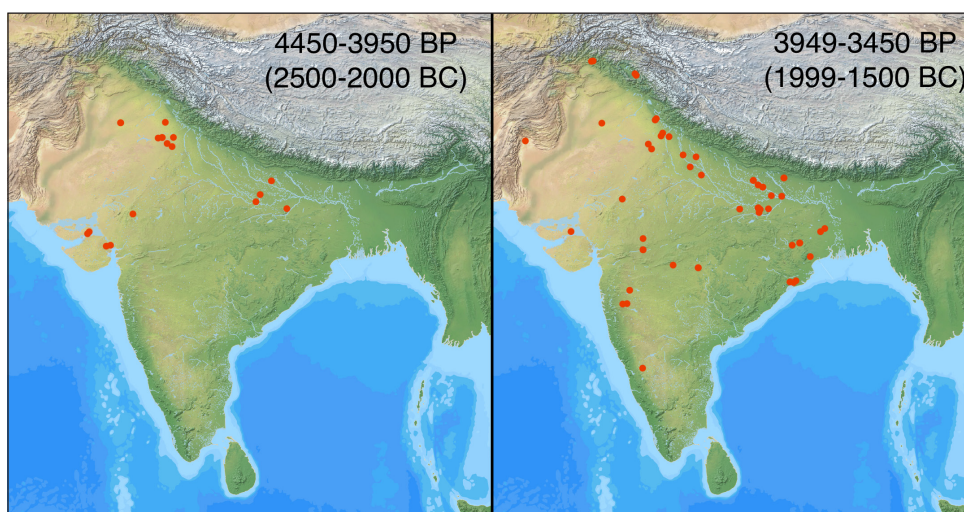


Figure 12: The location of sites with a reported presence of domesticated rice 4450–3950 BP (left) and 3949–3450 BP (right). Data from Stevens et al (2016).

India remains a mystery. Nevertheless, when rice did arrive it supported large farming settlements that lasted at least 500, and up to 1000, years. The coastal lowlands of Odisha (and the broader area of lowland east India which receives good summer monsoon rains) are particularly suitable for rice cultivation as they both retain water and receive high rainfall during the monsoons. Evidently, the rice harvest in this area was substantial enough to support significant settlement and populations, which would have been at least seasonally settled during the rice growing seasons from the early Neolithic onwards.

The seasonal sites in the highlands of Odisha, such as Bajpur and Malakhoja, which have no domesticated crop or domesticated animal remains, were likely used by hunter-gatherer groups/shifting cultivators of tubers (Fuller 2006, Harvey 2006, Kingwell-Banham and Fuller 2012). These sites are thought to have been in use throughout the Neolithic and Chalcolithic periods, as evidenced by the recovery of Red Ware (Basa 2000b, Mohanta 2002). Although extremely tentative, we can suggest that these groups would have been engaged in trade relationships with agricultural groups in the coastal lowlands, perhaps as part of the stone tool network. Several stone tool manufacturing sites have also been identified in the highlands of Odisha, important sources of dolerite in the region.

Implications for Sisupalgarh

The lack of winter crops in Neolithic and Chalcolithic Odisha suggests that farmers could have engaged in manufacturing (e.g. of stone tools, pottery and/or other goods) and/or trade during the winter months. The existence of such trade networks, and seasonally free labour, could have contributed economically to the establishment of the large, defended cities such as Sisupalgarh (Mohanty et al 2013, Mohanty and Smith 2008) that appear in the Early Historic period in Odisha c.2650 BP (Smith and Mohanty 2010) and shortly after the decline of the Eastern Wetlands Tradition. Equally, the production of a summer crop only would have allowed for a greater degree of labour mobilisation during the winter months than areas in which a winter crop was also being produced. This labour may have been utilised to construct the walled cities of eastern India. In addition, it is possible to suggest that the summer harvest of rice and pulses in this area was large enough to support the expanding populations of the Chalcolithic-Early Historic period, despite evidence for a drier climate c.3250–1800 BP (Tripathi et al 2014). In addition, evidence for *Citrus* fruits indicates that some cultivation of long-lived perennial trees was established prior to urbanisation, and this in turn implies well-established systems of land tenure that allowed for the decade long investments that tree fruit cultivation.

Conclusion

The beginning of the Neolithic in this area has been placed as early as 5500 BP based on the comparative typologies of stone tools (e.g. Dash 2000), however the radiocarbon results presented here indicate that the chronology of Odisha needs to be readjusted. The AMS radiocarbon dates taken directly from individual seeds place the beginning of

the fully sedentary agricultural Neolithic at around 3500 BP, but additional dating of individual grains from other Neolithic sites in this region will further refine the chronology.

Detailed archaeobotanical analysis can be used to examine patterns of subsistence, demography and migration and this paper has made some efforts to explore these issues in Neolithic-Chalcolithic Odisha. Further archaeobotanical work in this area of low lying east India, including parts of Andhra Pradesh, will see our understanding of Neolithic-Chalcolithic farmers develop further and will allow for broader syntheses and analyses beyond individual site level.

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Competing Interests

The authors have no competing interests to declare.

References

- Albert, R** and **Weiner, S.** 2001. Study of phytoliths in prehistoric ash layers using a quantitative approach. In: Meunier, JD and Coline, F (eds.), *Phytoliths: Applications in Earth Sciences and Human History*, 251–266. Lisse: A.A. Balkema Publishers.
- Asouti, E** and **Fuller, DQ.** 2008. *Trees and Woodlands of South India: Archaeological Perspectives*. Walnut Creek, Calif: Left Coast Press Inc.
- Basa, KK, Das, TK** and **Mohanta, BK.** 2000. Neolithic culture of Pallahara, Central Orissa. In: Basa, KK and Mohanty, P (eds.), *Archaeology of Orissa*, 264–284. Pratibha Prakashan.
- Behera, A.** 2013. Newly discovered archaeological sites in coastal Odisha. *Odisha Review*, 61–65. May.
- Behera, PK.** 2000a. Neolithic culture complex of Bon-aigarh, Orissa. In: Basa, KK and Mohanty, P (eds.), *Archaeology of Orissa*, 222–263. Pratibha Prakashan.
- Behera, PK.** 2000b. Excavations at Khameswaripali – a proto Historic settlement in the middle Mahandi valley, Orissa: A preliminary report. *Prāgdhārā*, 11: 13–34.
- Bellwood, P.** 2004. *First Farmers: The Origins of Agricultural Societies*. Malden, MA: Wiley-Blackwell.
- Bisht, RS, Dorje, C** and **Banerji, A.** (eds.) 1993–1994. *Indian Archaeology – a review*. Archaeological Survey of India. Available at: http://asi.nic.in/asi_publication_indian_archaeology.asp.
- Cappers, RTJ, Neef, R** and **Bekker, RM.** 2009. *Digital Atlas of Economic Plants*. Barkhuis.
- Castillo, C.** 2013. *The Archaeobotany of Khao Sam Kaeo and Phu Khao Thong: The Agriculture of Late Prehistoric Southern Thailand*. PhD Thesis. UCL (University College London). Available at: <http://discovery.ucl.ac.uk/id/eprint/1414947>.

- Castillo, CC, Tanaka, K, Sato, Y-I, et al.** 2016. Archaeogenetic study of prehistoric rice remains from Thailand and India: Evidence of early japonica in South and Southeast Asia. *Archaeological and Anthropological Sciences*, 8(3): 523–543. DOI: <https://doi.org/10.1007/s12520-015-0236-5>
- Dash, RN.** 2008. *Archaeology history and culture of Orissa*. Pratibha Prakashan.
- De Vareilles, A.** 2018. *Deeply set roots: An archaeological perspective on the origins of crop husbandry in the western Balkans*. PhD Thesis. UCL (University College London).
- Eichhorn, B, Neumann, K and Garnier, A.** 2010. Seed phytoliths in West African Commelinaceae and their potential for palaeoecological studies. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 298(3–4): 300–310. DOI: <https://doi.org/10.1016/j.palaeo.2010.10.004>
- Fuller, DQ.** 2003. African crops in prehistoric South Asia: A critical review. In: Neumann, K, Butler, A and Kahlheber, S (eds.), *Food, Fuel and Fields. Progress in African Archaeobotany*, 239–271. Cologne: Heinrich-Barth-Institut.
- Fuller, DQ.** 2006. Agricultural origins and frontiers in South Asia: A working synthesis. *Journal of World Prehistory*, 20: 1–86. DOI: <https://doi.org/10.1007/s10963-006-9006-8>
- Fuller, DQ.** 2007. Contrasting patterns in crop domestication and domestication rates: Recent archaeobotanical insights from the Old World. *Annals of Botany*, 100(5): 903–924. DOI: <https://doi.org/10.1093/aob/mcm048>
- Fuller, DQ.** 2011. Finding plant domestication in the Indian subcontinent. *Current Anthropology*, 52(suppl. 4). DOI: <https://doi.org/10.1086/658900>
- Fuller, DQ, Castillo, C, Kingwell-Banham, E, et al.** 2018. Charred pummelo peel, historical linguistics and other tree crops: Approaches to framing the historical context of early Citrus cultivation in East, South and Southeast Asia. In: Fiorentino, G and Zech-Matterne, V (eds.), *AGRUMED: Archaeology and history of citrus fruit in the Mediterranean: Acclimatization, diversifications, uses*. Collection du Centre Jean Bérard. Naples: Publications du Centre Jean Bérard. Available at: <http://books.openedition.org/pjcb/2173>.
- Fuller, DQ and Harvey, EL.** 2006. The archaeobotany of Indian pulses: Identification, processing and evidence for cultivation. *Environmental Archaeology*, 11(2): 219–246. DOI: <https://doi.org/10.1179/174963106x123232>
- Fuller, DQ, Qin, L, Zheng, Y, et al.** 2009. The Domestication Process and Domestication Rate in Rice: Spikelet Bases from the Lower Yangtze. *Science*, 323(5921): 1607–1610. DOI: <https://doi.org/10.1126/science.1166605>
- Fuller, DQ, Sato, Y-I, Castillo, C, et al.** 2010. Consilience of genetics and archaeobotany in the entangled history of rice. *Archaeological and Anthropological Sciences*, 2(2): 115–131. DOI: <https://doi.org/10.1007/s12520-010-0035-y>
- Fuller, DQ, Weisskopf, A and Castillo, C.** 2016. Pathways of Rice Diversification across Asia. *Archaeology International*, 19. DOI: <https://doi.org/10.5334/ai.1915>
- Harvey, EL.** 2006. *Early agricultural communities in northern and eastern India: An archaeobotanical investigation*. PhD Thesis. University of London. Available at: <http://discovery.ucl.ac.uk/1444783/>.
- Harvey, EL and Fuller, DQ.** 2005. Investigating crop processing using phytolith analysis: The example of rice and millets. *Journal of Archaeological Science*, 32(5): 739–752. DOI: <https://doi.org/10.1016/j.jas.2004.12.010>
- Hubbard, RN and al Azm, A.** 1990. Quantifying preservation and distortion in carbonized seeds; and investigating the history of friké production. *Journal of Archaeological Science*, 17(1): 103–106. DOI: [https://doi.org/10.1016/0305-4403\(90\)90017-Y](https://doi.org/10.1016/0305-4403(90)90017-Y)
- Joglekar, PP.** 2007–2008. A fresh appraisal of the animal based subsistence and domestic animals in the Ganga Valley. *Prāgdhārā*, 18: 309–322.
- Joglekar, PP and Patnaik, JK.** 2016. Faunal remains from the Chalcolithic contexts at Suabarei, District Puri, Odisha. *Bulletin of the Deccan College Research Institute*, 76: 29–44.
- Kar, SK.** 1995–1996. Further exploration at Golpalpur, Orissa. *Puratattva*, 26: 105–106.
- Kar, SK, Basa, KK and Joglekar, PP.** 1998. Explorations at Gopalpur, District Nayagarh, Coastal Orissa. *Man and Environment*, 23: 107–114.
- Kar, SK and Joglekar, PP.** 2000. Gopalpur; A Neolithic-Chalcolithic site in coastal Orissa. In: Basa, KK and Mohanty, P (eds.), *Archaeology of Orissa*, 368–391. Delhi: Pratibha Prakashan.
- Kingwell-Banham, E.** 2015. *Early rice agriculture in South Asia. Identifying cultivation systems using archaeobotany*. PhD Thesis. UCL (University College London). Available at: <http://discovery.ucl.ac.uk/1470410/>.
- Kingwell-Banham, E and Fuller, DQ.** 2012. Shifting cultivators in South Asia: Expansion, marginalisation and specialisation over the long term. *Quaternary International*, 249: 84–95. DOI: <https://doi.org/10.1016/j.quaint.2011.05.025>
- Kingwell-Banham, E, Petrie, C and Fuller, DQ.** 2015. Early agriculture in South Asia. In: Barker, G and Goucher, C (eds.), *The Cambridge World History Volume 2: A World with Agriculture, 12,000 BCE–500 CE*, 261–288. Cambridge: Cambridge University Press. DOI: <https://doi.org/10.1017/CBO9780511978807.011>
- Lu, H, Zhang, J, Wu, N, et al.** 2009. Phytoliths Analysis for the Discrimination of Foxtail Millet (*Setaria italica*) and Common Millet (*Panicum miliaceum*). *PLoS ONE*, 4(2): e4448. DOI: <https://doi.org/10.1371/journal.pone.0004448>
- Lucas, L.** 2014. *Crops, culture, and contact in prehistoric Cyprus*. BAR international series. 2369. Archaeopress.
- McClatchie, M.** 2014. Archaeobotany of Agricultural Intensification. In: Smith, C (ed.), *Encyclopedia of Global Archaeology*, 310–318. New York, NY: Springer New York. DOI: https://doi.org/10.1007/978-1-4419-0465-2_2262

- Mishra, LK.** 2012. Black and Red Ware pottery in Odisha: A study in its distribution pattern and cultural context. *IHC: Proceedings, 73rd Session*, 1187–1202.
- Mohanta, B.** 2002. *Neolithic and post-Neolithic cultures of Northern Orissa (with special reference to Mayurbhanj and Keonjhar Districts)*. PhD Thesis. Utkal University, Bhubaneswar, India.
- Mohanty, B.** 1994. Golbai: A new horizon in Orissan archaeology. *Orissa Historical Research Journal*, 39(1): 30–32.
- Mohanty, P.** 2000. Mesolithic culture and ethnography of Keonjhar District, Orissa. In: Basa, KK and Mohanty, P (eds.), *Archaeology of Orissa*, 114–152. Pratibha Prakashan.
- Mohanty, RK, Joglekar, PP, Thakuria, T,** et al. 2012. Preliminary report on exploration at Golbai Sasan, Talapada and the surrounding area, Dist. Khurda, Odisha, 2010–11. *Bulletin of the Deccan College*, 72–73: 153–166.
- Mohanty, RK and Smith, ML.** 2008. *Excavations at Sisupalgarh*. New Delhi: Indian Archaeology Society.
- Mohanty, RK, Smith, ML and Thakuria, T.** 2013. Excavations at Sisupalgarh 2009: The Northern Gateway and Activity Areas outside the Rampart. *Man and Environment*, 38(1): 55–65.
- Morrison, KD and Junker, LL.** 2002. *Forager-traders in south and southeast Asia long-term histories*. Cambridge: Cambridge University Press. DOI: <https://doi.org/10.1017/CBO9780511489631>
- Piperno, DR.** 2006. *Phytoliths: A comprehensive guide for archaeologists and paleoecologists*. Oxford: AltaMira Press.
- Rosen, AM.** 1995. Phytolith evidence for Mousterian and Epipalaeolithic plant exploitation at Hayonim Cave, Israel. *Paper presented at the 60th Annual Meeting of the Society of American Archaeology*. Minneapolis, Minnesota.
- Sinha, BK.** 2000. Golbai: A protohistoric site on the coast of Orissa. In: Basa, KK and Mohanty, P (eds.), *Archaeology of Orissa*, 322–355. Delhi: Pratibha Prakashan.
- Smith, M and Mohanty, RK.** 2010. Investigations at the Early Historic city of Sisupalgarh, India 2005–7. In: *Proceedings of the 19th Meeting of the European Association of South Asian Archaeology, Ravenna, Vol. II: Historic Periods*, 337–344. BAR, Archaeopress.
- Stevens, C, Murphy, C, Roberts, R, Lucas, L, Silva, F and Fuller, D.** 2016. Between China and South Asia: A Middle Asian corridor of crop dispersal and agricultural innovation in the Bronze Age. *The Holocene: A major interdisciplinary journal focusing on recent environmental change*, 1541–1555. DOI: <https://doi.org/10.1177/0959683616650268>
- Thapar, BK.** 1961–62. Excavations at Kuchai, District Mayurbhanj. *Indian Archaeology 1961–62-A Review*, 36.
- Tripathi, S, Basumatary, SK, Singh, VK,** et al. 2014. Palaeovegetation and climate oscillation of western Odisha, India: A pollen data-based synthesis for the Mid-Late Holocene. *Quaternary International*, 325: 83–92. DOI: <https://doi.org/10.1016/j.quaint.2013.12.005>
- Tropicos.org** [Online database]. Accessed 2018. *Flora of Pakistan*. Missouri Botanical Garden, St. Louis, MO, USA. Available from: <http://www.tropicos.org>.
- Weisskopf, AR and Lee, G-A.** 2016. Phytolith identification criteria for foxtail and broomcorn millets: A new approach to calculating crop ratios. *Archaeological and Anthropological Sciences*, 8(1): 29–42. DOI: <https://doi.org/10.1007/s12520-014-0190-7>

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