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Pearl millet and iron in the West African Sahel: Archaeobotanical investigation at Tongo Maaré Diabal, Mali

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ABSTRACT

Recent archaeobotanical analysis revealed that the botanical remains from the site of Tongo Maaré Diabal (Mali) are composed primarily of pearl millet remains (up to 85%). Contemporaneous West African sites (500–1200 Cal AD) usually display more diverse patterns, especially by the end of this period. Indeed, contemporary urban sites of the West African Sahel often comprise combined and diversified farming systems of millet (*Pennisetum glaucum*), African rice (*Oryza glaberrima*), sorghum (*Sorghum bicolor)*, *Echinochloa* sp. and fonio (*Digitatia exilis*). This article seeks to explain the near-exclusive focus of Tongo Maaré Diabal's agricultural economy on millet, particularly with regard to the site's status as a settlement of iron workers.

1. Introduction

The site of Tongo Maaré Diabal (TMD) is a habitation mound of approximately 3 to 4.5 m in elevation and 9 ha in extent. TMD was occupied from 500 CE to 1150 CE and is thus contemporary with a major expansion of urbanism in the Middle Niger as well as being situated on the periphery of the two largest known West African polities of the era: Ghana/Wagadu (c.AD 400–1100) and Kawkaw/Gao (c.AD 700–1100) (Gestrich and MacDonald, 2018). The site is important as part of the mid to late first-millennium AD settlement landscape of this semi-arid region which was composed largely of specialist iron workers. Local conditions have also facilitated the excellent preservation of architectural, artefactual and subsistence remains, all excavated in context. The present article considers the site's unique agricultural economy against its settlement history, environment and the development of cereal agriculture in the West African Sahel (see Figs. 1–4).

TMD is one of a dozen iron-working settlements of the same time period located at the eastern edge of the Inland Delta's ancient floodplain near the modern town of Douentza in a sandy flatland between two escarpments, the Bandiagara and the Dyoundé/Gandamia (Gestrich and MacDonald, 2018). This area is part of the "Gourma des Monts" region on the western margin of the Sahelian Gourma region which fills the area south of the Niger Bend. Currently, the narrow natural corridor in which the site lies is a major crossroads that connects the northern Bandiagara and the rich grain-growing plains of the Gondo region with the Inland Niger Delta (IND) (Gallais, 1975). The average annual rainfall around Douentza in recent decades was ca. 400 mm (de Bruijn and van Dijk, 1995). The peak rainy season in Douentza lasts from June through September, with May being a liminal period of occasional light showers. This is roughly comparable to the annual rhythm of the Inland Niger Delta – though without the ecological benefits of an adjoining floodplain or waterway. From 300 BCE to 300 CE, the past paleoclimatic evolution in the area and in the IND was characterised by an unstable, dry climate with the desertification of the Azawad (in the north of the IND). This system was followed by a wet optimum with higher precipitation levels than previous periods. The optimum humid conditions are thought to have been reached around 1000 CE. After this peak, the climate deteriorated quickly with very rapid oscillations, often within <30 years, between large flooding events to severe drought episodes. Around 1450 CE Lake Chad was completely dry and the Niger River had a very unstable flow rate with some very large flooding leading to extensive erosion within a very arid and dry landscape (McIntosh, 1998, 2005; Maley & Vernet, 2015).

In the past century Douentza's population and economy has been diverse with transhumant Peulh (Fulbe) and Tamasheq pastoralists and sedentary farming groups, the most numerous of which are Dogon and

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Songhai (Gallais, 1975). The town's crossroads position also means it is an important trading centre, attracting a diverse population from across West Africa. However, it is unlikely that the area was so ethnically diverse in the first millennium AD. According to local oral traditions collected by one of the authors between 1993 and 1996 (KCM), the foundation of modern Douentza (a Fulbe corruption of dogo nsan, meaning 'younger son' in Bambara), dates back to the mid-18th century, when the area was claimed by the Bambara state of Segu. There was then an Islamic 're-foundation' of the town when it was subsequently claimed for the Masina Caliphate in 1828 by Nouhoum Ejejguere, a prominent Marabout linked to Sékou Ahmadou. It subsequently fell under the Fulbe chiefdom of Boni, established later in the 19th century. These incursions are recent, set against a background of earlier Tellem/Dogon regional settlements and Songhai imperial incursions (ca. CE 1450–1600). Today the Dogon, Bambara and Songhai of the region cultivate millet primarily, with some sorghum, *Echinochloa* sp. and fonio, which are grown locally without irrigation using rains from the summer wet season. They also keep sheep, goats and domestic fowl. The local Peulh are the primary keepers of livestock, but are increasingly cultivating millet as well (the cattle herds of the *Cercle de Douentza* being reduced by the great droughts from ca.300,000 to only 62,000 in 1985; de Bruijn and van Dijk, 1995: 46).

2. Excavations at Tongo Maaré Diabal

Between 1993 and 1996 MacDonald undertook initial excavations at TMD, uncovering a continuous 650-year sequence of domestic life (AD 500–1150) over three 4 by 4 m excavation units. The excavation units by Gestrich in 2010 opened a much larger surface spanning two domestic and iron-working compounds dating to the time of the site's abandonment. The extensive evidence of iron-smelting and working, not only at TMD, but at most sites in the immediate vicinity, hints at a potential proto-industrial development of iron-production in the region (Gestrich, 2013). This chimes with increasing evidence that, in the period between around AD 500 and 1500, some areas around the Inland Niger Delta were specialising in large-scale iron production (Gestrich & MacDonald, 2018). Also, these excavations exposed some of the best-preserved examples of early Sahelian earthen architecture with mud-brick walls remains often still extant to a height of a metre or more. *In situ* well-preserved artefacts were also found including>30 intact pots, terracotta statuettes and more exceptionally some carbonised textile remains made of *Hibiscus* sp. (Gestrich and MacDonald, 2018).

The archaeological stratigraphy of the site is divided into five occupation horizons of superimposed earthen buildings.

2.1. Horizon 1 – AD 500–650 (units A, B & C)

During the initial occupation there are curvilinear structures of packed coursed earth associated with a succession of open-air, shallow, ashy hearths to the north (Fig. 4) (Gestrich and MacDonald, 2018). Similar and contemporaneous coursed earth circular houses are well-known in Sahelian contexts (see MacDonald, 2020), especially from Kirikongo (Dueppen, 2012; Gallagher and Dueppen, 2019), Oursi Hubeero (Petit et al., 2011) (Burkina Faso) and Birnin Lafiya (North Benin, Champion, 2019; Haour, 2018).

2.2. Horizon 2 – AD 650–750 (units A, B & C)

Horizon 2 is characterised by a shift to rectilinear structures made both in courses of packed earth and loaf-shaped mudbrick. Continuity has been suggested as the new structures are superimposed over the earliest circular rooms. The bipartite division of the space seems to indicate the presence of two separate domestic compounds, one in the north (in unit A) and one in the south (in unit B) (Gestrich and MacDonald, 2018).

2.3. Horizon 3 – AD 750–900 (units A, B & C)

Two features were exposed. First in the north part with 120 cm depth of dense iron working remains, mainly charcoal and iron working slag, points to the presence of a blacksmith's workshop (forge). From this point on, the compound appears to have been occupied by a succession of iron-working specialists over a 400-year period. Meanwhile, to the south a cluster of features shows evidence of a potter's workshop: nine intact vessels associated with a carbonised *Hibiscus* sp. potters mat, fragments of raw kaolinite, polished red ochre and lumps of raw clay. The presence of those two complementary workshops – potter's and blacksmith's – correspond to the present day gendered division of labor within the same lineage and same endogamous specialist group, whereby women are the potters and men are the blacksmiths (Gestrich

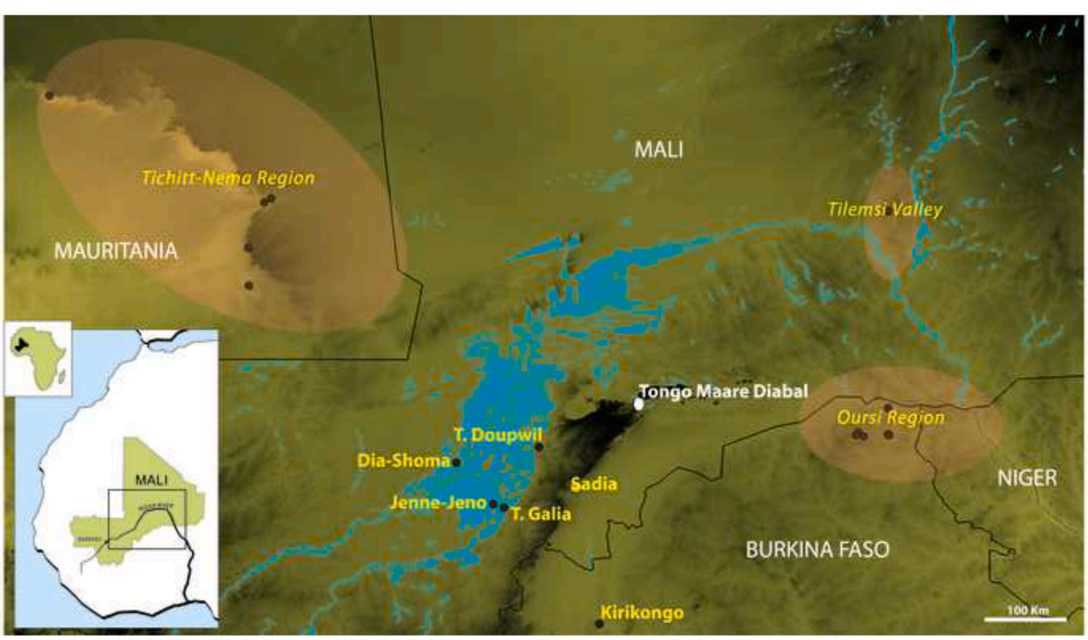

Fig. 1. Map of the sites cited in the text (Based on the database of Champion, 2019). COLOR.

and MacDonald, 2018).

2.4. Horizon 4 – AD 900–1000 (units A, B & C)

Horizon 4 is the continuation of Horizon 3, with some evidence of repairs on the south wall and remains of a terracotta equestrian statuette found in a pit before the doorway of the southeastern structure.

2.5. Horizon 5 – CE 1000–1150 (units A, B,C, D, E, F, and G)

In 2010, Gestrich opened a larger area, units E (9 × 5m) and F (7 × 5 m) just to the northwest of units A,B and C, with only the uppermost occupation horizon being excavated (Gestrich, 2013). With the continuation of the blacksmith's workshop and the find of a putative forge, units A and B gave evidence of three new small mudbrick rooms (Gestrich and MacDonald, 2018). In total, within this exposure, twelve rectilinear earthen structures were discovered. The find of hearths, burnt walls and floors associated with large amounts of charcoal, iron objects and slag attest to the presence of another working area for blacksmiths. Exposure 2, unit G, a 7x4m unit located in the eastern part of the site also shows very similar features made up of five contiguous mud-brick buildings (Gestrich and MacDonald, 2018).

In conclusion, the architectural division of space at TMD strongly suggests that the settlement was divided into long-lived compounds, presumably associated with lineages and comparable to documented settlement organisation in neighbouring regions (Walicka Zeh, 2000). Those compounds were built with two different techniques: loaf-shaped mud bricks and coursed earth (Gestrich and MacDonald, 2018).

3. Archaeobotany: Materials and methods

During excavations, the team systematically collected archaeobotanical samples whereby almost each context was sampled, except the wall remains. The average amount of soil collected was 5 L for each

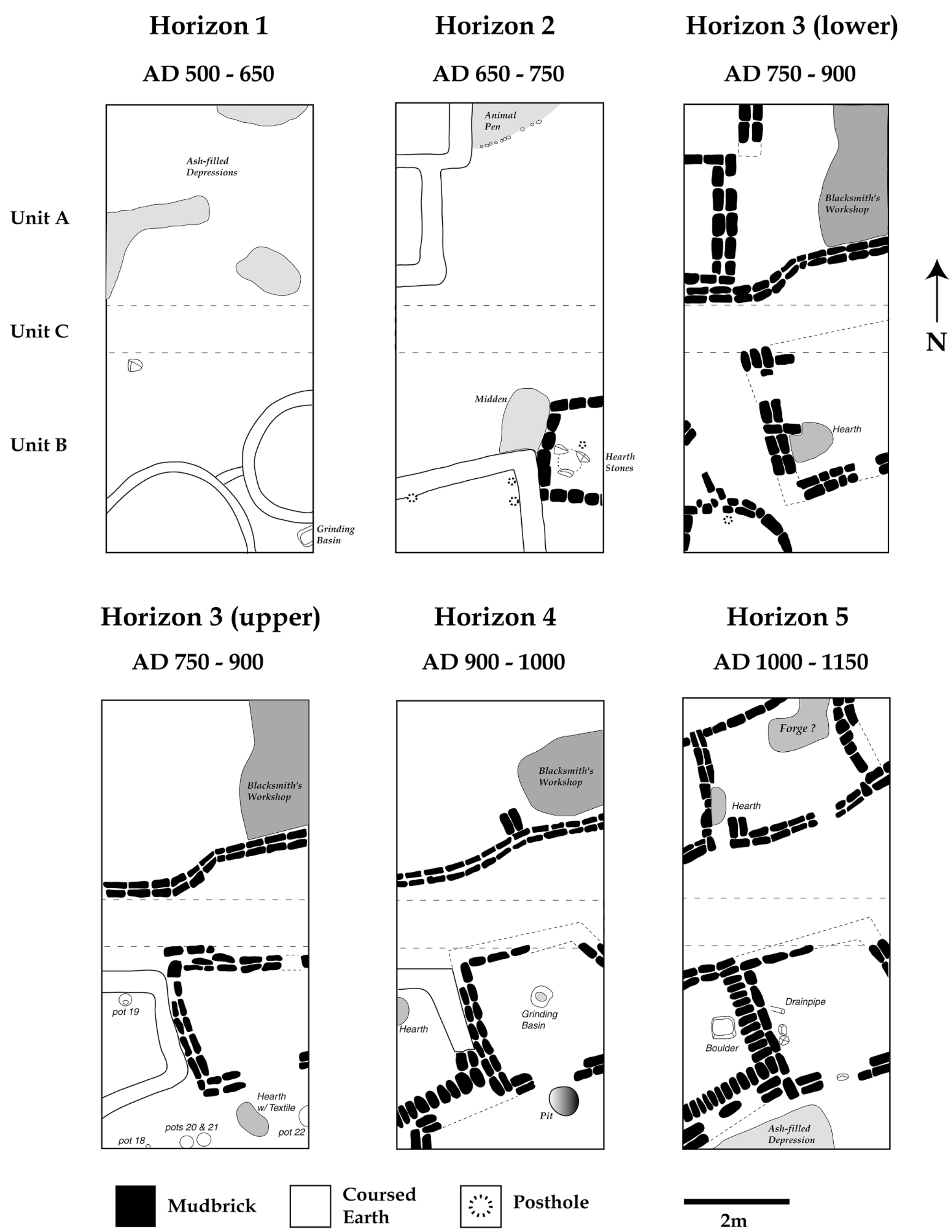

Fig. 2. The architectural sequence in units A, B and C (Plan by K. MacDonald).

Fig. 3. Excavations of units A & B at Tongo Maaré Diabal in 1995. Excavations would proceed for a further 1.5 m of depth (Photo K. MacDonald). COLOR.

sample, but some smaller contexts, such as hearths, were collected in their entirety.

In total, around 496 L of archaeological soil matrix coming from 114 samples was processed by bucket flotation directly in the field. Flotation is a method widely used to separate materials of different density and is the most common way of recovering charred plant remains from archaeological contexts, as soil particles sink,and charred plant remains float (Nesbitt, 1995). Whether mechanical (using a flotation drum or machine) or manual (using buckets), the basic principle is to mix the sediment with water to wet it and break it apart. The buoyant material — including the plant macro-remains — is then poured off and collected in a fine mesh (Fuller, 2008; Champion and Fuller, 2019). Each sample was sieved into five size fractions: >4mm, 2–4 mm, 1–2 mm, 0.5–1 mm, <0.5 mm. The $\geq$ 0.5 mm sub-samples were sorted for charred plant elements such as seeds, fruits, nutshell and parenchyma with the aid of a low-power stereomicroscope (10–40x).

Identification of cereals, chaff, pulses, millets, weeds, nuts and fruits were made by comparing taxa with specimens in the modern reference collection housed at the Institute of Archaeology, University College London. Photographs and descriptions of identification from a variety of published literature were also used (Fuller, 2003; Fuller and Harvey, 2006; Nixon et al., 2011; Murray, 2000, 2007a, 2007b; D'Andrea et al., 2001). For all the samples analysed, whole vegetal items were recorded by count in a list of taxa, from which tables of relative frequency were constructed, and ubiquity calculated (Table 1, Figs. 5 and 6). The relative frequency is the percentage of total seed count (Fig. 5). It can be calculated by sample, phase, trench or site as necessary. In addition, every taxon was logged in a ubiquity table. The ubiquity is the number of samples in which a taxon is present as a percentage of the total number of samples (Fig. 6).

4. Archaeobotany: Results

Each of the 114 collected samples analysed here contained non-wood charcoal plant remains. In total around 18,385 plants remains were recorded for an average density of 37 remains (excluding charcoal) per litre of soil. So far, this is the highest density of archaeobotanical finds found in West Africa (Champion, 2019). Almost all of these comprise carbonised seeds and are included in the counts in Table 1, Figs. 5 and 6, that provide frequency and ubiquity.

The archaeobotanical results indicate that the principal plant remains from TMD are domesticated pearl millet, accounting for around 85% frequency of the assemblage (15,480 grains and involucres) and are present in every sample (100% ubiquity). The grains consumed at TMD comprise mainly pearl millet and wild millet species (*Digitaria* sp.). The sporadic consumption of fruits of local trees (*Sclerocarya birrea* and *Vitex* sp.) is also indicated - these are recovered in lower quantity (3% frequency in average). The proportion of plant remains at TMD appears little changed throughout the occupation. The introduction of *Sorghum bicolor* is noticed from Horizon 3 (750-900AD) into the abandonment phase (1000–1150 CE), but in very small quantities (43, of 18,385 total plant remains).

Results of a preliminary study on wood charcoal by Dirk Uebel (unpublished) are summarised in Gestrich and MacDonald, (2018). Together with the macrobotanical results they indicate that Tongo Maaré Diabal was situated in a savanna mosaic of fields and fallows. Tree taxa such as *Faidherbia albida*, *Balanites aegyptiaca* and *Schlerocarya birrea* likely provided useful products (fruits/seeds/leaves) for human and animal consumption and thus were likely protected within cultivated fields, as they are today. *Guiera senegalensis* and *Combretum glutinosum* are present in the charcoal assemblage. These tree species recover well after cutting and are therefore seen as indicative of fallow fields (Höhn and Neumann, 2012). Tree taxa such as *Balanites aegyptiaca*, *Celtis integrifolia*, *Prosopis africana* and *Khaya senegalensis* also point to the presence of gallery forests, presumably along seasonal drainages. Neither grains nor wood charcoal analysis identified temporal trends in the botanical record, suggesting that TMD was founded within an already established mosaic of fields and fallows and that metallurgical activity evidenced at Tongo Maaré Diabal did not completely eliminate gallery forests in the vicinity of the site.

5. Livestock, manuring practices and stable isotopes in pearl millet

In addition to cultivation, it is evident from the beginning of occupation at the site that its inhabitants were also small stock keepers. About two-thirds of Bovid remains from each Horizon at TMD comprise sheep and goat (with the latter predominating) (Gestrich and MacDonald, 2018). Cattle are absent or scarce at TMD until post AD 750, when either the inhabitants started keeping small herds themselves or, more likely, began to interact seasonally with pastoralists. The notion of separate pastoral communities is supported by two factors. First is the site's location at the outer edge of a shallow seasonally inundated plain, as supported by geomorphology and fish remains, which may have precluded the presence of cattle year around in wetter years (Gestrich and MacDonald, 2018). The other is evidence for ephemeral occupations around TMD at localities like Orowal Débéré which may have been pastoral camps (Gestrich, 2013). Other domestic animals present at TMD throughout its sequence include both chickens and guineafowl, as well as dogs. As we shall see below, limited evidence suggests that manuring did not begin around the site until cattle herds were regularly present in the area.

Nitrogen isotopic composition analysis has been used on charred wheat and barley grains to reconstruct manuring practices at archaeological sites across Europe and Western Asia (Bogaard et al., 2013; Styring et al., 2017). A pilot study on pearl millet ^{15}N isotopes was carried out with grains from TMD to test the same methodology for West

Africa. Pearl millet grains from 15 archaeological contexts (7 to 15 grains by context) spanning Horizon 1 to 5 (500–1150 CE) were sampled from this site for Nitrogen (δ^{15}N) isotopic composition analysis by Amy K. Styring from Frankfurt University. These were analyzed alongside modern comparative control data from three modern pearl millet fields, which were also subjected to carbonization experiments (Styring et al., 2019) These modern comparative data were collected in Senegal within a similar climatic zone. Modern data suggest that lower manuring results in a mean δ^{15}N of ~-4.0‰ but ranging as high as −3‰ or more, while moderate levels of manuring resulted in a mean δ^{15}N of ~-4.5‰ but ranging to lower than −6‰. As the nitrogen isotope values of millet grains from Tongo Maaré Diabal fell mostly between −4.5‰ and −6.5‰ throughout the occupation, this was inferred to indicate modern levels of manuring fields, such as with household waste and/or manure from animals grazing after harvest (Styring et al., 2019). This would have been practiced alongside periods of fallowing as already inferred from the woody taxa present.

There is no obvious change in pearl millet δ15N values through time (Styring et al., 2019). Nevertheless, it is interesting that the only pearl millet grain sample classified as receiving high levels of manure derived from a context post-dating A.D. 750, suggesting that there might have been some tendency for agricultural intensification during the occupation of the site. As noted above, this period is also when faunal evidence for cattle increases. What is clear is that there is no decrease in manure application during the occupation of the site, implying strategic management of resources to ensure continuing crop productivity and soil fertility. This would have been particularly important, since the predominance of pearl millet would seem to preclude crop rotation or green manuring with legumes as alternative strategies of replenishing soil nutrients. Equally, the lack of increase in pearl millet δ15N values during the 650-year occupation of the site implies that manure/household waste was added relatively sporadically, rather than applied to the same plots annually (Styring et al., 2019). This continuity in manuring practice reflects the general lack of change in the botanical and charcoal assemblages but implies overall agricultural sustainability.

6. Discussion: Iron working and TMD's subsistence economy

The combined results from macro-botanical, isotopic and wood charcoal analyses show a very similar pattern, largely dominated by pearl millet (*Pennisetum glaucum*) cultivation with little significant change through time except for notional increases in the presence of cattle herds and manuring post AD 750. The high pearl millet involucre base numbers (10760 involucres for 4720 grains, representing 69% of the pearl millet assemblage, Table 1) suggest that pearl millet grain was stored as full panicles and these were threshed daily as and when needed. The bristle and involucre bases are usually separated from the grain during the threshing and winnowing steps of crop processing. This suggests it was processed in close proximity to household hearths or fires that were then used for rubbish disposal, and were therefore probably close to the household compounds.

As described, TMD has strong evidence for iron working. While the primary ore to iron reduction took place elsewhere in the adjoining countryside, a refining stage appears to have taken place at the site and the presence of slag waste from forge activity indicates that TMD was largely a smithing site (Humphris, 2013). Evidence of primary smelting in the form of furnaces and slag mounds was found at the nearby sites of Boata and Tangu 2 (Gestrich and MacDonald, 2018). One of the excavated bowl furnaces from Boata yielded a date of 251–620 cal. AD (GX-21726), possibly making it contemporaneous with TMD's early phase.

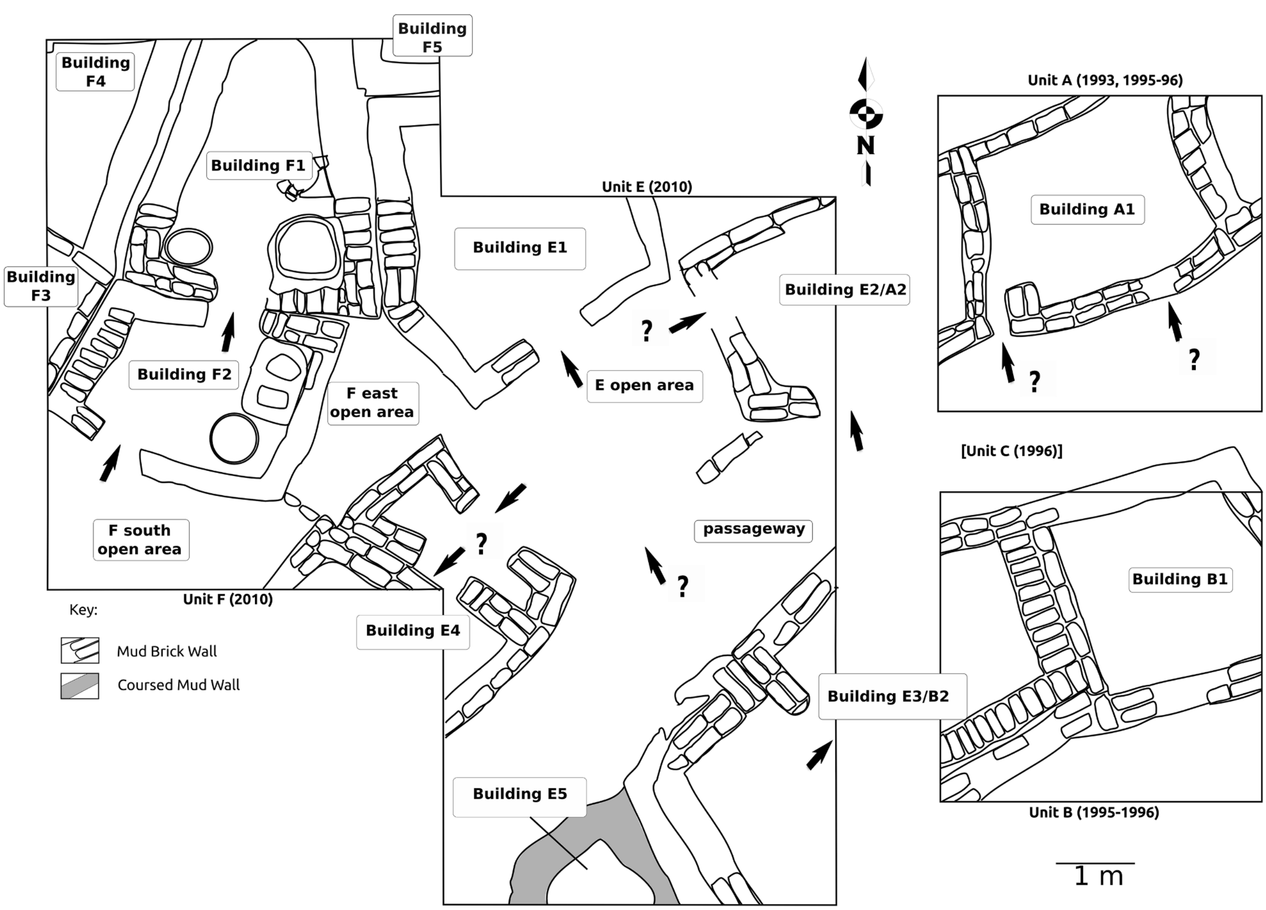

Fig. 4. Plan of Horizon 5 (CE 1000–1150) in exposure 1 (Units A, B, C, E and F)(Plan by N. Gestrich).

Table 1
Number of items recovered, Frequency and (Ubiquity) for the main crops at Tongo Maaré Diabal by Horizon. First line is the total number of items and second line gives frequency followed by (ubiquity). Chaff proportion is the number of chaff (Spikelets, bristles and/or involucres) in comparison with the total number of grains and chaffs within the same species.

Date AD	500–650	650–750	750–900	900–1000	1000–1150	Total
# samples (volume)	**4 (20)**	**16 (45)**	**19 (100)**	**21 (105)**	**54 (226)**	**114 (496)**
Pennisetum glaucum	115 + 272=	1625 + 255=	4159 + 1142=	2848 + 1803=	2013 + 1248=	10760 + 4720=
Chaff + grain = Total	**387**	**1880** 94% (100%)	**5301**	**4651**	**3261**	**15,480**
Frequency (Ubiquity)	87% (100%)		85% (100%)	85% (100%)	85% (100%)	85% (100%)
involucre proportion	30%	86%	78%	61%	61%	69%
Sorghum bicolor			9 + 5 = **14**	2 + 14 = **16**	0 + 13 = **13**	11 + 32 = **43**
Chaff + grain = Total	–	–				
Frequency (Ubiquity)			<1% (5%)	<1% (14%)	<1% (7%)	<1% (14%)
Chaff proportion			64%	12%	0%	25%
Tree/bush (fruit)	7	17	308	17	26	375
	1.6% (50%)	<1% (6%)	5% (3%)	<1% (14%)	<1% (18%)	2% (16%)
Vigna sp.	–	–	7	15	2	24
			<1% (5%)	<1% (5%)	<1% (4%)	<1% (3%)
Total Number	456	2146	6323	5372	4088	18,385
Density (Item/litre)	22.8	48	63	51	18	37

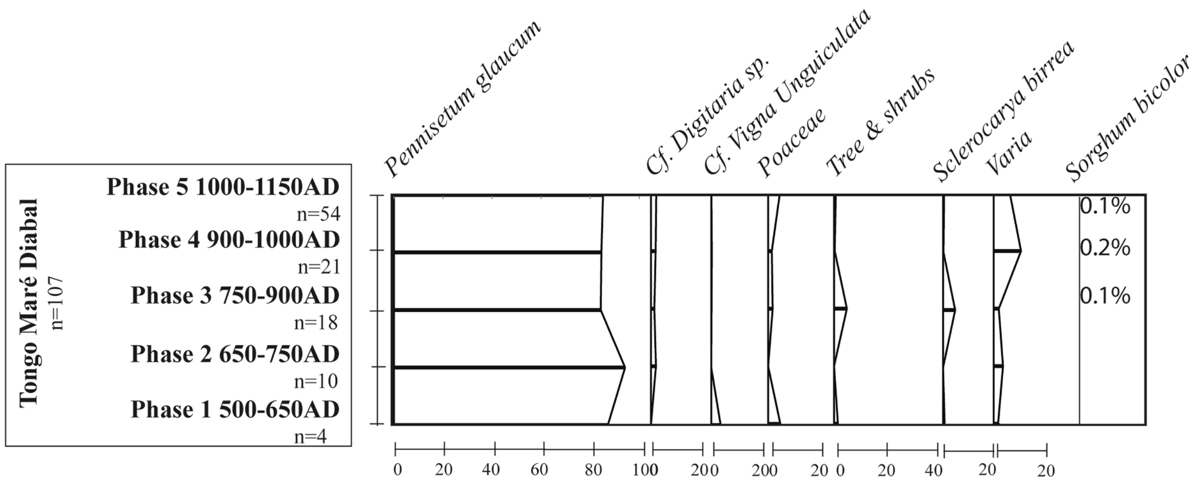

Fig. 5. Frequency (% of remains of a species compared with the whole period assemblage) for the archaeobotanical dataset at TMD, including 107 samples (n = number of samples by phase).

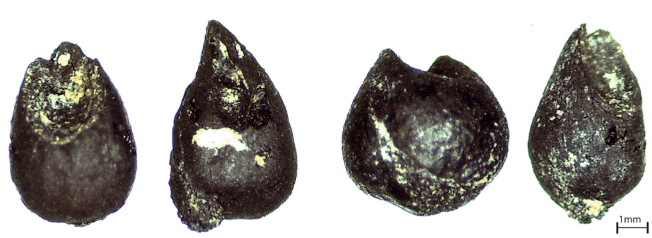

Fig. 6. Pearl millet caryopsis from Tongo Maaré Diabal phase 5.

The most peculiar point about TMD is that the site, and the surrounding area, appear to have been dedicated to metallurgy c. AD 500–1100 and it was not a segregated activity. This fact goes against current expectations: across most of West Africa, ethnographic, historic, and even archaeological studies, have clearly shown that peoples involved in ore to iron bloom reduction are often socially segregated. They either live in separate areas of a larger settlement or in specialised blacksmith's hamlets. The huge quantities of smithing slag at Tongo Maaré Diabal suggest that iron production was beyond the needs of local domestic activities and part of a wider proto-industrial iron production network, trading rough iron blooms or bars, in the Inland Niger Delta supra-regional network (Humphris, 2013; Gestrich and MacDonald, 2018). The growth of urban sites, such as Jenné-Jeno and Dia, and their hinterlands required massive iron quantities for the growth of farming populations. Moreover, after the fourth century AD Jenné-Jeno shows no further evidence of iron smelting (ore to iron bloom reduction) even if smiths' activities (iron bloom shaping) are still observable. This has led the excavators to suggest a shift from locally produced to imported iron (McIntosh & McIntosh, 1980; McIntosh, 1998, 2005). Thus, Gestrich and MacDonald (2018) suggest that Tongo Maaré Diabal is an example of an iron production area of either state-emplaced or entrepreneurial blacksmiths supplying growing populations and urbanization in the Inland Niger Delta.

This iron-producing community required a reliable caloric base, provided by pearl millet agriculture and pastoralism. One of the challenges or constraints of pearl millet is that it is relatively low yield, lower on average than Sorghum and significantly less productive that Near Eastern cereals like wheat and barley (Fuller et al., 2019). Recent data indicate a mean yield of ~450 kg/ha but with reported yields as low as ~225, compared to average yields in Sorghum of ~600 kg/ha and barley of ~1000 kg/ha (ibid.). In addition, studies indicate that if land is continuously cropped yields decline by >20% in the second year and >40% in the third year, without adding fertilizer (Bationo et al., 1993), thus requiring fallowing of fields after two or three years, often for 7 years. In light of this the evidence at TMD that both a fallowed landscape and manuring were important as efforts to maintain yields during cycles of cultivation, as well as years of fallow in between. Together this provided a stable agricultural base that sustained a substantial community

(9 ha, with an estimated population of c.2000 persons) at TMD for >650 years.

The lack of agricultural diversity recorded from the site, as will be discussed below, is probably linked to multiple factors differencing TMD from the Inland Delta. These include a more marginal climate (lower rainfall and no permanent water bodies) coupled with greater cultural homogeneity – a relatively low biomass landscape largely dominated by specialists involved in iron production.

7. TMD archaeobotany in regional context

Agriculture in the Middle Niger basin seems to have developed separately in two waves. The eastern wave has pearl millet cultivation dating from at least 2000 BCE, deriving from the Tilemsi Valley, a remaining Saharan water channel at a time of increasing desiccation (Manning and Fuller, 2014). Millet cultivation spread south of the Niger river bend into the Douentza region shortly thereafter (MacDonald et al., 2017). The western wave is that of the Mauritanian escarpments (Tichitt, Oualata and Nema), where evidence for early pearl millet cultivation dates from 1900 to 1700 BCE (MacDonald et al., 2009). In both areas pearl millet cultivation was coupled with cattle and ovicaprine herding, with this new agropastoralism spreading through much of Mali, Burkina Faso and northern Ghana during the second millennium BC (Kahlheber and Neumann, 2007; Champion and Fuller, 2018; MacDonald et al., 2017). The first millennium BC witnessed more diversified cereal agriculture, with the cultivation of African rice, sorghum, fonio and other small millets (e.g. Echinochloa sp., *Brachiaria* sp., *Panicum laetum*) (Kahlheber and Neumann, 2007; Champion and Fuller, 2018; Kay et al., 2019). Rice presumably spread from the Upper Niger into the IND by ca. 800–400 BCE (Murray, 2007a, 2007b), while sorghum spread westwards across the savanna reaching the Lower Niger in Benin by ca. 700 BCE (Champion and Fuller, 2018). Fonio (*Digitaria exilis*) might have been locally domesticated in the Inland Niger Delta or adjacent region as a crop that could take advantage of marginal soils (Champion and Fuller, 2018).

Sites from the Inland Niger Delta (Dia, Jenne-Jeno, Toguere Doupwil, Toguere Galia) indicate diverse agricultural practices mainly based on the use of African rice (which usually dominates), coupled to pearl millet, sorghum and fonio cultivation. Niger Delta agriculture was based mainly on wetland plant cultivation, complemented by those of dry land cultivation. Indeed, the archaeobotanical assemblages are largely dominated by samples that contain domesticated rice (*Oryza glaberrima), Echinochloa colona* and wild *Brachiaria* cf. *ramosa*. *Brachiaria* cf. *ramosa* is an annual wild grass that grows in very similar ecological conditions to floodplain rice (but not deepwater rice). The secondary agricultural practices are related to the cultivation of dry crops such as pearl millet (*Pennisetum glaucum*) and fonio (*Digitaria exilis*). Like in the Douentza region, pearl millet is present from the first millennium BC, and fonio is often more common on settlements during their final phases and just before the site's abandonment. The presence of sorghum, a décrue cereal, is also notable, but only present in very small quantities (Champion, 2019).

Despite this regional pattern of diversification of agriculture in the first millennium AD, the archaeobotanical results from Tongo Maaré Diabal indicate a tenacious focus on pearl millet cultivation. Around 80% to 90% of the plant remains consisted of pearl millet. Thus, the metallurgists of TMD appear to only have cultivated and ate pearl millet, with the scarce sorghum present from AD 750 potentially being imported. This is despite the fact that the local environment, even if marginal, was potentially suitable for sorghum, African rice, fonio and other smaller millet cultivation – all crops that were readily available in neighbouring areas the Inland Niger Delta at this time (e.g. Champion and Fuller, 2018; Kay et al., 2019). Such suitability is seen today in the Dogon country immediately to the south and the contemporaneous archaeological site of Sadia (700–1300 CE). where African rice, sorghum, fonio, *Echinochloa*, and other small millets are grown in marginal ecological conditions similar, potentially even dryer, geographical/ecological conditions than those of TMD (Champion, 2019; Champion et al., 2021.). Sadia's macro-botanical remains are largely dominated by pearl millet (Pennisetum glaucum). But from the tenth century AD, sorghum (Sorghum bicolor) and African rice (Oryza glaberrima) appear in small quantities, and fonio (Digitaria exilis) and barnyard millet/hungry rice (Echinochloa sp.). In Sadia, some samples also show remains of tree fruits from savannah parklands, such as baobab (Adansonia digitata), marula (Sclerocarya birrea), jujube (Ziziphus sp.), shea butter (Vittelaria paradoxa) and African grapes (Lannea microcarpa). Fonio and Echinochloa sp. cultivation appears to be a later addition that helped to diversify agriculture and buffer against failures that might affect the monoculture of pearl millet (Champion et al., 2021). The absence of agricultural diversification at TMD is also visible through isotope analyses. Recent carbon and nitrogen isotopes analysis on human teeth from people buried in the Bandiagara escarpement indicate diets with a major input of C4 foods (e.g. pearl millet) in the region of TMD, and more diversified diets mixing C3 (e.g. rice and cowpea) and C4 foods in the vicinity of Sadia towards the south (Dlamini et al., 2019). The question is – why did some parts of the population retain such an exclusive focus on pearl millet?

Agriculture in West Africa was considerably changed by the advent of iron tools, with a noticeable diversification in cultigens in the late first millennium BC, to include rice, sorghum, fonio, and a more widespread adoption of cowpea. Yet alongside this, people continued to rely on previous patterns of subsistence based on pearl millet, pastoralism, and fishing established in the Late Stone Age, and which is particularly visible at TMD. One reason might be linked to the relative ethnic homogeneity of populations around TMD in the first millennium AD. In their socio-economic syntheses of the deep-time Middle Niger, both, Gallais (1967), Gallais (1984) and McIntosh (1998), argue that ethnic diversity and subsistence specialism go hand-in-hand. They portray the recent historic Middle Niger as a seasonal symbiotic system including Bozo fisherfolk, Nono/Soninke rice farmers, Bambara millet farmers and Peulh pastoralists. Subsistence assemblages in the Middle Niger are therefore palimpsests of a common economy between these groups, a pattern which presumably extends for centuries, even millennia (MacDonald, 1994). This group-specific subsistence diversity is linked to the seasonal ecological diversity of the IND and its margins which diminishes territorial conflicts and encourages niche economies. However, such ecological diversity is lacking in the environs of TMD. The nearest permanent water to the site is Lake Korarou, some 40 km to the northwest, and geomorphological studies show that annual overflows into the plains around Douentza decreased and became intermittent after c. 2000 BCE (MacDonald et al., 2017). The region's soils are sandy and well drained, experiencing light seasonal rains – most suitable for millet cultivation. But it is the history and archaeology of the region that are more indicative of relative ethnic homogeneity.

As outlined in the introduction, the contemporary ethnic diversity of the Douentza region is largely a product of recent historic state expansions. Prior to the Empire of Mali we have reason to believe that only two groups were present in the region, perhaps with the intermittent passage of pastoralists (indicated by cattle remains). These two groups are attested to in our excavations and regional survey by two contemporary pottery traditions. Both ceramic traditions (featuring different formation and decorative techniques) occur in the same contexts across time and space at TMD as intact pots and as sherds. This would seem to imply the close contact, collaboration and potential co-habitation of two groups: autochthons (with their technical characteristics persisting in the ceramics of the area from before TMD's occupation to the present day) and incoming blacksmiths (the latter's pottery traditions being comparable to those from the Lakes Region and eastern margins of the IND) (Gestrich and MacDonald, 2018). We have argued elsewhere (ibid.) that the appearance of these blacksmiths in the Douentza region c. AD 500 is linked with either state-generated or entrepreneurial demand for iron, with the relocation of populations to zones such as this one with plentiful iron ore. It is less clear which of these two hypothetical groups (autochthonous + blacksmiths) were cultivating the millet (perhaps both). What is known is that millet was already being cultivated by groups in the Douentza area from c. 2000 BCE (MacDonald et al., 2017) and there is no reason to think that this ceased in the meantime.

Indeed, there is a long history of cultural entanglement between iron workers and pearl millet farming in this part of Africa. As Robion-Brunner (2010) indicates in her ethnographic study of Dogon villages in Mali that include separate metallurgist communities, smiths received a part of the pearl millet harvest as an annual allocation. However, some metallurgists grew their own millet crops during the rainy season, and in return some metallurgists are aided in the dry season by millet farmers in the excavating of ores. They also likely received assistance in charcoal production, although this point has received less ethnographic attention and requires further clarification. In return, these farmers received some of the bloomery iron for their labour. Within this exchange system, iron is not utilised as a product that is traded with currency or integrated into the market exchange, but rather forms part of a routine domestic cycle that links millet growing and the labour of the millet growers.

Thus, it is argued that millet mono-culture at TMD may be attributed to factors including: the non-urban characteristics of the settlement, the relatively limited ecological productivity of the area (without permanent water sources) and finally the specialist nature of the settlement itself (iron workers). All of these imply relatively low population diversity when compared to TMD's contemporary Middle Niger settlements, an assertion supported by the archaeology. As the economy of the wider region is strongly structured by occupational specialist groups (which often coincide with ethnicity), we suggest that this relative local homogeneity may have led to strong local reliance on a single grain crop, pearl millet.

8. Conclusions

In conclusion, the agricultural landscape at TMD was composed largely of pearl millet fields, intercropped with cowpea, and several useful trees maintained in fields and fallows. While pearl millet processing was likely a daily task, sorghum was much more occasional and potentially traded in. Many contemporaneous sites with archaeobotanical evidence in West Africa, and especially in the Niger River Basin, are totally different, and more diversified in terms of their archaeobotanical signature. This highlights something distinctive about TMD's iron workers and potentially allied autochthonous communities, with a focus on pearl millet and more intensive forms of production (including manuring). We contend that this relative mono-culture may have been part of a deeper time economic pattern for communities at the margins of the economic symbiosis documented for the Middle Niger, and may also connect to the economic provisioning of specialist communities.

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