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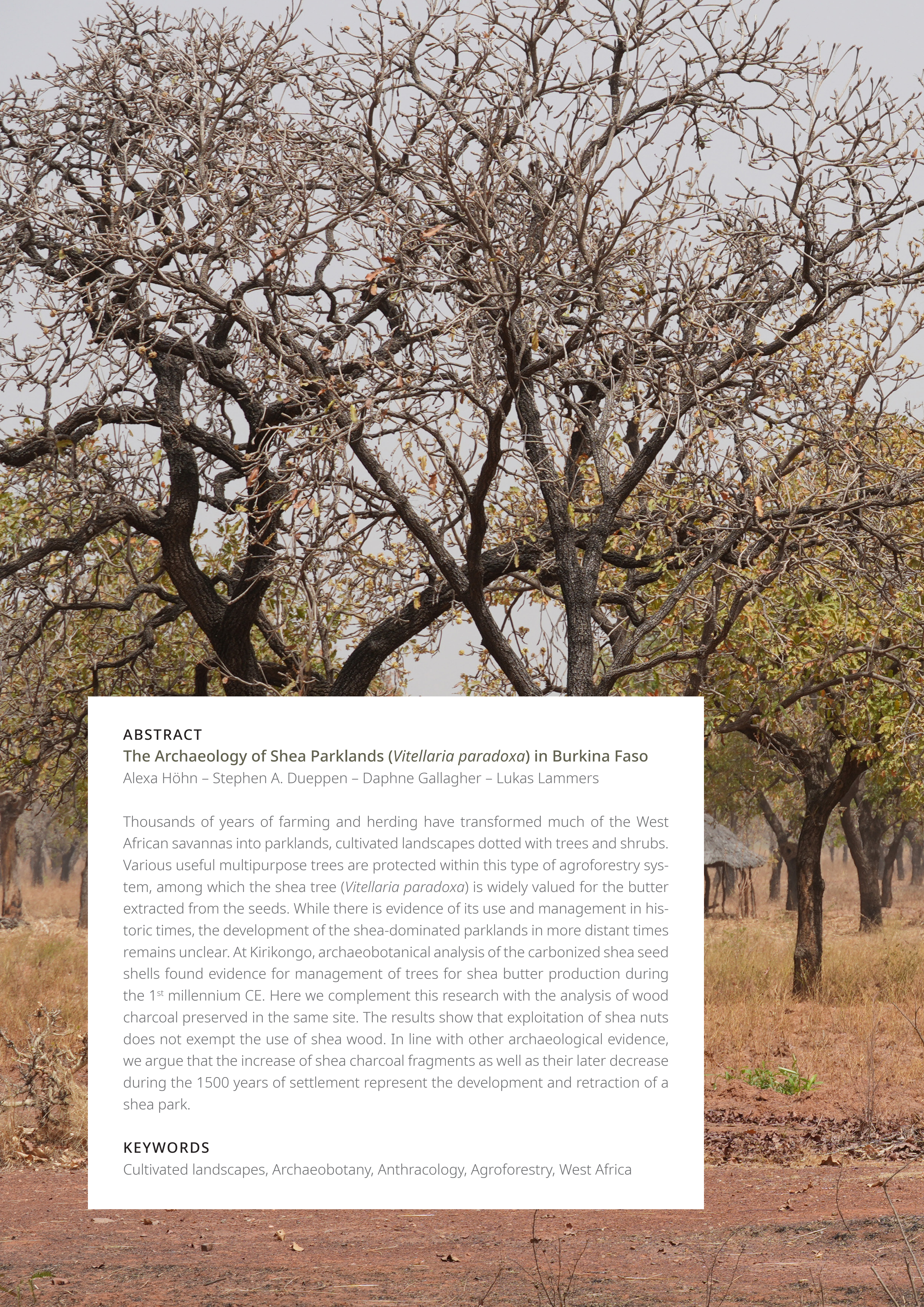

ABSTRACT

The Archaeology of Shea Parklands (*Vitellaria paradoxa*) in Burkina Faso

Alexa Höhn – Stephen A. Dueppen – Daphne Gallagher – Lukas Lammers

Thousands of years of farming and herding have transformed much of the West African savannas into parklands, cultivated landscapes dotted with trees and shrubs. Various useful multipurpose trees are protected within this type of agroforestry system, among which the shea tree (*Vitellaria paradoxa*) is widely valued for the butter extracted from the seeds. While there is evidence of its use and management in historic times, the development of the shea-dominated parklands in more distant times remains unclear. At Kirikongo, archaeobotanical analysis of the carbonized shea seed shells found evidence for management of trees for shea butter production during the 1st millennium CE. Here we complement this research with the analysis of wood charcoal preserved in the same site. The results show that exploitation of shea nuts does not exempt the use of shea wood. In line with other archaeological evidence, we argue that the increase of shea charcoal fragments as well as their later decrease during the 1500 years of settlement represent the development and retraction of a shea park.

KEYWORDS

Cultivated landscapes, Archaeobotany, Anthracology, Agroforestry, West Africa

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The Archaeology of Shea Parklands (*Vitellaria paradoxa*) in Burkina Faso

Introduction

1 Valued for various products such as fruits and seeds, leaves, bark and wood, managed trees are an important component of traditional savanna agroforestry systems in West Africa. The cultivated landscapes of fields and fallows dotted with trees have become known as and are researched under the term parkland (e.g. Amoako – Gambiza 2021; Bayu 2019; Boffa 1999; Karlson – Bolin – Bazié et al. 2023; Sanou – Koala – Ouédraogo et al. 2022) for their reminiscence of English parks by early European researchers (see Pullan 1974), despite the colonial connotation of the term. For the development of parklands, cultivation by hoe is decisive; it does not necessitate clearing a field from trees and stumps extensively, as it would for ploughing (Krings 1991). The protected useful trees and the resprouting stumps facilitate regeneration of the woody layer within the rotational field-fallow system. Today, 15 to 20 years are considered long fallow periods (Boffa 1999: 48; Gilg 1970; Hahn 1996: 162), but in the past old fallows would last up to 150 years (Raison 1988, as cited in Sheperd 1992: 17–18).

2 Parklands belong to savanna ecosystems, which are characterized by the co-dominance of two contrasting plant life forms, trees and grasses, with a continuous herbaceous layer and a discontinuous stratum of shrubs and trees (e.g. Sankaran – Ratnam – Hanan 2004). In fields, crops form the herbaceous layer instead of wild grasses. While the reduction of tree cover in cultivated areas changes woodland or savanna woodland to tree savanna (as defined in Yangambi, CSA 1956), the fallow patches within the area of arable land may even seem like untouched woodland or dry forests at first glance. Throughout West Africa, various forms of parklands exist. Environmental factors as well as cultural preferences and social structures, determine the set of characteristic tree species. Most prominent are parks with the shea tree (*Vitellaria paradoxa*, syn. *Butyrospermum paradoxum* or *B. parkii*) and those with winter thorn (*Faidherbia albida*, syn. *Acacia albida*). But to name just a few, parks with azobé (*Lophira alata*), iron tree (*Anonychium africanum* syn. *Prosopis africana*), and the African palmyra palm (*Borassus aethiopum*) have been described as well (e.g. Boffa 1999; Krings 1991; Pelissier 1980; Pullan 1974; Seignobos 2018; Seignobos 1982).

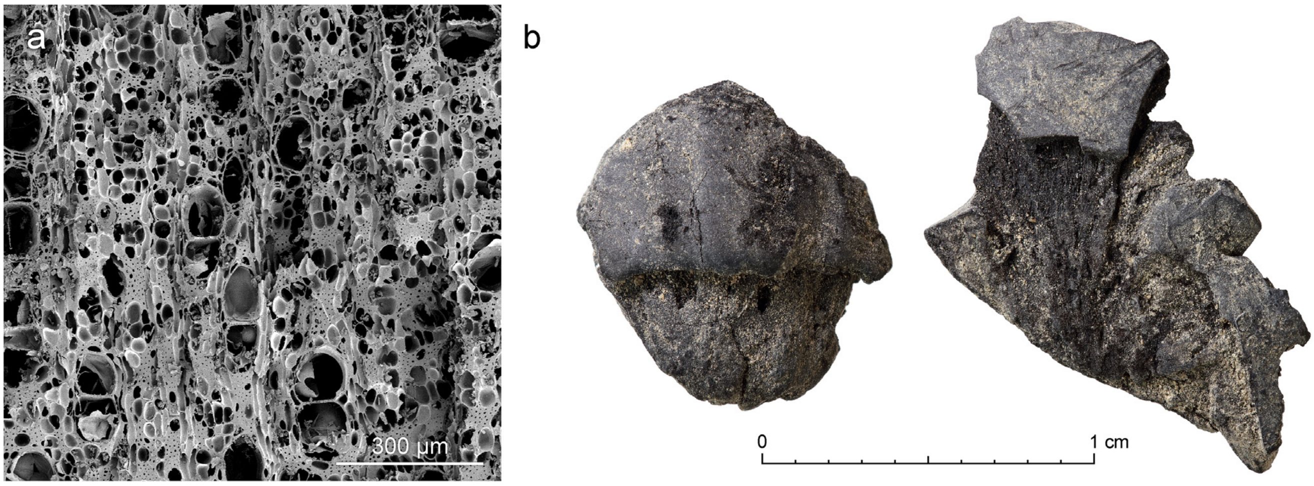


Fig. 1: Archaeobotanical remains attesting to shea exploitation from Oursi West, Burkina Faso, a) transverse section of charcoal fragment of VITELLARIA PARADOXA type b) seed coat fragments of *Vitellaria paradoxa*.

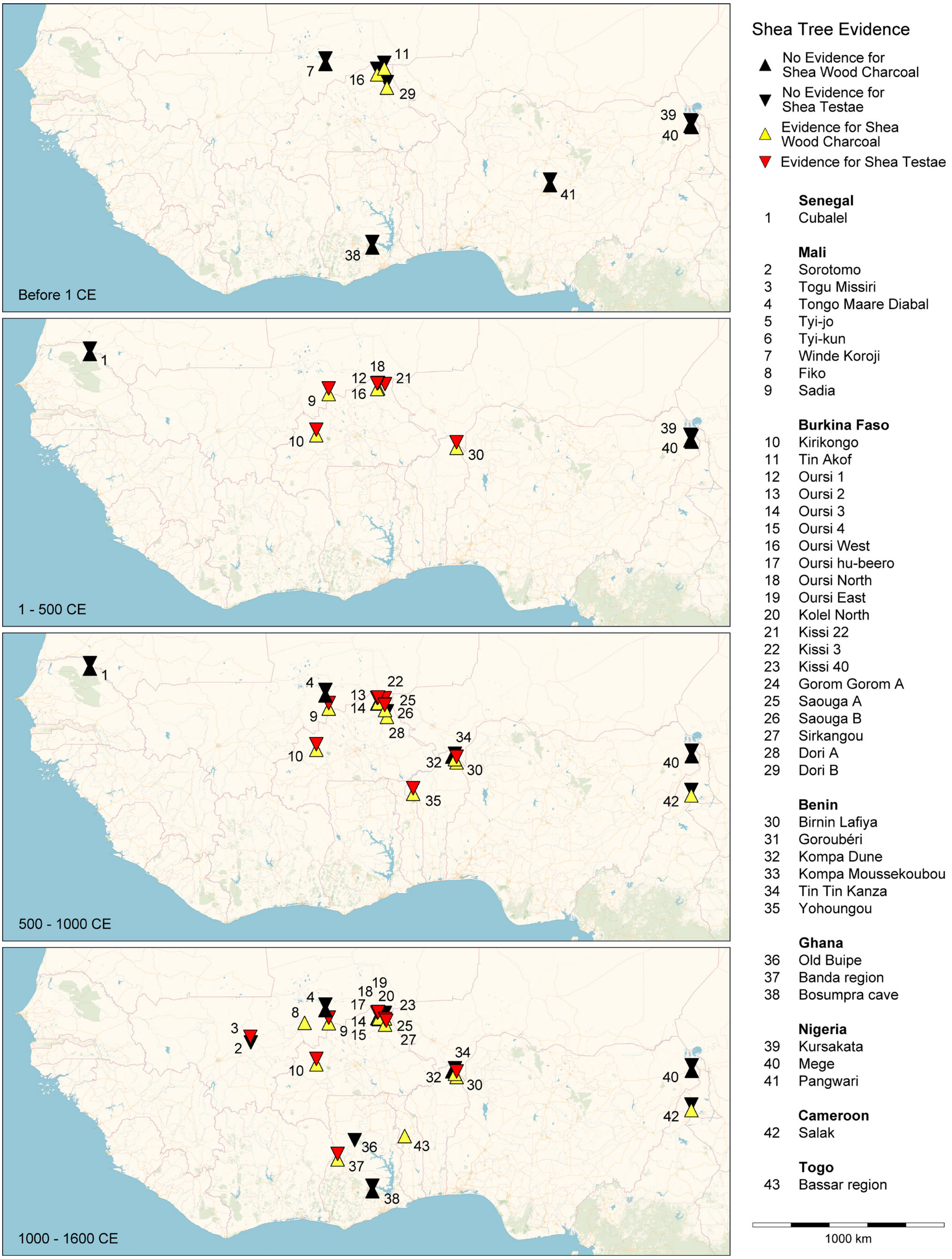
3 Among the numerous useful trees, the shea tree is, economically and culturally, the most important species in the Sudano-Sahelian region of Africa (Boffa 2015: 1). Commercially, but also culturally, the seeds are its most valuable product. They are the source of shea butter ("beurre de karité"), traditionally used as edible fat, in body care, as an illuminant, ritually and medicinally (e.g. Chalfin 2004). But there is more to the tree; the sweet fruit pulp is edible, the bark is used medicinally, the sap impregnates mud constructions, and the wood is used for construction and provides good fuel (Burkill 2000: 62–66; Hall – Aebischer – Tomlinson et al. 1996). Modeled, the range of shea distribution covers c. 3.41 million km^2 with 1.84 billion trees today, from Senegal to Sudan (Naughton – Lovett – Mihelcic 2015). There is evidence that this vast distribution and the density of shea trees is not entirely natural (Maranz – Wiesman 2003). The fact that shea trees in parklands may reach up to c. 80 % as opposed to c. 10 % in unmanaged woodland, intimately links the proportion of shea to human activities of protection, selection and dispersal (Boffa 2015: 7; Lovett – Haq 2000).

4 It is hypothesized that shea parklands specifically have been established for a long time, possibly thousands of years (e.g. Aubréville 1950: 430; Gallagher – Dueppen – Walsh 2016; Lovett 2018: 12), but so far, direct evidence for the beginning of the intimate relationship of shea and people, the beginning of parkland development, is missing. Historical records of consumption and trade of shea butter in West Africa date back to more than 700 years ago: "Among them it is plentiful and easy to come by, and it is carried from one town to another in big calabashes" (Ibn-Battuta travelling West Africa mid-14th century CE, cited as in Hamdun – King 1994: 40). The first written record of shea tree management however, is only about 220 years old. From his travels in West Africa, Mungo Park described, that shea is not planted, but that in clearing woodland, every tree but the shea is cut (Park 1858 (1799): 168). This provides a *terminus ante quem*, but it does not shed any light on the beginning of the evolution of the shea parklands.

Mapping the archaeobotanical evidence of shea – revisited

5 The appropriate tool to find evidence of shea exploitation and parkland evolution at greater temporal depth is archaeobotany. Two types of botanical macro-remains evidence shea tree exploitation in West African archaeological sites, fragments of wood charcoal and those of carbonized seed coats, i.e. testae (Fig. 1).

6 Expanding on the figure in Gallagher et al. (Gallagher – Dueppen – Walsh 2016: Fig. 1), we mapped the presence and absence of shea testae and wood charcoal in archaeobotanical assemblages at 39 sites from Senegal to Cameroon (Fig. 2). The red inverted triangles represent the identification of testae in the analyses; if black,



they were absent. Black upright triangles represent the absence of shea in the wood charcoal assemblages; yellow upright triangles indicate their presence. If only one find category has been analyzed so far, the sites are represented by one, upright or inverted triangle only. The figure includes new and unpublished findings (Data published at:

Fig. 2: Sites with archaeobotanical investigations in West Africa, showing evidence or lack thereof for shea exploitation across different periods.

https://doi.org/10.5281/zenodo.11385690) and presents the evidence divided into four time slices ranging from before the Common Era to 1600 CE. The maps offer a comprehensive summary of our current archaeobotanical knowledge of shea. However, since the sites cover different temporal depths and are spread over a distance of more than 3000 km, roughly the distance between Lisbon and Kiev, they can only provide initial insights into the evolution and spread of shea exploitation in West Africa.

7 The oldest archaeobotanical evidence of shea exploitation so far comes from the Oudalan region in northern Burkina Faso. Wood charcoal from the Late Stone Age open-air dune site Dori B is radiocarbon dated together with other charcoal types to the beginning of the 1st millennium BCE (Kahlheber 2004: 70). Shea charcoal fragments at Oursi West come from a Late Stone Age layer, but possibly mixed with Early Iron Age material from the lower layers of the Iron Age settlement mound above. Even though this region is outside of the distribution of the shea tree today (compare Aubréville 1950: 426; Hall – Aebischer – Tomlinson et al. 1996; Naughton – Lovett – Mihelcic 2015), archaeobotanical macro-remains (Fig. 2) and pollen record the presence of shea in the Oudalan, until the 15th century CE (Ballouche 2001; Neumann – Kahlheber – Uebel 1998). After the beginning of the Common Era evidence for shea exploitation becomes more numerous. The lack of evidence for seed shells at some sites may relate to archaeological contexts, as well as to the use of different parching methods for shea butter production that may reduce archaeological visibility as described in Gallagher et al. (Gallagher – Dueppen – Walsh 2016). However, at Lake Chad, the absence is rather related to the environment. Shea does not stand repeated flooding or high water tables and the analyzed sites are small sand islands within a large floodplain (Höhn – Breuning – Gronenborn et al. 2021). At Cubalel in northern Senegal, in-depth investigations did not reveal shea testae remains (Gallagher – Murray 2016; Gallagher – McIntosh – Murray 2018), neither did the ongoing analysis of wood charcoal. The site is also located close to floodplains and it is and possibly was already 2000 years ago outside the distribution range of the shea tree.

8 The mere presence of testae and/or wood charcoal fragments attests to the exploitation of shea trees, but is not evidence for the existence and management of shea parks per se. Even though the presence of shea parklands has been hypothesized for sites in the Sahel (e.g. Neumann – Kahlheber – Uebel 1998), the first robust evidence for shea management comes from Kirikongo, where the presence of thinner and more regular testae over time is possibly the result of shea tree management (Gallagher – Dueppen – Walsh 2016). It has not been clear however, how the existence of shea parks would manifest in wood charcoal assemblages, i.e. if anthracology is a suitable method to trace shea park existence and development over time. In general, anthracological investigations are well suited to reconstruct anthropogenic vegetation near settlement sites, as traditionally fuel collection is linked to vegetation clearance by-products (see Picornell Gelabert – Asouti – Martí 2011). Moreover, anthracology has already demonstrated that it can track agricultural intensification in West African savannas through an increase in charcoal types indicative of shorter fallow periods (Höhn – Neumann 2012). Shea wood is suitable as fuel and is used for charcoal production (Arbonnier 2002: 486). With shea the most common tree species in shea parklands, it is also the most available as dead wood for fuel collection (Lovett 2018: 20). The analyses at Kirikongo with 1500 years of occupation, shea exploitation and management, thus serve to prove the suitability of anthracological analyses for evidencing shea park presence and as a test case to trace the evolution of a parkland in West Africa.

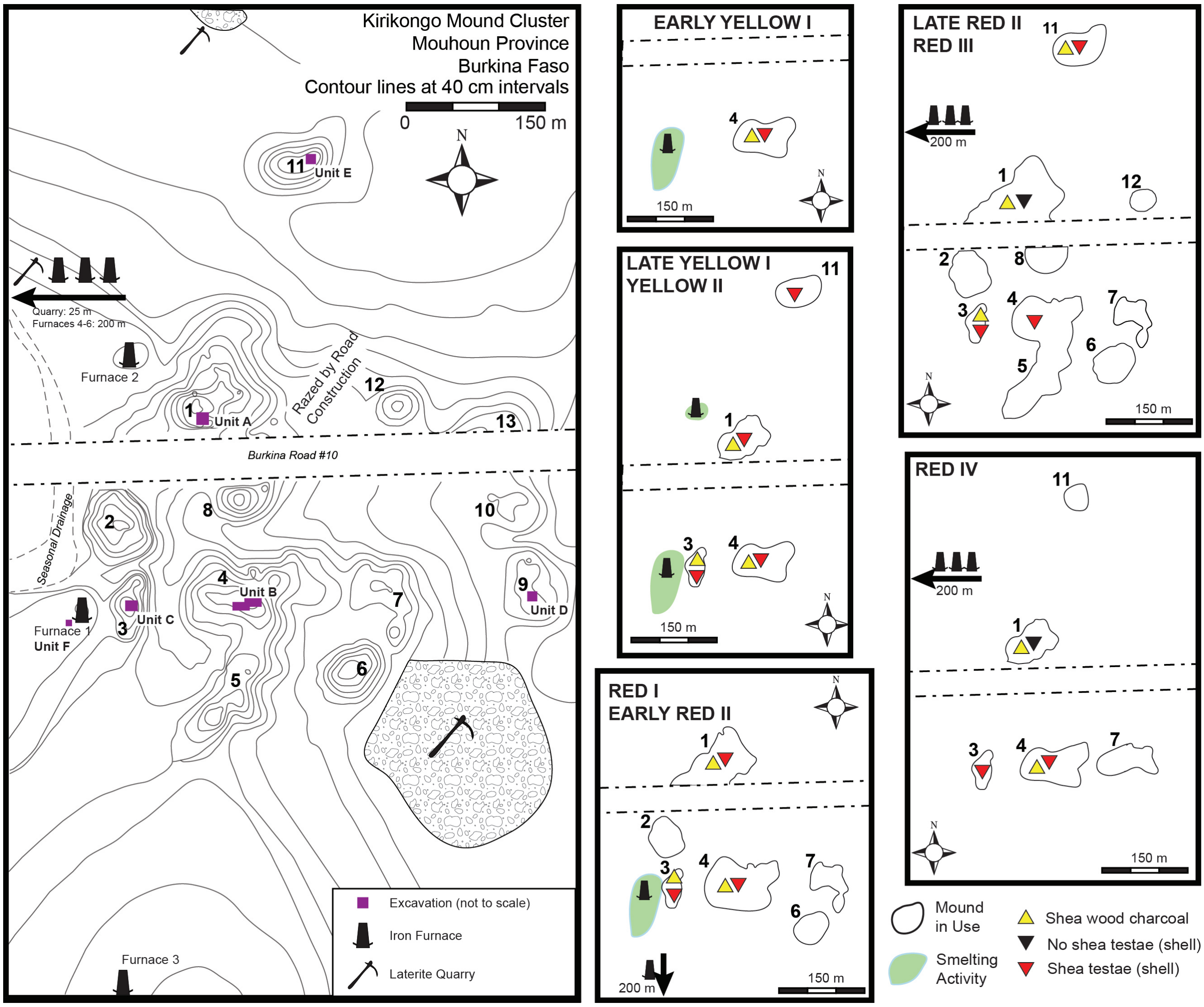


Fig. 3: Kirikongo, location of mounds, occupation per phases and shea presence over time.

Kirikongo – the archaeological site

9 Kirikongo is a large mound (tell) cluster composed of 13 mounds, quarries/mines, iron smelting locations, etc., spread over a 37.5 ha area and occupied from the cusp of the 1st millennium BCE/CE to ca. 1650 CE. Spatially, the site is divided into a 20 ha central core of 9 mounds and a northern exterior mound that contain areas dating until ca. 1500 CE, while the three eastern mounds date to the 16th and 17th centuries CE (Fig. 3). Excavation units, shovel tests, surface collections and documentation of road cut profiles have resulted in a detailed reconstruction of site formation processes and historical processes and events. This research has revealed that mounds were primarily created through ritualized practices involving construction of mortuary monuments and systematic conversion of domestic and industrial spaces to mortuary monuments (with retention of pavements and wall foundations), along with ritual depositions in pits and concavities (see Dueppen 2012; Dueppen 2022; Dueppen – Gallagher 2023). Carbonized plant samples, including the wood charcoal, were systematically recovered from excavation contexts. Contexts associated with ritualized depositions were most likely to have significant amounts of charcoal and represent the majority of contexts analyzed for this paper.

10 Based upon stratigraphic analyses, extensive AMS dating and a detailed relative chronology of architectural techniques and ceramic seriation, the occupation

Phase	Dates
Yellow I	100–500/550 CE
Yellow II	500/550–700/750 CE
Red I	700/750–1025 CE
Red II	1025–1200 CE
Red III	1200–1400 CE
Red IV	1400–1500 CE

Fig. 4: Kirikongo, site chronology.

can be divided into two architectural phases (Yellow and Red), with ceramic-based sub-phases (Dueppen 2012; Dueppen 2022; Fig. 4). Kirikongo has a dynamic site history. It was established as a lone economically generalized multi-family house at Mound 4, with associated metallurgical areas along the seasonal drainage to the west. By the 5th century, a second multi-family house was settled 150 m to the north with similar economic evidence, including its own smelting area to the west (Mound 1). With the establishment of the northern Mound 11 in the 6th century, a linear pattern of dispersed mounds was created. From the 7th to the 12th centuries more centralized socio-spatial patterns developed, as new mounds formed around Mound 4, iron-working evidence restricted to Mound 4, cattle were restricted to Mound 4's house, a cemetery mound (Mound 3) created to their west, and in the 10th century a two-story ritual complex was constructed on the high point of Mound 4. In the mid 12th century a series of decentralizing processes occurred at Kirikongo while the community continued to grow in size (shift from closed compounds to open room blocks, cessation of cattle-keeping, shift in specialized metallurgical production to Mound 11, specialization of pottery production at Mound 11, shift in the focus of the ritual complex, cessation of interment at the cemetery mound). Starting in the mid 14th century Kirikongo experienced a population loss likely caused by the Black Death pandemic (Dueppen – Gallagher 2016; Dueppen – Gallagher 2024; Gallagher – Dueppen 2018), with only a few mounds still in use by the early 15th century. It is likely that the socio-spatial changes over time were interrelated with field system location and farming strategies in complex ways, as for example, the initial linear pattern would allow some fields to ring the mounds whereas the large rounded community that developed in Red I would have likely had fields surrounding the entire settlement.

11 Kirikongo had a diversified agricultural economy. The extensively analyzed faunal assemblage (Dueppen 2022) has evidence for domestic animals from the start of occupation including cattle, goats, chickens and dogs, with sheep added in the 9th century and guinea fowl in the 13th. Cattle ceased to be kept after the 12th century as part of the political transformations (Dueppen 2022; Dueppen 2012), and it is notable that a horse was identified from the 12th century as well as a donkey from the late 13th century (Dueppen 2022). Evidence from hunted animals, as well as breed characteristics of domestic livestock, indicate that the Mouhoun Bend was a rich diversified landscape with gallery forest, areas for animals to graze, and abundant aquatic habitats (Dueppen 2022). While the 12th and 13th centuries may have been slightly drier, there is no evidence for environmental stress. In the faunal data, hunted animals include those that tend to avoid humans and there is continued evidence for animals hunted in gallery forest and abundant aquatic contexts throughout the sequence. Starting in the 14th century and increasing in the 15th century, faunal data indicate increasing forestation likely due to a combination of both increased rainfall and population losses associated with the Black Death pandemic (Dueppen 2022).

12 Analysis of seeds and fruits from flotation samples as well as individually collected carbonized seeds and fruits encountered during excavation have been completed for Unit A (Mound 1) (Gallagher – Dueppen 2019). In addition, the shea shells from Units A, B, C, and E (Mounds 1, 4, 3, and 11 respectively) have been intensively studied to understand the development of field systems (Gallagher – Dueppen – Walsh 2016). These studies have found evidence throughout the sequence for the cultivation of millet and fonio, extensive management of shea trees, and the use of baobab (*Adansonia*

digitata) and marula (*Sclerocarya birrea*). Currently, the botanical evidence for sorghum consists of a complete seedhead that carbonized when the ritual structure at Mound 4 was burned in the late 13th century (Dueppen – Gallagher 2021). These finds are complemented by a range of wild grasses and ruderal herbs. The occurrence of the *Scleria* sp. sedge, which is present in Unit A until the 8th century then reappears in the late 14th or early 15th century could indicate some changes in precipitation that may have affected the flow of the seasonal drainage adjacent to the site. Possible evidence for expansion of fallows close to the settlement late in the sequence could be indicated by the regular appearance of *Piliostigma* sp. seedpods in the Unit A assemblage in the 14th and early 15th centuries. As is the case for the wood charcoal, the majority of these samples are from ritualized depositions. While it is unknown whether specific plants were selected for inclusion that were distinct from those relied on for everyday use, the similar formation processes of the analyzed samples is such that they can be compared to identify trends and patterns within the site and through time.

Material and Method

13 The present analysis of the woody environment at Kirikongo is based on 32 samples from Mounds 1, 3, 4 and 11 and covers phases Yellow I to Red IV. The fragments were dispersed in the infill of various depositional contexts, and mostly come from the 2 mm fraction of bucket flotation of mostly 2 to 4 liters of sediment, systematically taken from stratigraphic units. Sample sizes vary from three to 50 analyzable fragments (Fig. 5). 14 samples contain 10 to 20 fragments and 13 samples consist of less than 10. Only five samples contain 25 or more fragments. The largest samples come from phase Red IV at Mound 4. The small size of most of the samples makes quantitative analyses problematic; we have calculated percentages and ubiquities, but use a semi-quantitative approach for the evaluation of the charcoal spectra per phases.

14 Fragments were manually fractured and transverse, longitudinal tangential and longitudinal radial planes were examined with a Leica DMLP reflected light microscope at the University of Oregon, Eugene. The material is on loan to the Department of Anthropology and will return to Burkina Faso once all analyses are finalized. Wherever possible, fragments were assigned to published charcoal types (Höhn – Neumann 2018; Höhn – Neumann 2016; Höhn – Neumann 2012; Höhn – Breuning – Gronenborn et al. 2021; Neumann – Kahlheber – Uebel 1998). The names of the charcoal types are written in small capitals, e.g. COMBRETUM MOLLE/NIGRICANS, to emphasize that the wood charcoal types are not identical with tree taxa as usually identified by morphological features such as flowers, leaves, bark and sap flow. The formatting underlines that assigning charcoal types is already an interpretative act (further explanations in Höhn – Neumann 2018). The InsideWood database (InsideWood 2004-onwards) was used for cross-referencing. Selected types were documented by Scanning Electron Microscopy (SEM) at the Center for Advanced Materials Characterization at the University of Oregon, and together with diagnostic features of all types are accessible in the Supplementary Material. The data is stored in the local MS Access, ArboDat 2018 “Sahel-Sudan-Charcoal Database” in Frankfurt and will eventually be accessible online via the Neotoma Database (http://apps.neotomadb.org/explorer/).

Dates-CE	Phase	Mound	Dueppen 2022 Context #	Dueppen 2022 Context Description		Sample size [l]	Mound	Vitellaria paradoxa	Terminalia spp.	Pterocarpus spp.	Combretum molle/nigricans	Detarieae II a, cf. Tamarindus indica	Terminalia (Anogeissus) leiocarpa	Detarieae II b, cf. Afzelia spp.	Lannea spp.	Senegalia/Vachellia (Acacia) spp.	Combretum micranthum	Diospyros spp.	Khaya spp.	Rubiaceaea I & II	cf. Sclerocarya birrea	Grewia spp.	Faboideae I undiff.	Flueggea/Hymenocardia	Terminalia/Pteleopsis	cf. Detarium spp.	bark	Indet	Sum	Sample diversity
100-500/550	YI	1	A-YI-a	Layer in probable mortuary feature	A173	3	1		6			2							1									2	11	3
500/550-700/750	YII	1	A-YII-b	Pit in Mortuary Monument	A164_ash	2,5	1	1	2	1	2	1				2												5	14	6
500/550-700/750	YII	1	A-YII-b	Pit in Mortuary Monument	A174	2,5	1	4	2	1	1			2														1	11	5
500/550-700/750	YII	1	A-YII-b	Pit in Mortuary Monument	A180	1,75	1	2		2	5			1								2						3	15	5
500/550-700/750	YII	1	A-YII-c	Pit in Mortuary Monument	A167	2	1		3		1																	1	5	2
500/550-700/750	YII	1	A-YII-d	Mortuary Monument	A144_int_fill	2	1	1	1		1																	1	4	3
500/550-700/750	YII	1	A-YII-d	Mortuary Monument	A146_fill	2	1	3																					3	1
700/750-1025	RI	1	A-RI-a	Courtyard area converted to mortuary space	A126_int_fill	2,5	1	6	2		1	4	1																14	5
1025-1200	RII	1	A-RI-b	Domestic structure converted to tomb	A109	2,25	1	9	1																			1	11	2
1200-1400	RIII	1	A-RIII-a	Foundation ritual pit	A76_int_fill	2	1	3		2	2		2															1	10	4
1400-1500	RIV	1	A-RIV-a	Courtyard area adjacent to architectural foundations (likely from mortuary ritual)	A21	4,25	1				4	1								1	4							3	13	4
1400-1500	RIV	1	A-RIV-a	Courtyard area adjacent to architectural foundations (likely from mortuary ritual)	A32_courty	2,25	1	6	1	4		4			1													2	18	5
100-500/550	YI	4	B-YI-d	Pit in Probable Mortuary Monument	B151	2	4			2	2		3															3	10	3
100-500/550	YI	4	B-YI-d	Pit in Probable Mortuary Monument	B158	2	4	1	2																			2	5	2
100-500/550	YI	4	B-YI-d	Pit in Probable Mortuary Monument	B172_botbulk	N/D	4	4	2		6	1	1					1											15	6
100-500/550	YI	4	B-YI-d	Pit in Probable Mortuary Monument	B172_bulkwch	N/D	4	7		1	3	9			1	1								2				1	25	7
100-500/550	YI	4	B-YI-d	Pit in Probable Mortuary Monument	B172_flot	N/D	4	3	7		5	2											2		1	1		4	25	7
500/550-700/750	YII	4	B-YII-a	Mortuary Monument	B144	2	4	2		2	2																		6	3
500/550-700/750	YII	4	B-YII-b	Probable Mortuary Monument	B136	2	4		1					1														3	5	2
700/750-1025	RI	4	B-RI-a	Mortuary Monument	B131	2	4		1																			2	3	1
700/750-1025	RI	4	B-RI-b	Ritual Complex (Early Layer)	B126	2	4		1				1															4	6	2
1400-1500	RIV	4	B-RIV-a	Pit in probable Mortuary Space	B25	3,5	4	1	5	11	4	4	2	3	1	1	7	3	3	1							2	2	50	13
1400-1500	RIV	4	B-RIV-c	Ritual Pit	B26	4	4		2	23	2	14		6			1											2	50	6
1400-1500	RIV	4	B-RIV-c	Ritual Pit	B75	2	4	2	1	12		10	2				1											2	30	6
500/550-700/750	YII	3	C-YII-a	Pit in Mortuary Feature	C100	2	3	8					4			1												4	17	3
700/750-1025	RI	3	C-RI-c	Mortuary Monuments	C73	2	3	2	1			1	4															2	10	4
1025-1200	RII	3	C-RII-a	Mortuary Monuments	C36	2	3	4		3	1																	1	9	3
1025-1200	RII	3	C-RII-a	Mortuary Monuments	C53	2	3						1															1	2	1
1025-1200	RII	3	C-RII-a	Mortuary Monuments	C59	2	3		3																			1	4	1
1200-1400	RIII	3	C-RIII-a	Veneration of Mortuary Monuments	C29	2,5	3	9																				1	10	1
1200-1400	RIII	3	C-RIII-b	Veneration of Mortuary Monuments	C18	1	3		7																			1	8	1
1025-1200	RII	11	E-RII-a	Foundation ritual pit in association with burial	E33	2	11	3							1													3	7	2
	Sum Kirikongo							81	51	64	42	53	21	13	4	5	9	4	4	2	4	2	2	2	1	1	2	59	426	
	Presence [n=32]							21	20	12	16	12	10	5	4	4	3	2	2	2	1	1	1	1	1	1	2			

Fig. 5: Kirikongo, charcoal counts per sample.

Results

Overall

15 426 fragments were analyzed, of which 365 were identifiable; 19 charcoal types were distinguished (Fig. 5). Fragments of the Vitellaria paradoxa charcoal type are present in 21 of the 32 samples. Terminalia spp. (20 samples) and Combretum molle/nigricans (16 samples) follow concerning overall ubiquity. Pterocarpus spp., Detarieae IIa (12), and Terminalia (Anogeissus) leiocarpa (10) are present in a third of the samples. The other 13 charcoal types are present in 1 to 5 samples. Vitellaria paradoxa was also present in the sampled burned architectural remains, to be further discussed in a later publication. 59 fragments (c. 14 %) were unidentifiable and two were identified as bark.

Per phase

16 The strong presence of Vitellaria paradoxa at Kirikongo, in frequency as well as in ubiquity (Fig. 6) shows that exploitation of shea nuts as attested in the carpological record (Gallagher – Dueppen – Walsh 2016) does not exclude exploitation of shea wood. Regarding results per phases, the highest frequency class is recorded from Yellow II to Red III. Lower values are present in Yellow I and especially in Red IV, where frequency drops below 10 %. Ubiquity of Vitellaria paradoxa remains comparatively high in all phases with above 60 % and only lower in Red I, but possibly related to two very small samples with one, respectively two identifiable fragments that are not Vitellaria paradoxa (Fig. 5). In the Red IV assemblage, Detarieae IIa, and especially Pterocarpus spp. are most frequent; The latter, only sporadically attested in the earlier phases reaches its highest frequency and ubiquity in Red IV, mostly because of the high frequency in the three Red IV samples from mound 4.

17 Combretum molle/nigricans and Terminalia spp., are present in samples from all phases. Combretum molle/nigricans drops in frequency from Yellow to Red, while Terminalia spp. reaches its lowest frequency only in Red IV (Fig. 6). Terminalia (Anogeissus) leiocarpa is also present in all phases but reaches only low frequencies and ubiquities, except for Red I. The other charcoal types are only present in one, two or three phases; the differences in presence/absence between phases relate mostly to the small sample sizes.

18 The number of analyzable fragments varies between phases (Fig. 6). In absolute numbers, Red IV is best represented, followed by Yellow I – due to the larger samples from mound 4 for both sub-phases. Yellow II is represented by 80 fragments, here relatively large samples originate from mounds 1 and 3. The other Red subphases are represented by only about 30 fragments each. Here individual sample sizes are usually 10 and below, with the exception of two samples of 11 and 14 analyzable fragments from Mound 1.

Discussion

Parkland development

19 Anthracological results at Kirikongo show that exploitation of shea nuts does not exempt the use of shea wood. Rather, the strong presence of probable *Vitellaria paradoxa* charcoal indicates high availability of the tree as a resource in the surrounding area. Shea wood is durable, used for building posts, mortars and domestic utensils, and

Phase	YI		YII		RI		RII		RIII		RIV		All phases	
	frequency	ubiquity	frequency	ubiquity	frequency	ubiquity	frequency	ubiquity	frequency	ubiquity	frequency	ubiquity	frequency	ubiquity
Vitellaria paradoxa	+++	IV	++++	IV	++++	III	++++	IV	++++	IV	++	IV	+++	IV
Pterocarpus spp.	+	III	++	III			++	II	++	II	++++	V	+++	II
Detarieae II a, cf. Tamarindus indica	+++	IV	+	I	+++	III					++++	V	+++	II
Terminalia spp.	+++	IV	+++	III	+++	V	+++	III	++++	II	++	V	+++	IV
Combretum molle/nigricans	+++	IV	+++	IV	+	II	+	II	++	II	++	IV	++	III
Terminalia (Anogeissus) leiocarpa	+	II	++	I	+++	IV	+	II	++	II	+	III	+	II
Detarieae II b, cf. Afzelia spp.			++	II							++	III	+	I
Lannea spp.	+	I					+	II			+	III	+	I
Senegalia/Vachellia (Acacia) spp.	+	I	+	II							+	II	+	I
Combretum micranthum											++	IV	+	+
Diospyros spp.	+	I									+	II	.	+
Khaya spp.	+	I									+	II	.	+
Rubiaceaea I & II											+	III	.	+
cf. Sclerocarya birrea											+	II	.	+
Grewia spp.			+	I									.	+
Faboideae I undiff.	+	I											.	+
Flueggea/Hymenocardia	+	I											.	+
Terminalia/Pteleopsis	+	I											.	+
cf. Detarium spp.	+	I											.	+
no of fragments/samples	91	6	80	9	33	4	33	5	28	3	161	5	426	

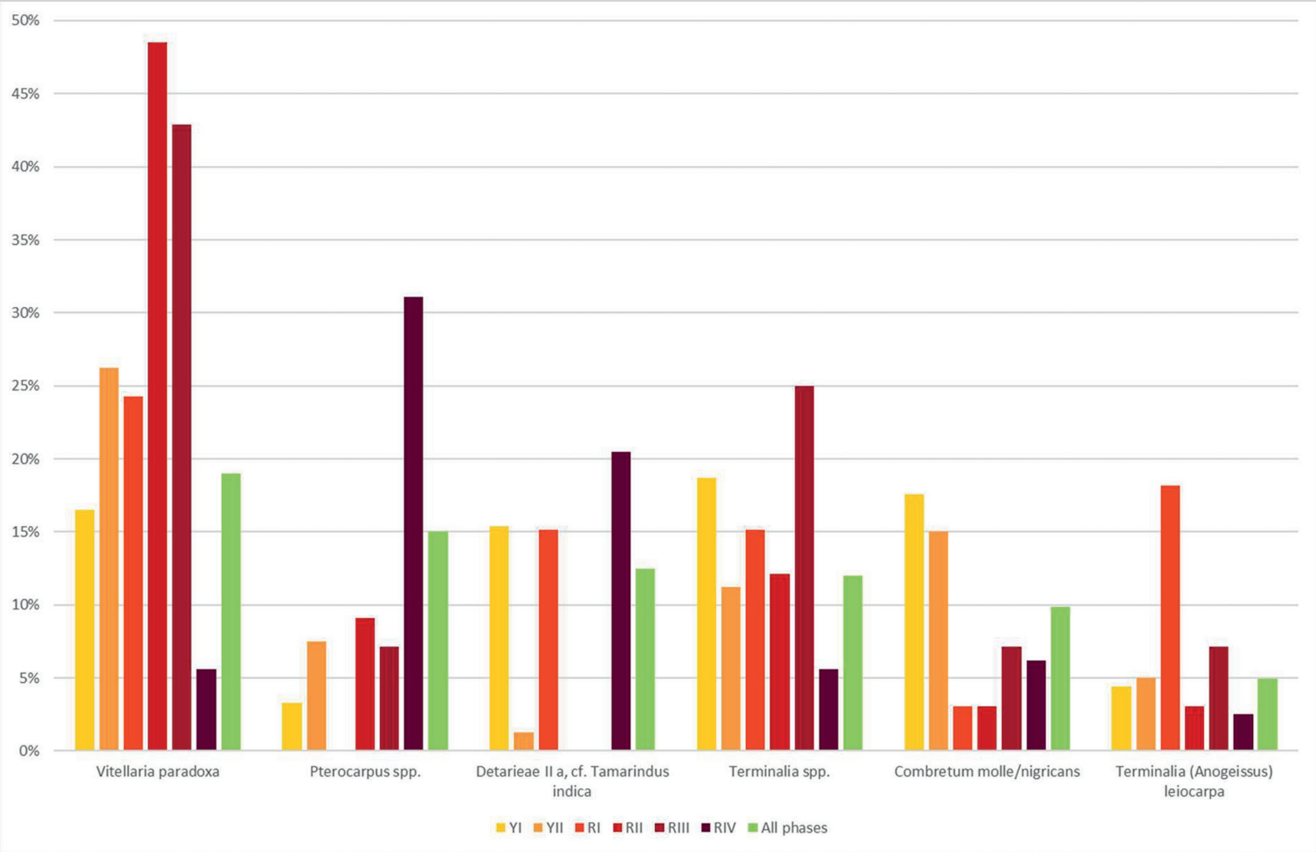
Frequency classes			Ubiquity classes	
	++++	20-<50%	V	80-100%
	+++	10-<20%	IV	60-<80%
	++	5-<10%	III	40-<60%
	+	1-<5%	II	20-<40%
	.	<1%	I	10-<20%
			+	<10%

Fig. 6: Kirikongo, frequency and ubiquity classes of charcoal types per phase.

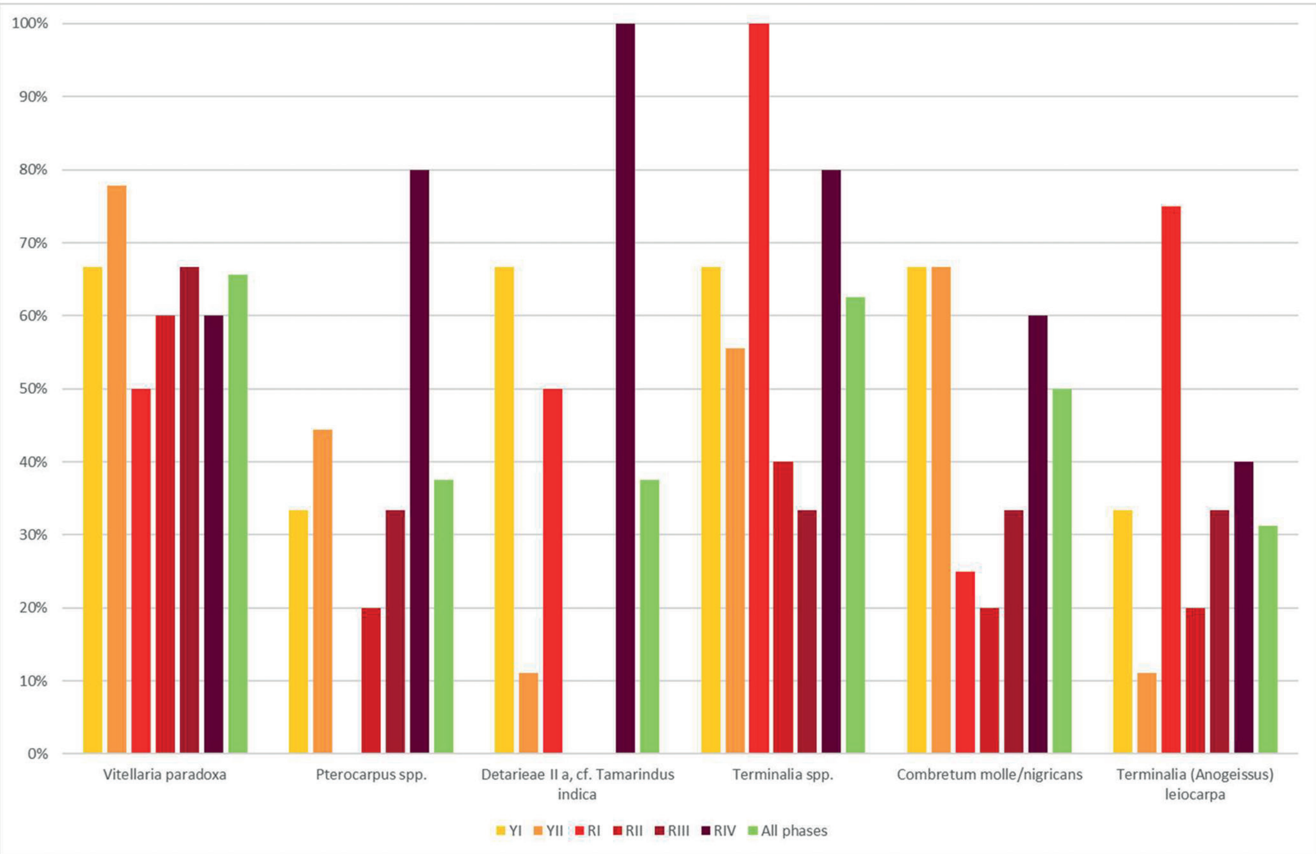
is valued as an excellent firewood and charcoal for cooking (e.g. Burkill 2000: 64; Lovett 2018: 9). It is not considered to be good for iron working and smelting as it burns quickly. But in spite of some reports of low or mediocre energy value (see Hall – Aebischer – Tomlinson et al. 1996: 83), more recent investigations into the calorific value of shea wood and charcoal have shown the values to be comparably high (Erakhrumen 2009; Ogunsanwo – Aiyeloja – Uzo 2007). In areas with shea fruit demand, shea wood may be harvested twofold: For large pieces of wood, such as for house posts or mortars, trees are cut when fruit-bearing stage has passed (Hall – Aebischer – Tomlinson et al. 1996: 82). Fuelwood rather derives from small individuals, which can be harvested with simple hand tools (Hall – Aebischer – Tomlinson et al. 1996: 43). Branches cut to promote fruiting, or reduce shading of crops (compare Hall – Aebischer – Tomlinson et al. 1996: 45) may also end up in hearths, as well as dead parts of otherwise vital trees.

20 The larger proportion of Vitellaria paradoxa in the assemblages of Yellow II to Red II/Red III, suggests an increase of shea tree proportion in the environment of Kirikongo over time. This pattern is likely not solely the result of taphonomy, due to the similarity of formation processes. The small sample size limits the robustness of the data, but the high frequency in Red II/Red III (Fig. 7) could indicate an increase of shea wood exploitation starting in Yellow II. Together with heavy reliance on shea butter as attested by shea testae remains, we propose that Kirikongo was already largely surrounded by shea parks by Yellow II and Red I, i.e. during the second half of the 1st millennium CE. In Red II and Red III, continuing selection of shea trees within the parklands and expansion of arable lands might have further increased the availability of shea in the surroundings of the settlement – at the expense of other less useful taxa, for instance those taxa evidenced by Combretum molle/nigricans fragments.

21 We suggest that the transformation of the environment into a "cultivated landscape" of parkland started immediately after the beginning of the occupation of Kirikongo. With shea nut exploitation evidenced by seed testae already in Yellow I (Gallagher – Dueppen – Walsh 2016), we can assume that people chose to retain mature shea trees when first turning the environment of Kirikongo into arable land. Quite quickly larger areas must have been taken into cultivation: Sustainable traditional management practices need extensive areas. Based on a rotation scheme of 4 years of cultivation and 20 years of fallow period, one active field turns a fivefold area into early stages of parkland in less than 25 years. If three short fallow periods are followed by a long fallow period of 100–150 years (Gallagher – Dueppen – Walsh 2016), a tenfold area



a



b

Fig. 7: Kirikongo, frequency (a) and ubiquity (b) of the six most ubiquitous charcoal types, summarized per phase.

is under cultivation in less than 125 years (compare Raison 1988 as cited in Sheperd 1992: 17–18). Each short fallow cycle increases the proportion of useful and wanted trees in relation to unwanted trees. We can assume that with the evidenced population growth in late Red II and Red III, the total area of arable land and thus the area of shea parks increased again. Today, a village of 120 inhabitants manages a zone of 200 ha of shea parks, including fallows (Bernard – Oualbadet – Nklo et al. 1995); at Kirikongo a tenfold number of inhabitants is postulated (Dueppen 2022: 32–39).

22 We should not imagine a landscape dotted with mature shea trees alone, as is the case today in intensively cultivated parts of the Sudanian savanna zone. The charcoal spectrum shows that other tree taxa persisted. At Kirikongo, it regularly includes charcoal types representative of *Terminalia* spp. and *Terminalia leiocarpa* (syn. *Anogeissus leiocarpa*) as well as those of *Pterocarpus* species, possibly *Tamarindus indica* and to a lesser extent of *Combretum molle* and/or *C. nigricans* (Fig. 7). These taxa are present in shrub and tree layers in what is termed today "old" to "very old fallows" (of 15 to 20 years) in the less populated east of Burkina Faso, together with *Pterocarpus erinaceus* in some cases (Hahn 1996: 40–53).

23 The limited charcoal data of Kirikongo alone is not sufficient to reconstruct increasing proportions of shea trees in the surroundings of the settlement and an expansion of parkland area in the surroundings of the settlement. However, it is in line with the carpological analysis, which also found evidence for the expansion of parkland with the growth of the settlement. Based on seed shell thickness, Gallagher et al. (Gallagher – Dueppen – Walsh 2016) argued that as households were added to the community, they harvested their shea from new locations that were brought under cultivation.

24 Dueppen's faunal analyses (Dueppen 2022) also support the trends possibly visible in the wood charcoal. While there are periods of increasing rainfall indicated in the mid to late 1st millennium CE, it is clear in animal remains that parkland likely expanded with population increases, particularly from late Red I through most of Red III. An increase in available grazing land (including in fallow) during this period is evidenced by sheep (present from the 9th century onward), horse (12th century), donkey (13th century), and increased frequency of grassland bovids (13th and early 14th centuries). The faunal remains include continual evidence for forest taxa and those that tend to avoid humans (and areas with livestock) suggesting that even in the early 2nd millennium there, was likely abundant natural resources nearby.

A new equilibrium after population loss?

25 After 1400 CE the fuel exploitation at Kirikongo seems to have changed (Fig. 7). In parallel to population loss and a possible new emphasis on the processing of wild animal commodities, like leather, skins, ivory, feathers and teeth, recorded for Red IV (Dueppen 2022), fragments assigned to shea wood constitute less than 10 % of the assemblage. Instead, wood assigned to *Pterocarpus* species as well as of possibly *Tamarindus indica* (Detarieae IIa) is ubiquitous and much more frequent.

26 Assuming that the change in the charcoal spectrum represents vegetation change, shea wood, ready to harvest as fuel wood, must have been less available. Instead, possible *Pterocarpus erinaceus* and possible *Tamarindus indica* should have gained ground. *Pterocarpus erinaceus* is known for its ability to readily invade fallows; natural regeneration is often abundant and the species may be quite invasive, if protected from grazing and the wood is suitable for fuel and charcoal production (e.g. Aubréville 1950: 314, Burkill 1995: 428; Duvall 2008). *Tamarindus indica* is typical of long settled and cultivated areas, and its wood is suited as fuelwood as well (Aubréville 1950: 226; Burkill 1995: 172). It is feasible to assume that the reduced number of people at Kirikongo

were not able to manage an area as large as before. The wood charcoal patterns are strengthened by the similarities in environmental reconstructions and economic activities indicated in the faunal remains. Post-pandemic reforestation peaking in the early to mid 15th century (see discussions in Dueppen 2022; Dueppen – Gallagher 2024) is consistent with the timeline for forest regeneration practices indicated in wood charcoal transformations. As indicated by species distributions, Dueppen (Dueppen 2022: 214–216, see also Dueppen – Gallagher 2024) has suggested that in the latter 14th and 15th centuries a process of reforestation occurred due to a combination of population loss from the Black Death and increased rainfall, such that deep forest animals are common. The timing of reforestation in the wood charcoal and faunal analyses match what would be expected of the timeframe for forest regeneration after a population loss. In addition, forest regeneration due to population losses also occurred at a time when fauna indicates a much wetter climatic setting, matching broader reconstructions that parts of West Africa in the 14th and 15th centuries were humid (Nash – De Cort – Chase et al. 2016).

27 We should also consider the changes to not reflect vegetation change but wood selection. The increased proportions of Pterocarpus spp. stem from mainly three samples, from two contexts of Mound 4 (Fig. 3). With the evidence for leather tanning and production of other goods from hunted animals in phase IV, we cannot rule out that the possible *P. erinaceus* and *T. indica* charcoal may have been a by-product of tanning. The bark of *P. erinaceus* is used in tanning hides indeed (Burkill 1995: 429) and leaves and bark of *T. indica* are rich in tannins as well (De Caluwé – Halamouá – Van Damme 2010) and are used in tanning and dying (Burkill 1995: 172–173). While the analyzed samples are not from unambiguously industrial contexts, the ritualized depositions appear to have a relationship to life activities (Dueppen 2022). It is thus possible that this temporal pattern in the wood charcoal reflects the coinciding known change in economic practices at the site.

Archaeology of shea parks beyond Kirikongo

28 Shea was almost certainly an important resource in large areas of West Africa. Within the rich environmental setting of the Mouhoun Bend, the likely extensive landscape of shea trees must have been accompanied by a range of other trees. Due to the relatively small sample volumes and the correspondingly small number of fragments per sample, the charcoal spectrum of Kirikongo of 19 charcoal types most certainly does not show the full spectrum of exploited tree taxa. Under comparable environmental conditions, anthracological analysis of more than 2,000 fragments at Péntènga, a Late Holocene rock shelter site in Southeastern Burkina Faso, furnished 50 charcoal types. The type accumulation curve stabilized at c. 300 fragments indicating that in order to reach qualitative representativeness charcoal samples from sites in the Sudanian savanna zone should ideally contain several hundred fragments. The type richness at Péntènga is probably not solely based on the sample size; we should consider that farming did not take place there. At Kirikongo, exploiting cultivated landscapes, the number of tree species in these landscapes is reduced and a lower diversity could be expected.

29 In dryer areas slightly to the north of Kirikongo, in the Seno plain of Mali, such at Sadia (Fig. 2), shea wood could have been a larger proportion of utilized wood. The climatically more limited forest cover could have resulted in lower tree diversity around the site due to a focus on shea uses. At Sadia, shea charcoal makes up one third to half of the charcoal assemblage in the samples dating to around 1,000 CE (Huysecom – Ozainne – Jeanbourquin et al. 2015). Still, charcoal diversity is slightly higher than at Kirikongo. 1,307 fragments from 32 samples, several with about 100 fragments, and

with a mean size of 41 and a median of 27 fragments, furnished 26 types (unpublished data). At Kirikongo mean and median sample sizes are lower with 12 and 10 fragments respectively.

30 Even drier locations of the northern Sahel, such as Oudalan in northeastern Burkina Faso may mark the edges of the shea system. Shea trees may have been much more infrequent, and only able to live in particular soils with good water retention but without waterlogging. In the charcoal assemblages there, shea wood charcoal is mostly below 5 % in all samples. The charcoal samples from the region reach qualitative and quantitative representativeness usually around 150 to 200 fragments (Neumann 1999; Höhn 2005). Within more than 15,000 fragments analyzed in Iron Age samples 39 charcoal types were distinguished. Anthracologically this is the best-researched region in West Africa so far.

Conclusion

31 The wood charcoal analyses at Kirikongo document that the active management of shea to produce nuts does not limit the use of the valuable wood of the trees. Rather, it increases the use of this significant economic resource due to its extensive availability in fallows and active field systems. When combined with data from settlement history, faunal analysis, seed and fruit studies, our wood charcoal analyses also substantiate overall understandings of economic practices and environmental reconstructions. For example, as seen in shea testae data, wood charcoal substantiates a picture of the continual expansion of agricultural parkland environments from the start of site occupation corresponding with population growth. The shea trees can create a sustainable landscape of wood resources while simultaneously providing vegetal oils. With population reductions likely from the Black Death pandemic, lower shea frequencies may indicate reforestation in abandoned field systems as the landscape was less managed by a reduced human community, a pattern also seen in faunal analyses and in those seed and fruit analyses completed to date.

32 Overall, the abundant evidence for use of multiple products of shea trees at Kirikongo starting from the establishment of the settlement on the cusp of the 1st millennium BCE/CE provides historical context for more recent centuries where western Burkina Faso has been an important producer of shea for local consumption and commerce. Given the limited sample sizes and taphonomic complexities, additional detailed analyses of other sites built upon multiple lines of evidence, are needed for comparison to Kirikongo. But we suggest that in wooded savanna zones with diverse woody cover, changing shea wood ratios in charcoal samples with sufficient fragment numbers for quantitative analyses should be able to be used as a proxy for population estimates as a reflection of landscape management practices.

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Supplementary Material

35 Charcoal types – diagnostic remarks & SEM documentation (Fig. 8, Fig. 9, Fig. 10, Fig. 11, Fig. 12, Fig. 13, Fig. 14).

Types, this publication	Diagnostic remarks (more details for some types in Neumann et al. (1998) and, in German, Höhn (2005))	Type names as in Höhn & Neumann (2012)	Images
Combretum micranthum	Exclusively solitary vessels, often semi-ring porous or in diagonal pattern, no included phloem, axial parenchyma usually not visible. Vestured inter-vessel pits. Uniseriate rays with procumbent, square and upright cells mixed throughout the ray, and with enlarged cells, in which rarely the prismatic crystals are preserved.	*Combretum micranthum*	Fig. 9, this document & https://arachne.dainst.org/catalog/954/692010
Combretum molle/nigricans	Not described in above references: Exclusively solitary vessels, axial parenchyma vasicentric and aliform, included phloem (diffuse) present. Vestured inter-vessel pits. Mostly uniseriate rays with procumbent, square and upright cells mixed throughout the ray, and with enlarged cells, in which rarely the prismatic crystals are preserved.	n/a	Fig. 10, this document
Detarieae IIa, cf. Tamarindus	The type shares a combination of features with other taxa within the Detarioideae, such as vestured pits, aliform to confluent parenchyma, comparably low rays of procumbent ray cells, narrower than 5 cells, and prismatic crystals in chambered axial parenchyma. This subtype is distinguished based on the dominant aliform axial parenchyma distribution and the presence of bi-seriate rays.	*cf. Tamarindus indica*	https://arachne.dainst.org/catalog/954/616802 then Detarieae IIa
Detarieae IIb, cf. Afzelia spp.	See description for Detarieae IIa above. The Detarieae IIb subtype is separated based on the presence of wider, 3-4-seriate rays.	n/a	https://arachne.dainst.org/catalog/954/616802 then Detarieae IIb
cf. Detarium spp.	Generally in line with the typical features of many Detarioideae as described above, this type is characterized by the presence of axial intercellular canals in tangential bands and mostly 3-4 seriate rays, with some areas of square (rarely upright) marginal cells.	*Detarium microcarpum*	https://arachne.dainst.org/catalog/954/691895
Diospyros spp.	Some radial multiples of 2-4, occasionally up to 10 vessels. Axial parenchyma is diffuse-in-aggregates. Uni- to biseriate rays with procumbent, square and upright cells mixed throughout the ray, containing numerous prismatic crystals.	*Diospyros mespiliformis*	https://arachne.dainst.org/catalog/954/692013
Faboideae I	Described in Höhn & Neumann 2012 Axial parenchyma paratracheal banded (more than 3 cells wide). Vestured inter-vessel pits. 2-3-seriate rays composed exclusively of procumbent cells. Prismatic crystals in chambered axial parenchyma. Vessel elements, rays, and axial parenchyma (mostly as strands of two cells) distinctly storied.	n/a	In: Höhn & Neumann (2012): SOM, S37, Figure 12.5-8.
Flueggea/ Hymenocardia	Longer radial rows of comparatively small vessels. Rays composed of mostly upright and/or square cells, 1-3-seriate. Vessel-ray pits with much reduced borders to apparently simple, pits horizontal (scalariform, gash-like) to vertical (palisade). Septate fibres present.	*Flueggea virosa/ Hymenocardia acida*	https://arachne.dainst.org/catalog/954/692007
Grewia spp.	Most characteristic is the presence of tile cells in rays. The fragments from Kirikongo do not show ring porosity, pointing to possibly Grewia venusta/ villosa type; the number and size of fragments, however, made us refrain from the more precise allocation.	*Grewia* cf. *venusta/villosa*	Fig. 11, this document https://arachne.dainst.org/catalog/954/691894

Fig. 8a: Documentation of charcoal types: diagnostic remarks and references to descriptions and illustrations.

Types, this publication	Diagnostic remarks (more details for some types in Neumann et al. (1998) and, in German, Höhn (2005))	Type names as in Höhn & Neumann (2012)	Images
KHAYA SPP.	Description in Höhn & Neumann 2016 Axial parenchyma mostly scanty to vasicentric. Inter-vessel pits minute, often with coalescent apertures. 5–6-seriate rays, with procumbent body cells and with 1–2 rows of square/upright marginal cells with prismatic crystals. Fibres septate.	*Khaya senegalensis*	In: Neumann et al. (1998): 66, Figure 7e–f.
LANNEA SPP.	Axial parenchyma almost absent, thin-walled fibres present. Rays 2-4-seriate, with radial canals up to 6-seriate, body cells procumbent, 1 to 3 marginal rows of mostly upright cells. Silica in procumbent and prismatic crystals in upright ray cells. Vessel-ray pits with much reduced borders to apparently simple, pits horizontal (scalariform, gash-like) to vertical (palisade). Fibres exclusively septate. The presence of silica bodies and of wider rays containing the radial canals allow distinguishing this type from cf. Sclerocarya birrea (below).	*Lannea sp.*	No file
PARKIA SPP.	Like many Fabaceae the type has vestured inter-vessel pits, aliform to confluent axial parenchyma, comparably low rays of procumbent ray cells and prismatic crystals in chambered axial parenchyma. With 4-5- seriate rays, the rays are slightly wider and usually shorter than that of Detariaeae IIb.	cf. *Parkia biglobosa*	https://arachne.dainst.org/catalog/954/692115
PTEROCARPUS SPP.	Axial parenchyma paratracheal confluent and in narrow bands up to 4 cells wide. Vestured inter-vessel pits. Mostly uniseriate rays composed exclusively of procumbent cells. Prismatic crystals in chambered axial parenchyma. Vessel elements, rays, and axial parenchyma (fusiform cells or as strands of two cells) distinctly storied.	*Pterocarpus lucens*	https://arachne.dainst.org/catalog/954/691890
RUBIACEAE I & II	Both Rubiaceae charcoal types described for West Africa have almost exclusively solitary vessels, 2-3-seriate rays with over 4 rows of upright/square marginal cells, and multiseriate portion(s) often as wide as uniseriate portions. While two charcoal types can be distinguished on vessel diameter size, and vessel density, this was not possible at Kirikongo.	Rubiaceae type I, Rubiaceae type II	https://arachne.dainst.org/catalog/954/616511
CF. SCLEROCARYA BIRREA	Axial parenchyma almost absent, thin-walled fibres present. Rays 2-4-seriate, occasionally with radial canals, body cells procumbent, 1 to 3 marginal rows of mostly upright cells, prismatic crystals in marginal ray cells. Vessel-ray pits with much reduced borders to apparently simple, pits horizontal (scalariform, gash-like) to vertical (palisade). Fibres exclusively septate. The absence of silica and the presence of narrow rays containing the radial canals allow distinguishing this type from Lannea spp. (above).	cf. *Sclerocarya birrea*	https://arachne.dainst.org/catalog/954/691887
SENEGALIA/ VACHELLIA (ACACIA) SPP.	Mostly confluent, abundant parenchyma, typical, broad homocellular rays combined with crystals in chambered parenchyma, often quite large, and vestured inter-vessel pits characterize the type. At Kirikongo ray width was mostly 4-5 seriate.	*Acacia sp.*	Fig. 12, this document & https://arachne.dainst.org/catalog/954/616551

Fig. 8b: Documentation of charcoal types: diagnostic remarks and references to descriptions and illustrations.

Types, this publication	Diagnostic remarks (more details for some types in Neumann et al. (1998) and, in German, Höhn (2005))	Type names as in Höhn & Neumann (2012)	Images
Terminalia (Anogeissus) leiocarpa	In cross-section short to long radial rows of vessels but usually little parenchyma visible, thick-walled fibers and ray cells reminding of a string of pearls. Most characterizing is the radial section, where in rays one to a few rows of procumbent cells alternate vertically with usually one row of square cells. The latter may contain prismatic crystals.	*Anogeissus leiocarpus*	https://arachne.dainst.org/catalog/954/691873
Terminalia spp.	Combination of paratracheal scanty, vasicentric, aliform and confluent combined with diffuse apotracheal parenchyma. Vestured inter-vessel pits. Mostly 2-3-seriate rays, occasionally wider, with procumbent, square and upright cells mixed throughout the ray.	*Terminalia avicennioides/ macroptera*	https://arachne.dainst.org/catalog/954/691891
Terminalia spp./ Pteleopsis spp.	Similar to Terminalia spp., but with uniseriate rays.	n/a	Fig. 13, this document
Vitellaria paradoxa	Vessels mostly solitary, in clusters and short radial multiples, axial parenchyma apotracheal diffuse in aggregates and in narrow irregular tangential bands, very thick-walled fibers. Up to 4-seriate rays with body ray cells procumbent and 1 to 6 rows of square/upright marginal cells. Vessel-ray pits with much reduced borders to apparently simple, pits mostly horizontal (scalariform, gash-like). Crystals in chambered axial parenchyma, silica occasionally present in ray cells. The parenchyma distribution is irregular and in tangential view, the heterocellular rays appear "disorderly". Other possible Sapotaceae have longer radial rows of vessels and less parenchyma.	*Vitellaria paradoxa*	Fig. 14, this document & https://arachne.dainst.org/catalog/954/691888

Fig. 8c: Documentation of charcoal types: diagnostic remarks and references to descriptions and illustrations.

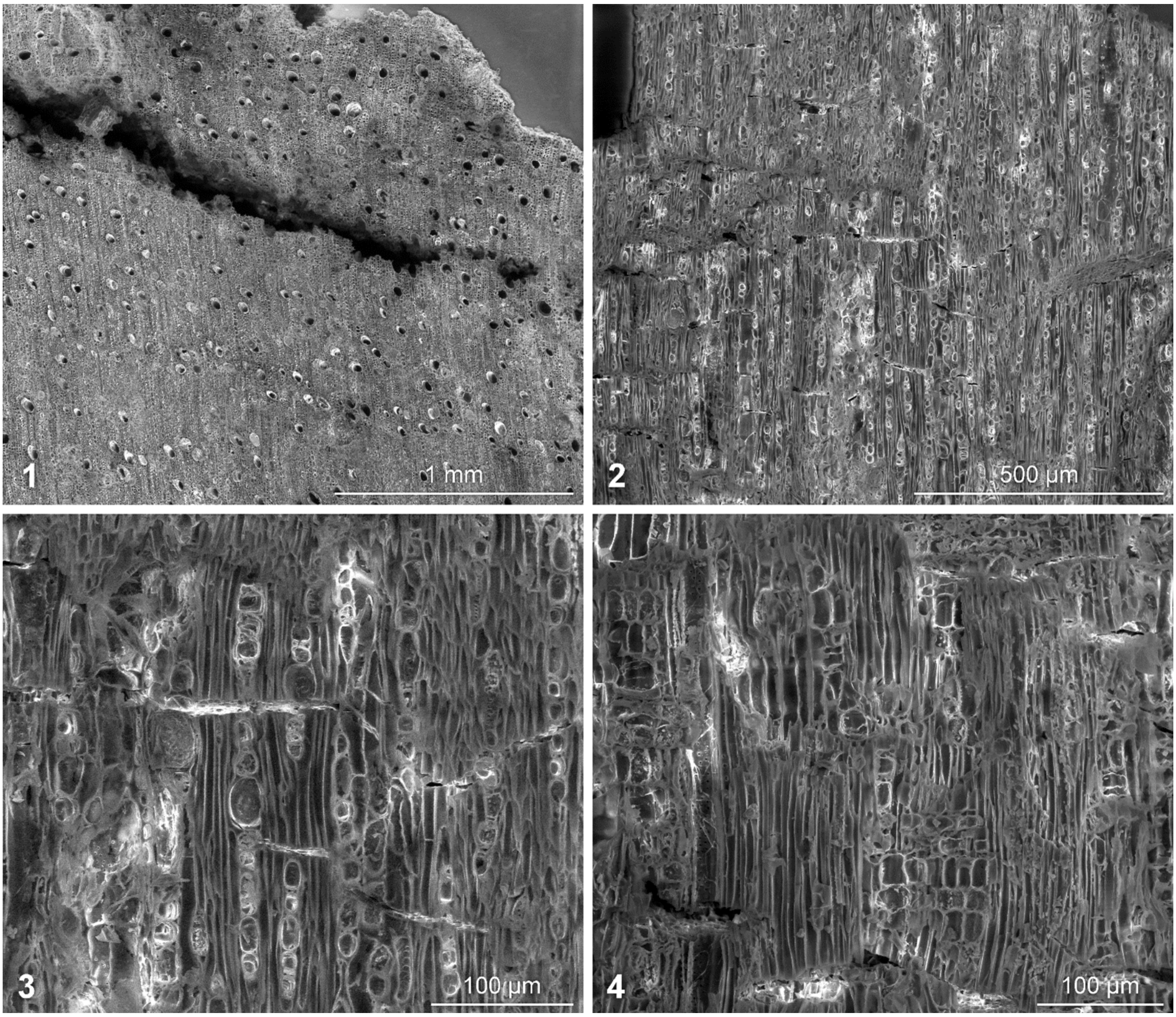

Fig. 9: SEM images of fragment 5 from sample B25 at Kirikongo, allocated to COMBRETUM MICRANTHUM. 1: transverse section, 2 & 3: longitudinal tangential section, 4: longitudinal radial section.

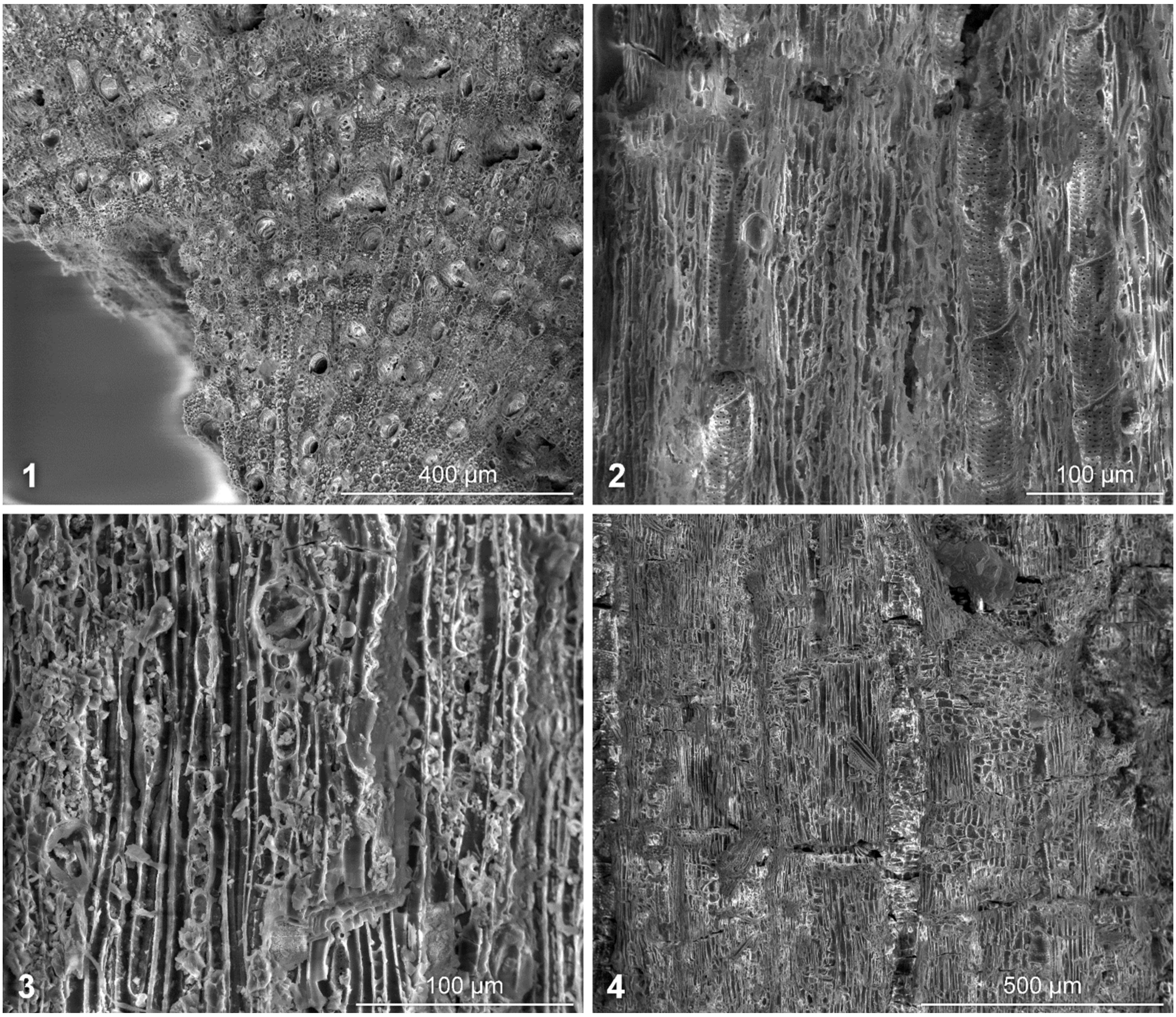

Fig. 10: SEM images of fragment 164 from sample A164 (1-3) and fragment 24 from sample B25 (4) at Kirikongo, allocated to COMBRETUM MOLLE/NIGRICANS. 1: transverse section, 2 & 3: longitudinal tangential section, 4: longitudinal radial section.

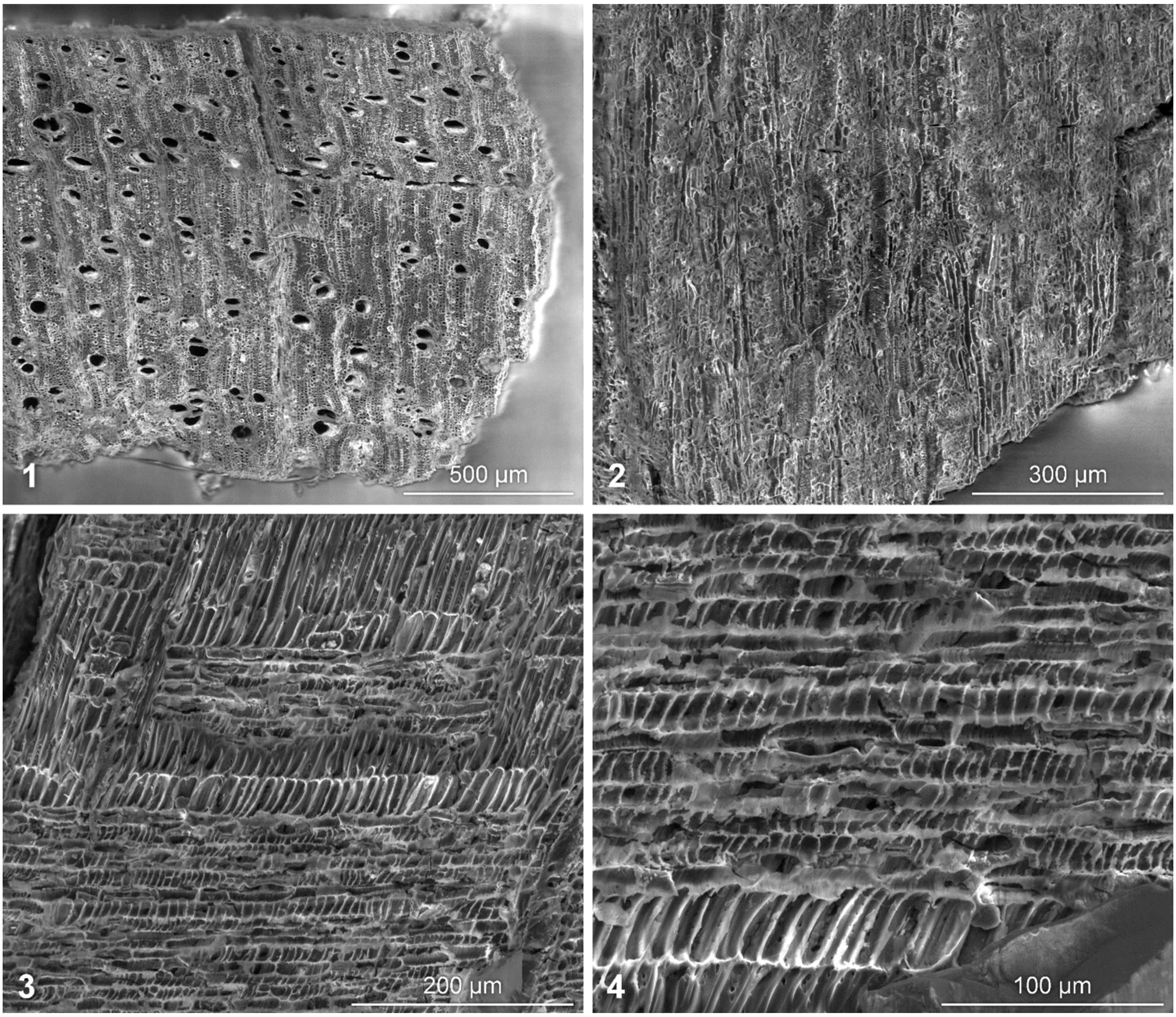

Fig. 11: SEM images of fragment 9 from sample A180 at Kirikongo, allocated to GREWIA SPP. 1: transverse section, 2: longitudinal tangential section, 3 & 4: longitudinal radial section rays with tile cells present.

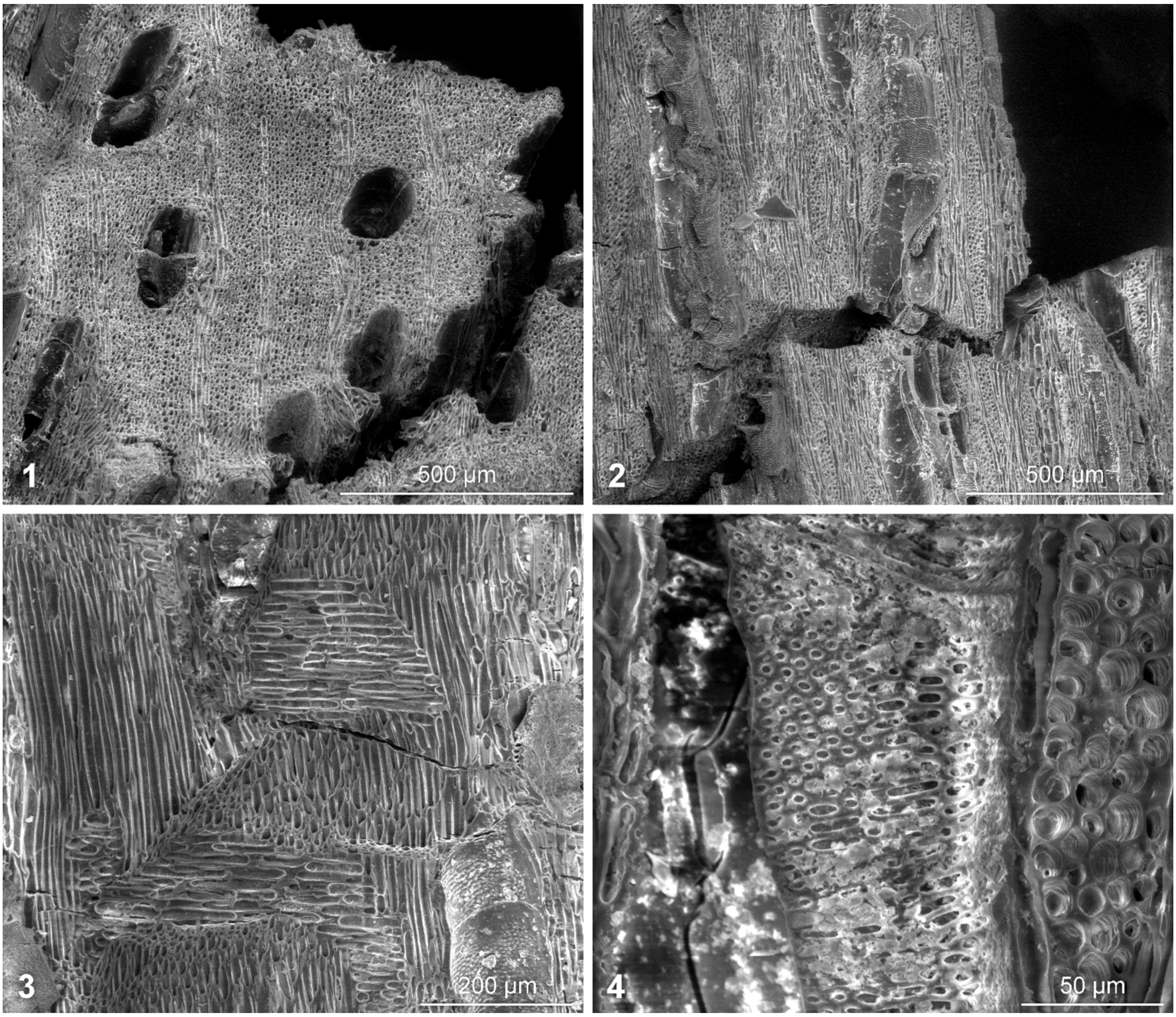

Fig. 12: SEM images of fragment 29 from sample B25 at Kirikongo, allocated to SENEGALIA/VACHELLIA (ACACIA) SPP. 1: transverse section, 2: longitudinal tangential section, 3: longitudinal radial section, 4: longitudinal tangential section, vestured inter-vessel pits.

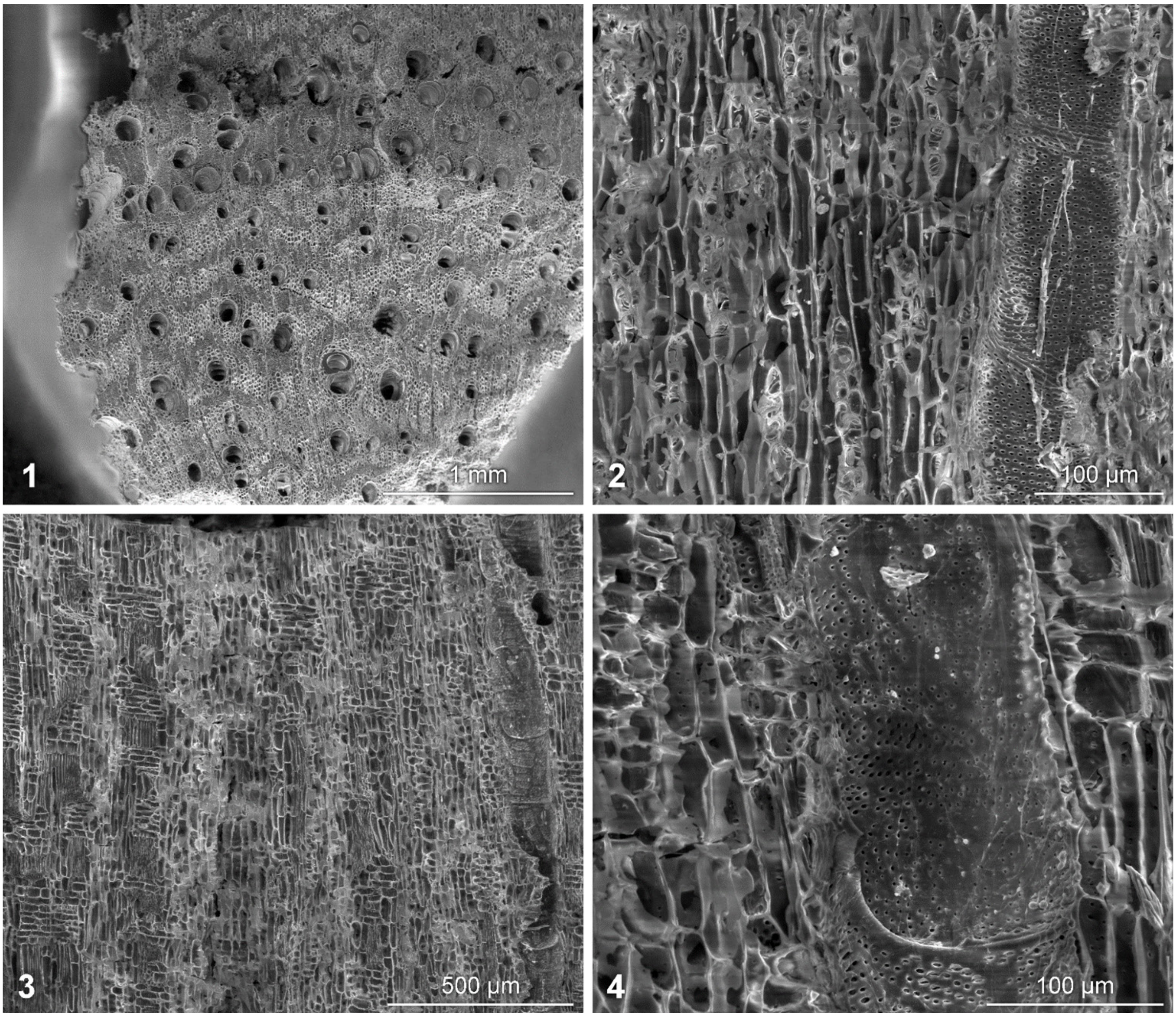

Fig. 13: SEM images of fragment 8 from sample B220B at Kirikongo, allocated to TERMINALIA/PTELEOPSIS. 1: transverse section, 2: longitudinal tangential section, 3: longitudinal radial section, 4: longitudinal radial section, vessel-ray pits with distinct borders; similar to inter-vessel pits in size and shape throughout the ray cell.

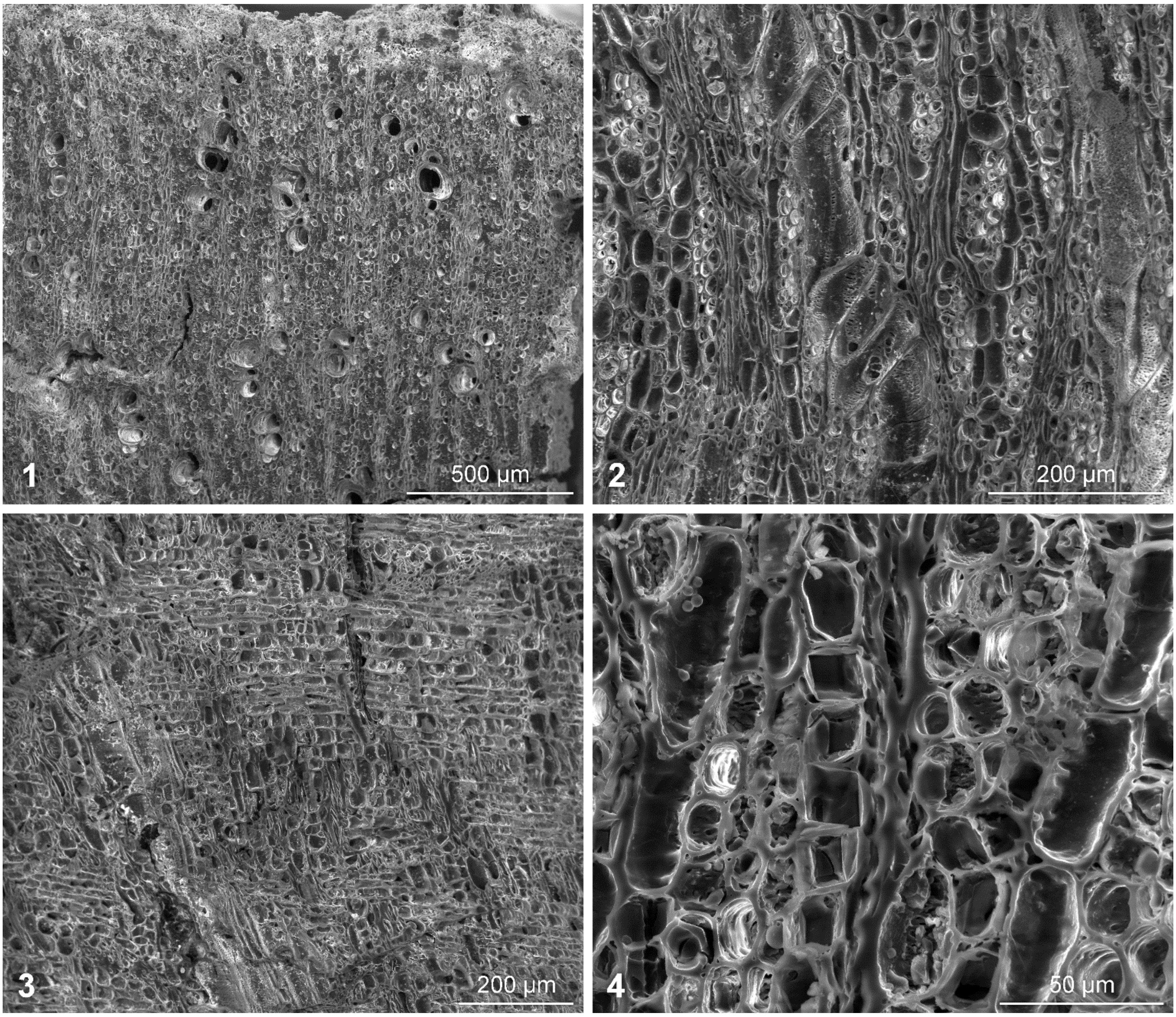

Fig. 14: SEM images of fragment 1 from sample B114 at Kirikongo, allocated to VITELLARIA PARADOXA. 1: transverse section, 2: longitudinal tangential section, 3: longitudinal radial section, 4: longitudinal tangential section, prismatic crystals in chambered axial parenchyma cells.

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