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ORIGINAL ARTICLE

The Sangha River Interval, Its Earliest Village Settlements, and the Bantu-Speakers' Expansion During the Late Holocene (Cameroon, Central African Republic, Congo Republic)

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Abstract A broad agreement exists that towards the end of the Holocene in Central Africa there was a drier climatic episode called the "Late Holocene Forest Crisis" (LHFC) that impacted the Central African rainforest, its peak lying between c. 2500 and 2000 cal yr BP. The Sangha River Interval or SRI is such a hypothesized rainforest biome where savannas were understood to have developed. This climate-driven LHFC has been thought to have benefited the first village communities, migrating from Cameroon towards the south before 3000 cal yr BP. We review for the first time all the pertinent and extant data relating to the paleoenvironment and archaeology of this region from the last 3000 years. We conclude the SRI was more limited in extension than previously thought, that tropical forests were maintained within it throughout the period, and lastly, that the earliest pottery-using settlements are dated from c. 2200 cal yr BP. Thus, the SRI probably did not play a role in the expansion of the first village communities because when the Interval was initially settled, villagers had already reached the Congo River near the border to Angola some 800 km away to the south passing through coastal forests and savannas and the inland forests, bypassing the SRI.

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Résumé Il existe un large consensus sur le fait que vers la fin de l'Holocène en Afrique centrale, il y a eu une phase climatique plus sèche dénommée "Crise Forestière de l'Holocène Tardif" (LHFC) qui a affecté la forêt tropicale d'Afrique centrale. L'intervalle de la rivière Sangha (SRI) est l'une des régions concernées. Cette crise forestière a eu en Afrique centrale un impact maximum sur le couvert forestier entre environ 2500 et 2000 ans cal BP. Cette crise climatique aurait profité aux premières communautés villageoises migrant du Cameroun vers le sud depuis avant 3000 cal BP. Nous passons en revue pour la première fois toutes les données pertinentes relatives au paléoenvironnement et à l'archéologie de cette région pour les 3000 dernières années. Nous pouvons conclure que la surface occupée par le SRI était plus restreinte qu'envisagé auparavant, que des forêts tropicales s'y sont maintenues tout au long de la période, et enfin que les premières commu-

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nautés utilisatrices de poterie sont datés aux environs de 2200 cal BP. Cet intervalle de la rivière Sangha n'a donc probablement joué aucun rôle dans l'expansion des premières communautés villageoises car lorsque l'Intervalle a été initialement peuplé, d'autres villageois avaient déjà atteint le fleuve Congo, près de la frontière angolaise, à quelque 800 km de là vers le sud, traversant les forêts et savanes côtières ainsi que les forêts de l'intérieur, contournant le SRI.

Keywords Central Africa · Sangha River Interval · Holocene · Iron Age · Late Holocene Forest Crisis · Bantu-speakers' expansion

Introduction

The *Sangha River Interval*, or SRI, is a vast area covering parts of south-east Cameroon, south-west Central African Republic (CAR), and north Congo. It is located between the two main floristic sub-centers of endemism proposed by White (1978, 1979): (i) the Guinean to the west and (ii) the Congolian to the east. The SRI was primarily defined using biogeographic interpretations of botanical data, but its boundaries were not well defined (Doumenge et al., 2014), consequently no map defines precise boundaries (Fig. 1 for the most reproduced version and Fig. 2 for a better one).

Our SRI study is firmly set into a regional paleoenvironmental sequence developed recently based on a reassessment of all the data from the sites studied on land and offshore (Bouimetarhan et al., 2021; Giresse et al., 2020, 2023; Lézine et al., 2019, 2023). Anthropogenic Impact (AI) identification mainly depends on the existence of archaeological sites from the time period considered and on wood charcoal deposited in soils, rivers and lakes, and on pollen from secondary vegetation, presumably resulting from land clearing by local communities (e.g., Lanfranchi & Schwartz, 1990a, 1990b). This was necessitated by hunting, for pest reduction, horticulture, obtaining wood or charcoal for cooking, pottery-making, and iron smelting.

Previous studies show that the limits of the SRI were never properly described (see the latest approximation in Schmitt et al., 2023, Fig. 1), the paleo-evidence had never been correctly processed, and a full archaeological assessment was needed for the data collected since M. Eggert's (1992) early fieldwork. Though Eggert's results were only fully studied and reported in a PhD thesis (Seidensticker, 2017, 2021), the main results (presented recently in English, Seidensticker, 2024) come from radiocarbon-dated excavations outside the SRI as illustrated by Fig. 2.

Between 2020 and 2022, we carried out an in-depth review of the SRI evidence by compiling botanical, palynological, and archaeological data together. Successive versions of our work in progress were made available in pre-prints on the Research Gate web site. Since then, some of the environmental conclusions were made available elsewhere (Giresse et al., 2020, 2023). We focus here on the archaeology and a discussion of the environmental evidence from within the "new SRI."

We argue in this paper that:

i. the extent of SRI savannas was very restricted and did not form a "corridor." The contraction of the tropical forest, which appears today to have been far less than previously reported, was not an important factor driving the first villager/horticulturist expansion into Central Africa that started from the Cameroon at the latest around c. 3000 cal yr BP, centuries before the peak of the LHFC;
ii. based on the present state of knowledge, the first village settlers did not invest the SRI before c.2200 car yr BP and iron-working was not practiced before c.1900 cal yr BP;
iii. the AI was probably limited to the installation of the first villagers, subsequently growing and becoming significant in the record by the Late Iron Age (LIA) as a result of increased demographics and the development of iron metallurgy;
iv. the SRI hosted a secondary and much younger expansion of possibly Bantu-speaking pottery-using communities through the equatorial rainforest centuries after an initial one, which probably followed the western Atlantic coastline.

The Ancient Environment and Climate

Following a somewhat cold Late Pleistocene when the forests of Central Africa were restricted to refuges (e.g., Lézine et al., 2019; Maley et al., 2018), the Early and Middle Holocene witnessed a humid period

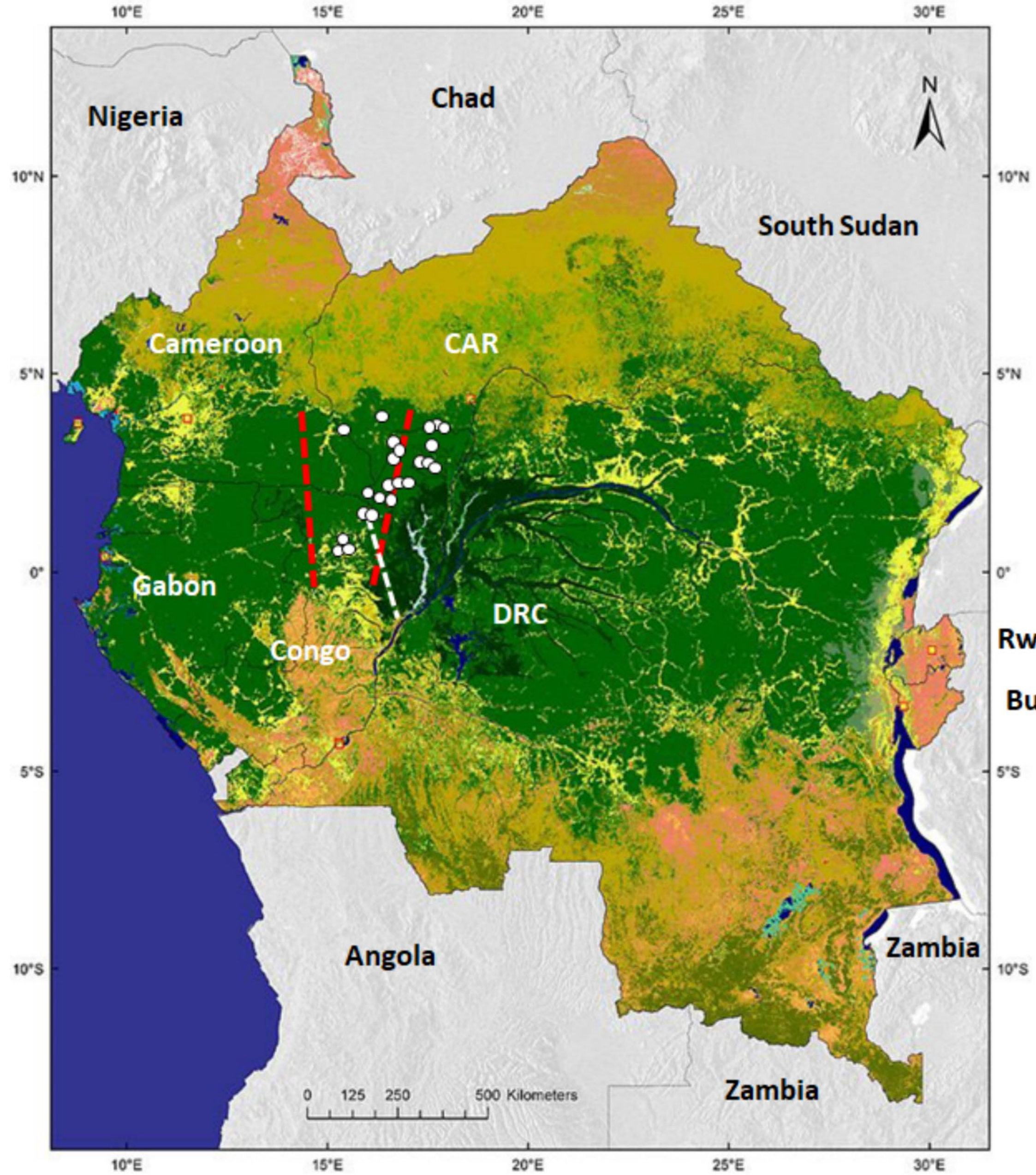


Fig. 1 Botanical map of Central Africa with the limits of the Sangha River Interval (red dashes), the position of the Sangha River (white dashes), the sites with paleo-evidence (white dots), and the main vegetation types (very dark green: edaphic forest; dark green: dense moist forest; light green: forest savanna mosaic; light brown: savanna woodland; yellowish: from shrubland to grassland). Adapted from Verhegghen et al. (2012), Fig. 3

initiated in the Late Pleistocene (Lézine et al., 2019) that permitted a vast expansion of rainforests (Maley, 1996), the African Humid Period (AHP). During the Late Holocene, from c. 3500 cal yr BP, a much drier climatic episode is supposed to have allowed an expansion of savannas at the expense of forests on the edge of the massif and along the Atlantic Ocean coastline (Maley, 1990; Schwartz, 1991). The data

Fig. 2 Location map of the paleo-evidence sites and the limits of the SRI, adapted from Doumenge et al. (2014). 1: Mopo Bai. 2: Goualougo Lake. 3: Bemba Yanga. 4: Bodingué. 5: Mbaéré River. 6: Loamé River

indicated a regional reduction in forest cover. According to Maley (1990, 2002) and Schwartz (1992), openings in the equatorial rainforest c. 2500–2000 cal yr BP resulted from climatic dry episodes rather than human activity known to have existed since the Stone Ages (Lanfranchi & Clist, 1991). As early as 1992 Schwartz argued that this climatically induced change enabled horticulturalist communities—possibly Bantu-speakers—to move through the forests, while some highlighted a coastal expansion (e.g., Clist, 1990, 1991; Vansina, 1990).

An ongoing debate since the 1990 s led to a series of studies to disentangle the respective roles of climate and human activity regarding forest regression (see syntheses in Lanfranchi & Schwartz, 1990a; Schwartz & Lanfranchi, 1993; Vincens et al., 2000). This led to the question of whether the incomers were responsible for any long-term changes resulting in the composition of modern-day forests, in other words what was the "Anthropogenic Impact" (e.g., Lanfranchi & Schwartz, 1990a; Clist, 1999; Willis et al., 2004; Brnic et al., 2007; Kiahtipes, 2019; for the latest see Giresse et al., 2020, 2023). With increasingly drier conditions, it has been suggested that by c. 2500–2000 cal yr BP, the Equatorial rainforest had fragmented into a western and an eastern "refuge" separated by a large savanna corridor along the Sangha River, the SRI, that linked the Northern Sudanian savannas to those of the Southern Batéké Plateau (Fig. 1) (Maley, 1990, 2001; Maley & Willis, 2010). On the other hand, Bayon et al. (2012a) and Garcin et al. (2018a) posited that the widespread vegetation change of the Late Holocene was due to the expansion of iron-using farmers who cleared land around their villages. This has been vigorously contested because of the possible low numbers of inhabitants coupled with unequal spatial spreading of the villages (Clist et al., 2018a, 2018b; Giresse et al., 2018; Maley et al., 2012; Neumann et al., 2012). Predictably, the authors have reacted (Bayon et al., 2012b; Garcin et al., 2018b, 2018c).

The doubt regarding the alleged important expansion of savannas within the SRI had been proposed earlier in a few papers (Doumenge et al., 2014, Bentaleb et al., 2015, Bremond et al., 2017, and Desjardins et al., 2020, the latter specifically about southern Cameroon) and two unpublished PhD theses (Gillet, 2013; Kiahtipes, 2016); Bentaleb et al. (2015) then concluded that "the vegetation of the Guineo-Congolian Region was disturbed between 3000 and 2000 BP (Before Present) without an extreme savannah expansion" contradicting both Grollemund et al. (2015) and Bostoen et al. (2015), both published at the same time. A ground-breaking study by L. Bremond and colleagues found, using a multi-proxy approach, that out of 18 cores obtained within the SRI to investigate past vegetation changes, 16 showed a continuous forest pattern, at some time since c. 6000 cal yr BP (Bremond et al., 2017; and see below "Sangha River Interval: soil profiles"). Giresse et al. (2020) making use of more recent fieldwork concluded that the corridor was not covered by savanna but by pioneer taxa and an open canopy forest with a low density of large trees; it has been further suggested, based on archaeology and M. Eggert's data from his few excavations and associated radiocarbon dating south-east of the SRI, that the interval was settled late c. 2200–2000 cal yr BP (Clist, 2022). This idea has been strengthened recently in a PhD thesis studying surface-collected artifacts by Eggert along the Sangha River near Ouesso, i.e., from within our newly defined SRI. It found no pre-2200 cal yr BP pottery there (Seidensticker, 2017, edited later in book form in Seidensticker, 2021).

Today, there is broad agreement among most specialists that the expansion of fragmented vegetation into previously forested lands was climate driven (Bayon et al., 2019; Giresse et al., 2020; Maley et al., 2018). A drier climate starting c. 5000 cal yr BP (Schwartz, 2003) had the largest impact on forests between c. 2500 and 2000 cal yr BP (Maley et al., 2018). The full spatial extent of forest fragmentation remains uncertain because of the paucity of good empirical data for research. What is true today was even more so back in 2015. It has been further suggested this fragmentation first occurred on the periphery before extending deeper into the forests, like the SRI area, and that it could have been limited for edaphic reasons to specific sectors of the forest. Subsequently, a more humid climatic phase followed, that led to a new expansion of forests after c. 2000 cal yr BP, before the onset of the "Medieval Warm Period" (MWP) dated between c. 1200 and 800 cal yr BP, and the "Little Ice Age" (LIceA) dated between c. 700 and 100 cal yr BP (e.g., DeMenocal et al., 2000a, 2000b; Lüning et al., 2018; Mann, 2002; Nash et al., 2016; Russell & Johnson, 2007; Verschuren & Charman, 2008; Verschuren et al., 2000). It has been suggested these were not global events, but regional variations (Neukom et al., 2019). The real impact on Central Africa of the latter two climatic periods has been recently investigated, concluding "… that northern Congo has experienced long dry periods and burning and yet has remained forested throughout the last 2580 years testifies to the resilience of its tropical forest" (Giresse et al., 2023, 18).

The Bantu-Speakers Expansion Models and the Environment

The well-recognized bantu languages diffusion from Central Africa to Eastern and Southern Africa has benefited from a long tradition of academic studies with a strong historical perspective (e.g., Vansina, 1979, 1980, 1984, 1990, 1995). These led to the publication of a series of expansionist models for the documented languages (Bostoen et al., 2015; Grollemund et al., 2015; Koile et al., 2022; Rexova et al., 2006; Russell et al., 2014) (too) often associated with archaeology (Eggert, 2005; Vansina, 1990). P. de Maret reminded us that "… *from a methodological standpoint, Bantu is a linguistic term, while a mute archaeological artefact is not Bantu*" (de Maret, 1989: 129).

The chronology of the languages expansion hinges around the use of their respective calibration points. These points were identified different ways: making use of the oldest pottery associated radiocarbon dates identifying the oldest period of occupation (Bostoen et al., 2015; Russell et al., 2014; Vansina, 1990), i.e., "*to compile archaeological radiocarbon dates for their first observed occurrences throughout the geographical region of interest, and to look for spatial gradients in arrival times"* (Russell et.al. 2014: 2), and by extrapolating a parallel between the evolution of the material culture and the evolution of languages (Grollemund et al., 2015; Koile et al., 2022). Koile and colleagues have copied the ones from Grollemund et al. "*We calibrated four parts of our trees: three using date ranges and one as a fixed point*" (Grollemund et al., 2015). The calibration ranges are extrapolated from the Stone Age layers of the Shum Laka rockshelter, whose burials were later identified to be of non-bantu hunter-collectors (Lipson et al. 2020), from the Obobogo site near Yaoundé in Cameroon, and from the Urewe ceramic tradition in the Interlacustrine region of Eastern Africa. The connection between Central and Eastern Africa Bantu-speakers is notably hampered by a chronological gap (Ehret, 2015).

The latest model, in 2015, has included the notion of a vast savanna corridor extending over the SRI (Grollemund 2015; Bostoen et al., 2015), a view still accepted until recently by historical linguists (e.g., Grollemund et al., 2023) and also by some archaeologists (e.g., de Maret, 2018). Evidence is now solid that the expanding languages were carried by moving peoples as demonstrated by genomics (Fortes-Lima et al., 2023; but we need to remain cautious about some aspects, see Eggert, 2016). Several authors consider that the first farmers or horticulturalists of the Early Iron Age (EIA), perhaps Bantu-speakers, could have used this hypothesized savanna corridor as an opening through the forests leading to the southern savannas of the Congo, the Democratic Republic of Congo (hereafter DRC), and to Angola (Russell et al., 2014; Grollemund et al., 2015, 2023; Bostoen et al., 2015; de Luna, 2017; Holl, 2017; Coupé et al., 2017; de Maret, 2018; Almeida, 2020; Koile et al., 2022).

Sangha River Interval Botanical Evidence

According to White (1979), the SRI is at least 400-km wide and extends from 14° to 18° E in the Guineo-Congolian regional center of endemism in south-eastern Cameroon, south-eastern CAR, and the northern Congo (Gillet & Doucet, 2012) (Fig. 2). Its eastern edge is characterized by large areas of swampy forest, especially along the lower Sangha, the Likouala, and the Likouala-aux-Herbes rivers (Gond et al., 2013) where vast deposits of peat have arisen since at least c. 10,700 cal yr BP (Dargie et al., 2017; Garcin et al., 2022). White (1978, 1979) defined the SRI by the absence of certain endemic plant species otherwise found in the Guineo-Congolian Region. However, White's (1983) chorological definition of the Guineo-Congolian Region classification was mainly based on the interpretation of empirical data in a first attempt to clarify the boundaries of bio-geographical regions.

Later, using cluster analysis and non-metric multidimensional scaling of species distributions, Linder et al. (2005) classified the SRI area in the "Congolian undifferentiated" category, with fewer species than the surrounding "Congolian" group. According to these authors, however, care must be taken with their interpretation, since the smaller number of species could simply reflect collecting intensity rather than an actual difference in species richness.

This hypothesis was confirmed by Sosef et al. (2017), for example, Gillet and Doucet (2012) found many species that had never previously been reported in the SRI. Indeed, Droissart et al. (2018) showed that the SRI lies at the boundary between two endemic sub-centers of the Guineo-Congolian region, the west of lower Guinean affinity, the east with a greater Congolese affinity, and transition zones to the north and south. In their classification, the SRI corresponds to an overlap and/or admixture between biogeographical sub-centers. Fayolle et al. (2014b) also found little support for floristic differentiation in the SRI, its vegetation mainly belonging to a "moist cluster." The climate of the SRI is relatively homogeneous, and the vegetation is predominantly that of a semi-deciduous forest (Philippon et al., 2019).

Seven functional types of *terra firma* forest coexist in the SRI (Fayolle et al., 2012, 2014a).

The local abundance of extremely large trees of light-demanding species such as *Triplochiton scleroxylon* and *Terminalia superba* is indicative of old secondary forests. These forests probably developed two centuries ago as shifting cultivators abandoned their lands (Bourland et al., 2015; Gillet & Doucet, 2013; Morin-Rivat et al., 2017). In the SRI, human occupation patterns were strongly modified following the colonization of the Central African region in the 1900 s. Local communities were forced to gather along main roads and abandoned cultivated areas allowing the regeneration of woody species that today dominate the canopy (Van Gemerden et al., 2003; Aleman & Fayolle, 2020).

In some places, *Marantaceae* forests (De Namur, 1990; Gillet & Doucet, 2012), or very open forests (Gond et al., 2013), cover important areas. In those forests, tree regeneration is prevented by the dominance of the *Marantaceae* and *Zingiberaceae* families. The mechanism shaping the dominance of these giant herbs is explained by an old, intensive and widespread human occupation on relatively humid soils (Brncic, 2002). Gillet and Doucet (2013) found in their soil a great abundance of wood charcoal with charred *Elaeis guineensis* (oil palm) endocarps dated between 2300 and 900 BP.

Only some areas of the SRI are savannah. According to Harris (2002), their position towards the main savanna-forest boundary to the North, and the sandy soil on which they occur, indicate that both climatic and edaphic factors may explain their origin. Their persistence can be understood by the occurrence of annual fires that prevented forest colonization.

A forest nature of SRI vegetation is thought to have persisted over the last two millennia, with only its north-eastern part being "bistable." The probability of observing savannah in the SRI over the last two thousand years is very low (Aleman et al., 2020) except in the extreme north of the Republic of Congo and the south of the Central African Republic. In summary, these various studies show that the relative poverty of the SRI in endemic species is linked to an intermediate phytogeographical position and not to savannah colonization, since these were not present during the last two millennia.

Sangha River Interval Paleo-Evidence

The SRI shows practically no lacustrine depressions likely to preserve sedimentary records or register a continuous chronostratigraphy of Quaternary paleoenvironments. As a result, there is scarce paleoenvironmental information available from alluvium, areas of swamp forest, or soil profiles from which pollens have generally disappeared. Only one site, Mopo Bai (Fig. 2, n°1), has a depression that acted as a sedimentary basin. A single coring provides the most complete record to date and its study will be presented as a primary reference. We will then consider the more fragmentary and time-restricted data available from other sites, noting that they are either on or near its eastern border (Mopo Bai, Goualougo lake, and Bemba Yanga), or outside of it (Bodingué, Mbaéré River, and Loamé River).

We illustrate our presentation by providing simplified pollen diagrams adapted from the original publications describing sites within the SRI (Figs. 3, 4, and 5). Species representing a minimum of 20% of total counts are shown for Mopo Bai and Goualougo, with the exception of Celtis at Mopo Bai, of Poaceae and *Elaeis guineensis* at Goualougo, and a minimum of 10% of total counts at Bemba Yanga.

Sangha River Interval Pollen and Micro-charcoals

Mopo Bai is a small sedimentary basin located in a swampy area south of the Dzanga-Ndoki protected area in a logged, semi-deciduous lowland forest of the northern Congo (50 km north Ouesso) (Fig. 2, n°1). The site is in the central part of the bio-geographic SRI. A multiproxy palaeoecological analysis has been done on a 1-m-long core (Brncic et al., 2009).

The analyses included fossil pollen, geochemical assays, and microscopic charcoal analysis. The chronology, based on eight ^{14}C (AMS) and Optically

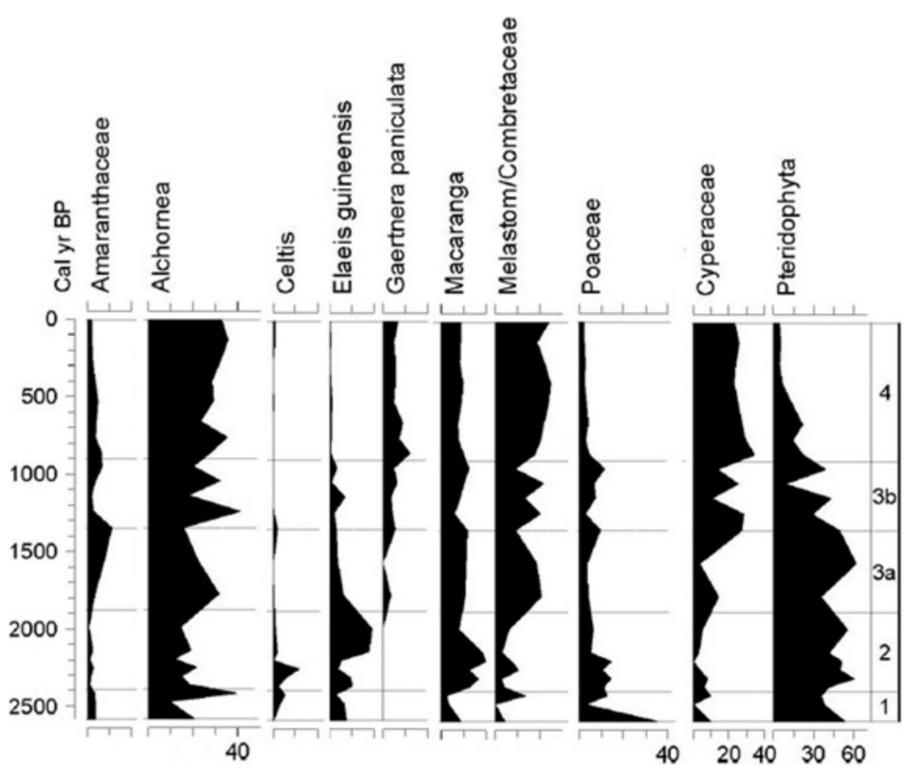
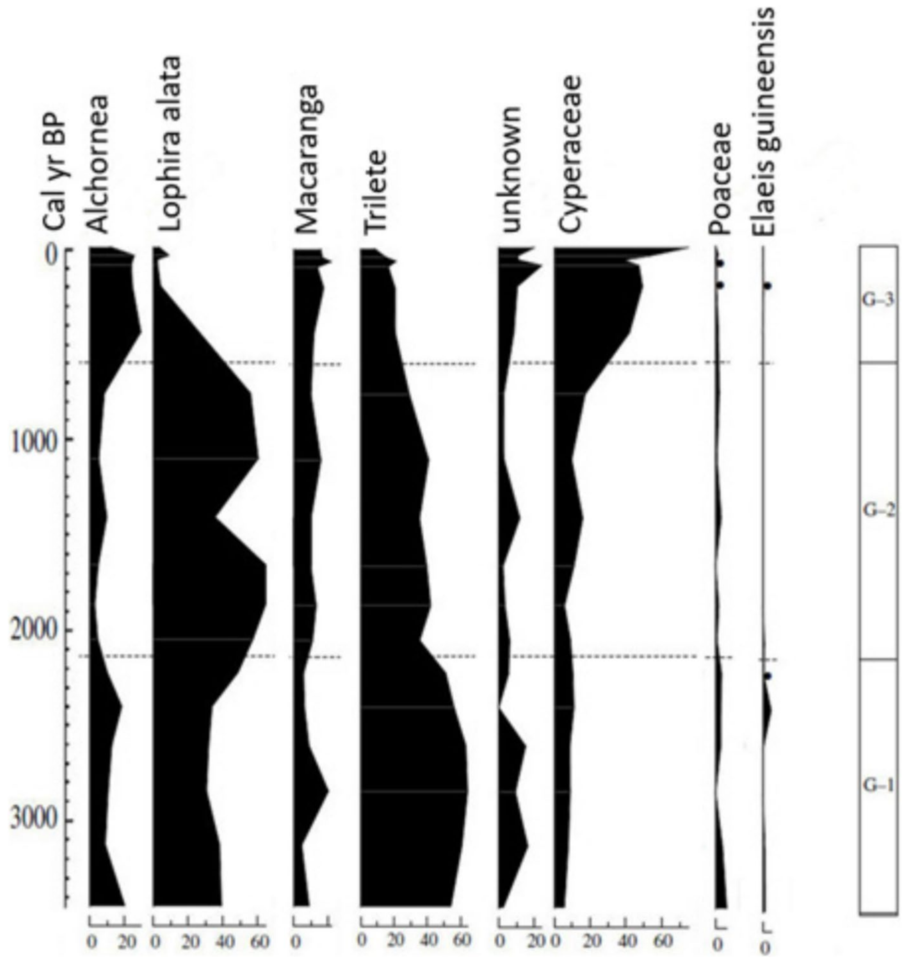


Fig. 3 Mopo Bai pollen types plotted against age and pollen zones. Redrawn from Brnic et al. (2009), fig. 4. Pollen counts limited to 20% and over

Fig. 4 Goualougo lake pollen types plotted against age and pollen zones. Redrawn and adapted from Brnic et al. (2007), fig. 4. Pollen counts limited to 20% and over



Stimulated Luminescence (OSL) dates, indicates that the base of the core dates to c. 2500 cal yr BP.

Goualougo lake is located c. 60 km east of Mopo Bai in Nouabale-Ndoki National Park (Congo) (Fig. 2, n°2). It lies in a vegetation zone of semi-deciduous rainforest. A sedimentary core approximately 68 cm in length was collected from this basin that records roughly the last 3300 years of landscape history (Brncic et al., 2007). Six samples were dated by AMS ^{14}C and ^{210}Pb. However, because the sedimentation rate was almost twice as slow at Mopo Bai, the recording resolution of Goualougo was less precise.

Bemba Yanga is a small nonephemeral pond northeast of Goualougo lake, without any in or out flowing stream. In the dry season, it is 100 m in diameter and 1-m deep (Tovar et al., 2019; and our Fig. 2, n°3). A 52-cm-long core was extracted, with its bottom dated at c. 4700 cal yr BP. Only the upper part was studied which yielded a 2700-year stable pollen profile.

At Mopo Bai, micro-charcoal is present from the base of the core up to around 1345 cal yr BP, with minor peaks at c. 2415 and 2250 cal yr BP. After c. 1345 cal yr BP, charcoal concentrations increase in a series of successive peaks. At Goualougo, a peak before 2400 cal yr BP may correspond to the one from Mopo Bai. Another c. 2000–1500 cal yr BP is unique to Goualougo. The later profile is again similar to Mopo Bai, with well-marked increases in charcoal deposits from 1240 cal yr BP to modern times.

The wood charcoal signature implies an increase in anthropic impact, rather than natural fires. This impact might have resulted from slash-and-burn horticulture and an increase in iron smelting activities, which are well documented by the increase in ^{14}C dates from

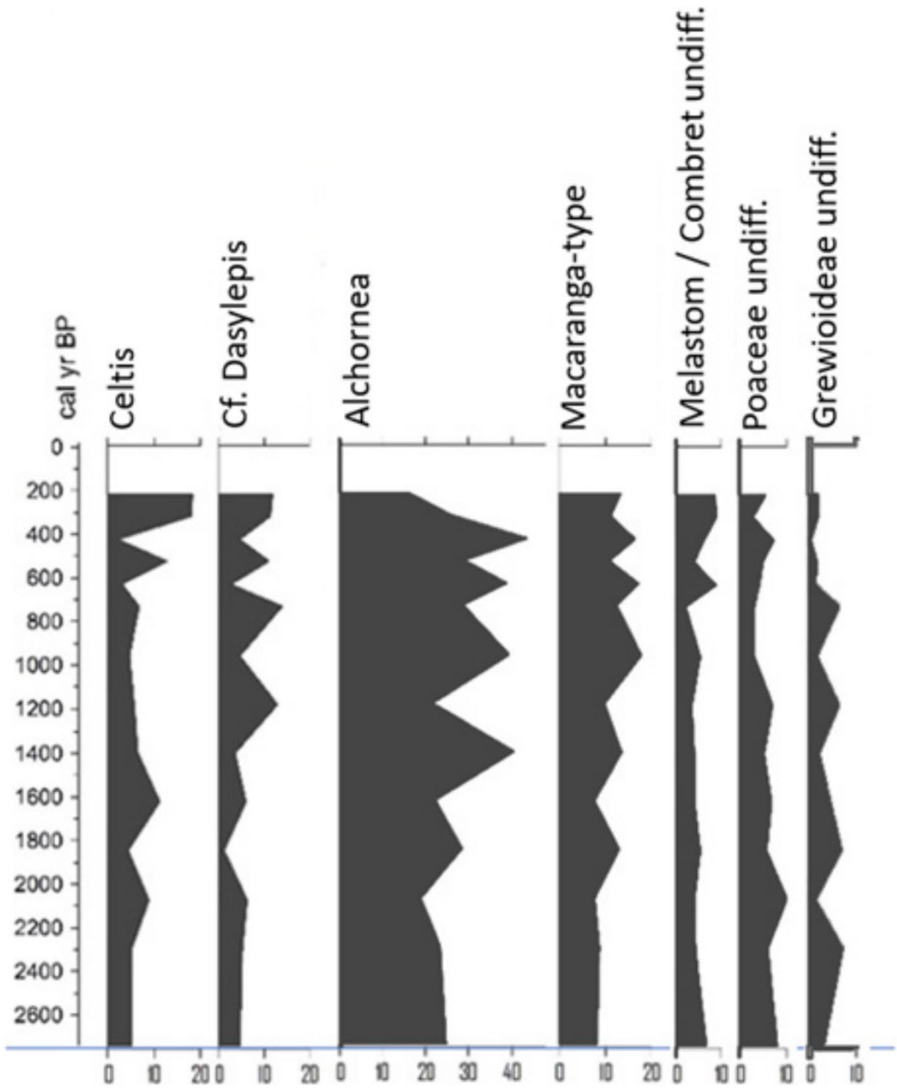


Fig. 5 Bemba Yanga pollen types plotted against age. Redrawn and adapted from Tovar et al. (2019), pollen counts limited to 10% and over

archaeological villages and the number of iron-working sites. These would have contributed to the fire signal and to other indications of local forest degradation (see below section "SRI Archaeological Evidence" and the 160 ^{14}C dates in the Appendix).

The results of the microscopic charcoal analysis at Mopo Bai and Goualougo recorded low levels of charcoal concentration in the lower part of the core, and an increase in the upper part after 1400 cal yr BP or at Bemba Yanga where this is dated after 500 cal yr BP.

Overall, data gathered from the three sites found along the eastern edge of the SRI (Fig. 2) not far from each other is the best and cover the most time, extending over slightly more than 3000 years.

Apart from the lower part of the Mopo Bai sequence where a marked development of Poaceae is present (Fig. 3), "which is probably related to a brief period of local savannah expansion" (Giresse et al., 2020, 10), all the other pollen zones (Fig. 3) illustrate that "a semi-deciduous lowland forest exists at similar abundances throughout the sequence, indicating the persistence of lowland semi-evergreen rainforest" (Giresse et al., 2023, 12). The Goualougo and Bemba Yanga pollen profiles circa 60 km to the east illustrate a similar situation (Figs. 4 and 5).

Sangha River Interval: Soil Profiles

In a multi-proxy approach to investigate past vegetation changes, soil organic carbon $\delta^{13}C$ was analyzed from 18 soil profiles across the SRI, with phytolith signatures obtained from four of them (Bremond et al., 2017). Their geolocation shows that they come from the center and the eastern side of the SRI (Fig. 1).

Modern $\delta^{13}C$ values for forests are all under −24‰, with values for a forest/savannah ecotone at around −21‰, and savannahs at or greater than −18‰ (Aleman et al., 2012; Desjardins et al., 2013). These values are consistent with others obtained in Cameroon, the CAR, Congo, and Gabon (Clist, 2006a; Guillet et al., 2000; Makaya et al., 2012; Runge, 2001; Schwartz et al., 1990, 2000).

According to the AMS ^{14}C dates, the oldest age of profiles obtained from Soil Organic Carbon (SOC) is c. 6000 cal yr BP. They are thus all Middle-Late Holocene. Three of the four profiles studied for phytoliths were from a modern *Marantaceae* forest (F7, F17, F19), with the fourth from a present-day wooded savannah (F15). The lowest portion of the four profiles is dated from 3650 to 4770 cal yr BP. The series of profiles thus cover the period of the LHFC.

Sixteen of the locations portray with their SOC $\delta^{13}C$ isotopic composition a continuous forest signature during the Crisis. The phytolith assemblages confirm the persistence of forest cover. Only two of 18 profiles have $\delta^{13}C$ values that are clearly higher than −25‰ indicative of a wooded savannah or a savannah. The F15 profile illustrates a change from a forest to an open forest, then a savannah, starting around 3100–3000 cal yr BP, which is consistent with the LHFC timing. The Mpu site shows a continuous savannah profile. The F15 site is situated on the southern periphery of the rainforest in Congo, while the Mpu site is in the CAR on its northern limit. They support the notion the LHFC mainly impacted the periphery of the rainforest.

Other Evidence from Pollen, Micro-charcoals, and Soil Profiles

Three other similar studies lie outside the Interval: Bodingué, Mbaéré, and Loamé rivers situated in the Ngotto forest (CAR) (Fig. 2, n°4, 5 and 6 respectively).

Using pedological analysis of cores, AMS dating of soil organic matter, and $\delta^{13}C$ readings, Neumer et al. (2008) had already concluded that a stable forest cover existed throughout the Holocene without any expansion of savannahs (Fig. 2, n°5): "The delta 13 C values point to a permanent afforestation of the valley during the Holocene. These values legitimate the assumption that within this valley plain neither grass-dominated savanna vegetation nor the flood grasslands, characteristic for valleys under comparable climatic conditions, have developed" (Neumer et al., 2008, 132).

Later, Kiahtipes (2016) reported palynological and geochemical data from three cored fluvial deposits in the same area: the Bodingué (FC000; Kiahtipes, 2016, 104–115), Mbaéré (FC300; Kiahtipes, 2016, 115–136), and Loamé rivers (FC400; Kiahtipes, 2016, 136–159) (Fig. 2, n°4–6). The three cores were obtained near archaeological sites discovered by K. Lupo and colleagues (Kiahtipes et al., 2011; Lupo et al., 2015, 2018; Schmitt et al., 2019). The distance between the coring sites varied from 40 to 80 km (Kiahtipes, 2016).

The Bodingué River core showed a slow and discontinuously accumulating alluvial deposit at the edge of the floodplain. It was radiocarbon dated by three assays, with the bottom deposit (62-cm depth) dated to c. 2632 cal yr BP. The Mbaéré River core sampled over bank deposits on the convex bank of a river meander was also radiocarbon dated by three samples, with the bottom deposit at −250 cm dated to c. 1240 cal yr BP. The core from the Loamé River sampled deposits from a filled river channel. The deepest deposit at −200 cm was only c. 345 cal yr BP in age, but this was the only ^{14}C processed. The result was supplemented by data from ten samples between −15 and −60 cm dated by ^{210}Pb and ^{137}Cs. They gave very recent results.

Taken together, the c. 2600 years of vegetation history shows little variability in $\delta^{13}C$ values, all the readings being at or higher than −28‰ at Bodingué, between −26 and −28‰ at Mbaéré, and from −24 to −28‰ at Loamé. This pattern is also visible looking at the pollen diagrams where the ratios are stable since c. 2350 cal yr BP. It is only the lower part of the Bodingué River core which documents the LHRC. The base sample dated c. 2450–2350 cal yr BP stands out. *Uapaca*, *Pycnanthus*, *Phoenix*, and *Raphia* are present at 5% or over 10%, and are drastically reduced in number or disappear immediately after. Though *Alchornea* jumps from less than 5% to over 25% after c.2350 cal yr BP, all the other pioneer types and the shrubs, *e.g., Nauclea/Pausinystalia*, *Macaranga*/*Mallotus*, and *Zizyphus* significantly increase contemporaneously.

From the more detailed Loamé site, in the upper part of the documented period, the last four centuries, we witness the regression of closed forests, an increase in grasses, a strong representation throughout the core of associated pioneer trees and secondary forest taxa and shrubs, and a high level of fire activity.

Sangha River Interval Archaeological Evidence

Our data is drawn from a limited number of archaeological projects carried out in the SRI and its immediate surroundings over the last 50 years: in the CAR by R. de Bayle des Hermens (in 1968), L. Koté (between 1987 and 1990), R. Lanfranchi (between 1991 and 1997), J.-P. Ndanga (between 1996 and 2005), and K. Lupo (in 2017, 2019, 2020, and 2022; this project is still ongoing). In the Cameroon by M. Eggert (1997, 2005, 2008, and 2009), and in the Congo by R. Lanfranchi (1984 and 1985) and M. Eggert (1987).

Overall, excavations where work supervised by archaeologists was conducted are found in or near the northern and south-eastern parts of the Interval (Fig. 6, n°1–7, 8, 15, 21–28). During botanical research, artifacts were found associated with dated charred wood and tree fruit in Cameroon by N. Bourland (Bourland et al., 2015) and J. Morin-Rivat (Morin-Rivat, 2017; Morin-Rivat et al., 2016, 2017), and in Congo by J.-F. Gillet (Gillet, 2013; Gillet & Doucet, 2012, 2013) and J. Morin-Rivat (Morin-Rivat, 2017; Morin-Rivat et al., 2017). From an archaeological standpoint, these are limited test excavations (Fig. 6, n°10–14, 16–20). Furthermore, as Fig. 6 shows, only sites n°3–6 and n°16–20 lie within or near the SRI as illustrated in Fig. 2. To better discuss immigrating populations to the Interval, we have expanded

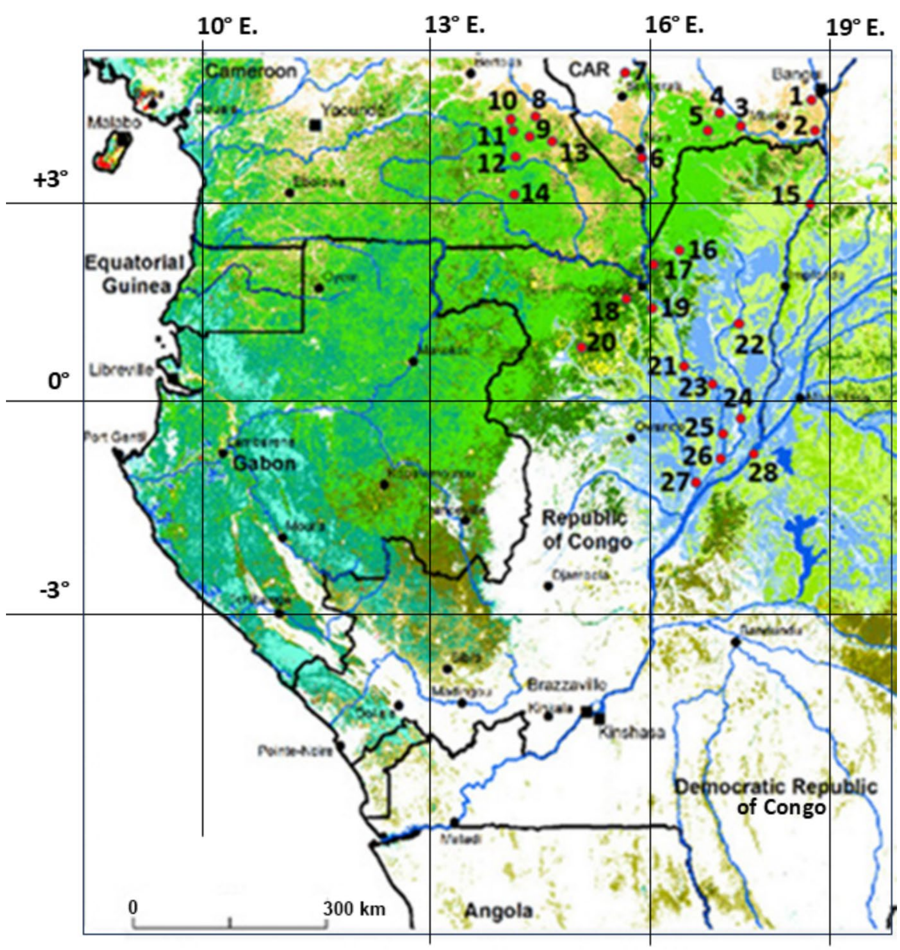


Fig. 6 Archaeological radiocarbon-dated sites of the SRI and its immediate periphery (see Appendix for the catalog and the site names). Adapted from Verhegghen et al. (2012), Fig. 3

our view to its peripheries where fieldwork has been carried out at sites n°1, 2, and 15 in the north-east, n°7–14 to the north and north-west, and n°21–28 to the south. A catalog of their 160 radiocarbon dates has been created (see Appendix). Overall, the available evidence from archaeological excavations, while limited, concurs with some important conclusions.

Stone Using Communities in and Around the SRI

Late Stone Age communities inhabited the late Holocene forests. The Nangara-Komba rock shelter in the RCA (Fig. 6, n°7), at the northern limit of the SRI, has evidence of stone-using forest hunter-gatherers (hereafter FHG) from c. 7000 cal yr BP until a few centuries ago (Fig. 7 and Appendix, n°84–107; see Lupo et al., 2021). They used a few earthen pots, probably obtained from neighboring villages c. 2400 cal yr BP at the latest (Appendix, n°92–93). Hunting is suggested by the recovery of mammalian, bird, snake, and rodent bones. Mollusk shells and carbonized fruit endocarps from *Canarium schweinfurthii* (incense tree) and *Elaeis guineensis* (oil palm) trees were also identified (Lupo et al., 2021). *Canarium* is exploited from c. 6967 cal yr BP, and *Elaeis* use is possibly dated to c. 2931 cal yr BP in feature 2. A test pit at Mbol in southern Cameroon (Fig. 6, n°13) yielded two stone flakes with charcoal dated to c. 1778 cal yr BP (Appendix, n°114). This is an unexpectedly late date for the use of stone tools (Morin-Rivat et al., 2014) since EIA villages were well established in the surrounding landscape by that time. Other examples of recent stone-using FHG exist in some parts of Central Africa (Clist, 2022) but it is obvious that more fieldwork is needed on late use of stone artifacts by these communities. The items of interest that identify possible exchanges between FHG and villagers found on hunter-gatherer sites have been listed as pottery, iron tools, and evidence of food production (Lupo & Schmitt, 2023).

Pottery-Using Communities Within the SRI and Its Immediate Surroundings

Progressing from north to south through the SRI, the evidence will be grouped into northern (Cameroon, CAR, Congo; sites n°1–15, Fig. 6), central (Congo; sites n°16–20, Fig. 6), and southern sectors (Congo, DRC; sites n°21–28, Fig. 6). Grouping the excavated radiocarbon dates from the Interval (see Appendix) provides a statistically usable set of 160 dates (Fig. 7). Throughout the Holocene up to c. 2400–2500 cal yr BP, there is irregular evidence for the presence of FHG probably because the data comes from a single site, Nangara-Komba. Most of the material is from pottery-using people later than 2400 cal yr BP (Fig. 7). Their combined anthropogenic impact can be seen at a few paleoenvironmental sites, as described above. The anthropic radiocarbon profile from the SRI since c. 2500 cal yr BP is fully compatible with all others published from Central Africa (Clist, 2022; Clist et al., 2023; de Saulieu et al., 2021; Garcin et al., 2018a; Oslisly et al.,

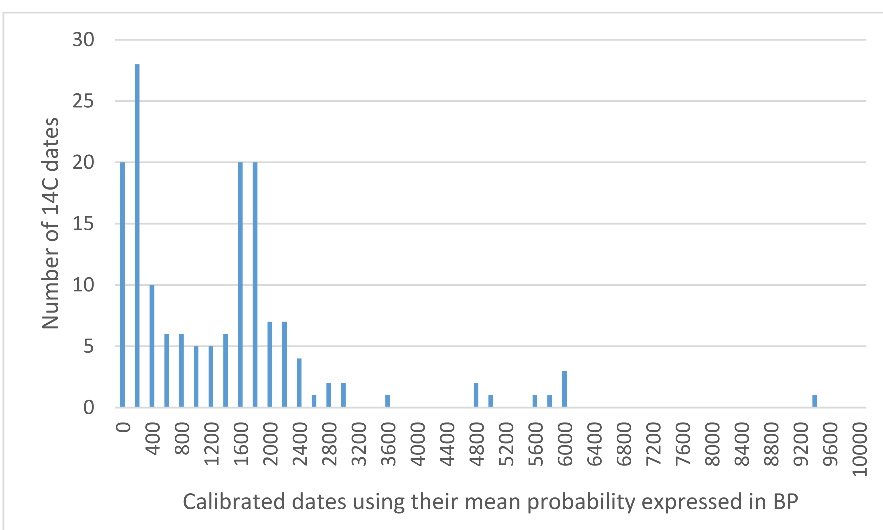


Fig. 7 Distribution of the 160 Holocene radiocarbon dates from the Sangha River Interval and its periphery using 200-year bins and median probabilities. Source: see Appendix

2013; Seidensticker et al., 2021; Wotzka, 2006). In the SRI, there is an increase in carbon dated from c. 2500 to 1900 cal yr BP, followed by a high plateau from c. 1900 to 1400 cal yr BP, a decrease or "bust" between 1300 and 1100 cal yr BP, and a clear second peak from c. 1100 cal yr BP to historical times (Fig. 7). Even during the "bust," there are enough ^{14}C data-points to indicate the area was still inhabited (Schmitt et al., 2019). What follows is a coarse-grained picture of the admittedly still incomplete archaeological sequence.

In the northern sector, the earliest evidence for villages is found west of the SRI fringe at Bagofit in Cameroon, dated as early as c. 2640 cal yr BP (Meyer et al., 2009; Fig. 6, n°8; Appendix, n°126)—and in the CAR c. 2400 cal yr BP in the vicinity of the Nangara-Komba rock shelter (Appendix, n°92–93) (Lupo et al., 2021). While the Bagofit date is fully compatible with the cultural dynamics found in southern Cameroon, i.e., an expansion of villages from the Sanaga River southwards, it remains an isolated example away from the Interval. All the other early dates for pottery-using communities are much later c. 2200–2100 cal yr BP (Fig. 6, n°9–14; Appendix, n°108, 110, 120–122, 124. See Eggert, 2002; Meister, 2008; Meyer et al., 2009: Bourland et al., 2015; Morin-Rivat et al., 2014, 2016; Morin-Rivat, 2017). Iron-working is not identified before c. 1840 cal yr BP at Bagofit (Fig. 6, n°8; Appendix, n°126) or c. 1650 cal yr BP at Mampang (Fig. 6, n°8; Appendix, n°128–129. See Meyer et al., 2009). Apart from Nangara-Komba far to the north in the CAR (Fig. 6, n°7), the series of excavated pottery-containing sites (Fig. 6, n°1–6, 15) is not older than c. 2200 cal yr BP at Z-02 (Fig. 6, n°4; Appendix, n°77). The single date of c. 2416 cal yr BP from Limbumba was obtained in a questionable context because the sample dated was squeezed between four LIA dates, two above and two below, ranging from c. 120 to 210 bp (Appendix, n°78 and for the LIA assays, see n°20, 27, 33, 36). See Lupo et al., 2018; Schmitt et al., 2019). Along the Ubangui River further east, the only published pottery is the Batalimo-Maluba group—that developed between c. 2100 and 1500 cal yr BP. They made extensive use of *Elaeis guineensis* as attested by the two sites so far excavated, Batalimo and Maluba (Fig. 6, n°2 and 15; Appendix, n°3–16. See Aumassip, 1975; Bayle des Hermens 1975; Koté, 1992; Eggert, 1987, 1993; Seidensticker, 2021). Regarding the eight dates from Batalimo, our Appendix shows that six of them have standard errors exceeding 100 years. At Maluba, out of six dates, three exceed 100 years. We are left with only two "good" dates from each site, and only one related to the EIA or the Batalimo-Maluba style group, c. 1474 cal yr BP at Batalimo and c. 1921 cal yr BP at Maluba. The spatial extent of these villages along the Ubangui River drainage area suggests their artifacts mark an expansion from the CAR savannahs into the rainforests of the Congo basin. There is no evidence of iron working before c. 1800 cal yr BP in the northern area of the Interval, where it is indicated at LE2 and Bécaré 2 (Fig. 6, n°3 and 6; Appendix, n°72, 74. See Schmitt et al., 2019; Lanfranchi et al., 1998). A surprising early date of c. 2718 cal yr BP has recently been obtained near Ndola at Namboui 2 for iron working (Appendix n°81). It needs confirmation before being included in the local sequence as the site has been "*heavily impacted by pedestrian traffic as well as deflation and erosion*" (Schmitt et al., 2023, 6). The paleo-evidence suggests the earliest villages were situated in a forested environment around 2200 cal yr BP. After c. 1200 cal yr BP, our catalog shows an increase in iron working activity, culminating in the last few centuries, after c. 1100 cal yr BP (Lupo et al., 2015).

In the central sector, the data mostly come from limited botanical pits excavated by Gillet (Gillet, 2012; Gillet & Doucet, 2012, 2013) and Morin-Rivat (Morin-Rivat, 2017; Morin-Rivat et al., 2014) (Fig. 6, n°16–20). The earliest indication for pottery-using people is from Landjoué at c. 2100 cal yr BP (Appendix, n°132). Evidence for iron working comes from slag dated to c. 1470 cal yr BP at the Mambili River and c. 1650 cal yr BP at Ngombé (Appendix, n°134–135). Some of Gillet's pot sherds are said to be associated with the Pikunda-Munda group which extends as far as Ikelemba, 70 km south-east of Ouesso (Seidensticker, 2021). Sites of this group are dated from c. 1900 cal yr BP, 70 km further downstream on the Sangha River (see Appendix and Seidensticker, 2021). In 1987, while surveying the upper reaches of the Ngoko and Sangha rivers near to Ouesso, Eggert found surface-collected pottery which was described in a PhD thesis and assigned to the c. 2150–1800 BP period (or 200 BCE–200 CE; Seidensticker, 2024).

In the southern sector east of the Interval, M. Eggert surveyed in 1987 the Sangha/Ngoko and Likouala-aux-Herbes rivers, excavating eight sites and dating five (Sangha River: Pikunda, Munda, and Mobaka; Likouala-aux-Herbes River: km 186 and Mitula). The results, published in extensive preliminary reports (Eggert, 1992, 1993), were only fully studied recently without changing much of the opinion expressed by Eggert (Seidensticker, 2017, later edited in book form, Seidensticker, 2021). Along the lower segment of the Sangha River 250 km from Ouesso, villages such as Mobaka and Mitula existed around c. 2220–2280 cal yr BP (Fig. 6, n°25–26; Appendix, n°158–159). They are considered to be a westward extension of the Imbonga group, which was established on the east bank of the Congo River around c. 2400 cal yr BP (Seidensticker, 2016, 2021; Wotzka, 1995). Imbonga has no relationship to the first villages of the SRI and the origins of this cultural group are still in question (Eggert, 1987, 1992; Seidensticker, 2016, 2021, 2024; Wotzka, 1995). According to Eggert, Imbonga pottery users did not expand further upstream towards the Interval or Ouesso. A later Pikunda-Maluba group with evidence for iron working has been identified along the riverbanks, downstream towards the Congo River (Eggert, 1992, 1993). It is dated by nine data points coming from one feature at Pikunda and three others at Maluba to between c. 1900 and 1500 cal yr BP (Fig. 6, n°21, 22; Appendix, n°141, 143, 147–154). Iron working evidence was found at Pikunda in a pit feature and at Munda from two distinct features dated to c. 1700 and 1570–1530 cal yr BP (Seidensticker, 2021: 355–356; Appendix nos. 147–150). This group extends from the Congo River, as far as Ikelemba 70 km south-east of Ouesso on the Sangha River (Seidensticker, 2021). The partially excavated pit at km 186 on the Likouala-aux-Herbes River contained atypical pottery dated to c. 1889 cal yr BP (Eggert, 1992; Seidensticker, 2021. Appendix n°157).

Sangha River Interval: Fire Events Documented by Charcoal and Charred Fruits

Macro- and micro-charcoal are good proxies for human use of the tropical forests. They were produced and used for various purposes: horticulture, cooking, heating, pottery-making, iron working, pest control, and hunting. The latter two were more of use in savannah environments and at forest margins.

Macro-charcoal has been shown to be deposited on land within 1 km of a fire and micro-charcoals can be carried more than 6 km from their origin (Aleman et al., 2013; Scott, 2018; Tovar et al., 2014; Whitlock & Larsen, 2001). It has been suggested they are not transported under tropical forests as far as in other biomes (Tovar et al., 2014). Their wind dispersal is limited because the fires are slow spreading, forest humidity decreases their intensity thus lessening their thermal buoyancy, the forest canopy restricts dispersal, and there is a lack of high winds. More rarely, charcoal can also result from ignition provoked by lightning strikes (Tutin et al., 1996). The latter occur more frequently during dry climatic episodes and periods of rapid climate change when switching from a humid to a dry period (Scott, 2018), e.g., at the start of the LHFC c. 2500 cal yr BP. It has been proposed that "*paleofires are rarely natural*" (Morin-Rivat et al., 2017: 89) so associating most wood charcoal to anthropic activity. Though lightning strikes burning down trees are rare, they do happen and create large patches of "super" macro-charcoals from mature and towering trees. Their contribution to the stock of carbon deposited after centuries must have been significant.

By using charcoal reflectance, we can distinguish between natural and some anthropic fire events with confidence (Belcher et al., 2018; Scott, 2018): the higher the temperature reached, the higher is the reflectance. It can potentially discriminate wood charcoals from land clearance or natural fires from lightning strikes reaching temperatures between 400 and 450 °C (e.g., Scott, 2018)—from charcoals obtained from pottery production (600–800 °C, e.g., Gosselain, 2002) or charcoals from iron smelting activities (1000 °C and over, e.g., Bocoum, 2004). Reflectance studies have not yet been carried out in Central Africa.

Within the SRI, botanical studies have identified fire events documented by wood charcoal and charred oil palm kernels found in soils.

Central African Republic

In the present mature rainforest of the Dzanga-Ndoki National Park in southern CAR, in the northern part of the Interval, Fay collected carbonized oil palm kernels from numerous soil profiles (Fay, 1993, 1997). Eighty samples of these kernels were radiocarbon dated. The shape of the resulting diagram is suggestive of a c. 2100–1800 cal yr BP period of irregular presence of *Elaeis*, followed around c. 1800–1600 cal yr BP by an increase in this pioneer tree that may be related to anthropic impact (Maley et al., 2018). Later, it is characteristic of a natural phase of progressive replacement of a pioneer vegetation by a more mature one (Maley & Willis, 2010). It is possible the turning point was c. 1700 cal yr BP. After 900 cal yr BP, a more mature forest developed to its present condition, with *Elaeis* falling back to its "natural" frequency as found in samples dated to 2400–1800 cal yr BP.

Cameroon and Congo

J. Morin-Rivat has conducted research in south-eastern Cameroon and in northern Congo (Morin-Rivat, 2017; Morin-Rivat et al., 2014, 2016, 2017). The oldest charred *E. guineensis* kernel is found c. 2098 cal yr BP in Congo and the oldest *C. Schweinfurthii* kernel at c. 1912 cal yr BP in Cameroon (Morin-Rivat et al., 2014). Her ^{14}C dates, processed from charred fruit kernels and wood charcoal, extend from c. 2300 cal yr BP to the present. They show two major fire events between c. 2300 and 1400 with two separate peaks occurring at 2150–2050 and 1800–1550 cal yr BP. Smaller peaks are present at 1300–1200, 1050–950, and 700 cal yr BP to the present.

Congo

Gillet and Doucet (2013) also found a great abundance of wood charcoal associated with charred *Elaeis* endocarps in the forest soils of northern Congo between the Sangha and the Likouala-aux-Herbes rivers in the eastern part of the SRI. Ten kilometers of transects was studied using 37 auger samplings down to 2 m in depth, with a further 13 down to 0.8 m and another 10 pedological trenches. These samplings clearly differentiated charred *E. guineensis* endocarps from other charcoal. Most of the macro-wood charcoals (size ≥ 1 mm) were limited to the − 20/− 80-cm depth—as observed in the vast majority of other sites already discussed. Ten radiocarbon dates were processed from samples collected between − 20 and − 55 cm, five of them from *E. guineensis*. They range from c. 2300 to 200 cal yr BP (Gillet & Doucet, 2013); the earliest *Elaeis* is dated c. 2000 cal yr BP.

Later fieldwork in the same general area was aimed at testing if specific modern forest types were due to ancient fire events (Tovar et al., 2014, 2019). Eleven sediment cores were obtained west and east of the Ndoki River near to the SRI's pollen sites we have already discussed. A twelfth was dug some 100 km to the south-east. All of them were extracted from swampy depressions, small lake basins, and small wet hollows without inflowing streams, as recommended by Whitlock and Larsen (2001). OSL, radiocarbon and ^{210}Pb dates were processed by Tovar et al. The macro-charcoals collected (charcoals larger than 150 μmm) were examined. They show the existence of four periods of fire activity: (i) 2500–1100 cal yr BP, when fires were rare; (ii) 1100–500 cal yr BP, when fires events started to spread; (iii) 500–300 cal yr BP, when fires spread further and their intensity increased; (iv) since 300 cal yr BP, when wood charcoal density peaked at all sites. Furthermore, tests were conducted leading to the conclusion of temporal asynchrony between sites. Two additional interesting factors are that Marantaceae forests, which are interpreted as evidence of past Anthropogenic Impact, have witnessed more fire events than others, and again there is no evidence of past savannah in the studied areas. Tovar et al. conclude that fires after 1100 cal yr BP, but not before, probably result from slash-and-burn activities carried out by horticulturalists, following an increase in human densities in this late period, associated with increased needs for wood charcoal to sustain a higher demand for iron tools like hoes and axes.

Discussion

Existence of a Savannah Corridor in the SRI During the LHFC

The botanical reality of the Interval was already questioned in a paper entitled "The Sangha River Interval: myth or biogeographic reality" (Doumenge et al., 2014). The SRI's environmental history has been associated to that described from several sites in the western Congo Basin characterized by a marked savannah expansion episode around c. 2500 BP (Giresse et al., 2020; Maley et al., 2018). But the results from six forest sites, three in the SRI studied by Brnic and Tovar (Mopo Bai, Goualougo, Bemba Yanga), three to its north-east documented by Kiahtipes (Bodingué, Mbaéré, Loamé) (Fig. 2), coupled with 18 soil profiles obtained by Bremond and colleagues, geolocated over the Interval (Fig. 1), and further observations by Tovar in northern Congo on 11 sites illustrate that the hypothesis of large-scale forest destruction 3000 years ago must be revised. Between c. 2500 and 2000 cal yr BP, the moist tropical forests of the Congo Basin did suffer on their periphery a short-term forest disturbance leading in some limited areas to the replacement of mature forest by pioneer and secondary forest formations. This was already suggested in 2013 in several SRI studies (Bentaleb et al., 2015; Bremond et al., 2017; Doumenge et al., 2014; Gillet, 2013 for the latest), but only recently put into a regional context. This led to a conclusion that an open canopy forest developed during the Interval caused by a combination of climatic, edaphic, and hydrographic factors (Giresse et al., 2020, 2023). In the last 1000 years, the SRI rainforest and elsewhere has remained stable (Giresse et al., 2023, but see also Morin-Rivat et al., 2017).

The forest disturbance was probably responsible for a local increase of *Poaceae* at Mopo Bai, the early *Elaeis* peaks at Mopo Bai and Bemba Yanga, giving the $\delta^{13}C$ profile from a single site on the rainforest periphery that indicates a change from a forest to more open undergrowth (Bremond et al., 2017). This is further supported by the small peaks in charcoal deposits before c. 2200 cal yr BP at Mopo Bai, Goualougo, and Bodingué probably associated with natural events.

Some of our Iron Age data finds parallels with global climatic episodes following the Forest Crisis we briefly described in our introduction, the MWP and the LIceA. They probably impacted LIA communities of Central Africa as described in a regional study (Giresse et al., 2023) and outlined in several other papers.

Working on several swamps of the Lopé reserve (central Gabon), Bremond et al. (2021) highlighted a 1400–800 cal yr BP dry episode; this is supplemented at the nearby Kamalété lake after 1400 cal yr BP by the maximum extension of disturbed forest and an increase in pioneer *E. guineensis* numbers (Ngomanda et al., 2005). The findings better correspond to a local signature of the Medieval Warm Period because archaeology recognizes a depopulation in Central Gabon entailing limited AI during this period (Oslisly, 1995).

We argue that since the nineteenth century there has been an underlying Euro-centric bias that views the "primary" forest of Equatorial Africa as a very difficult environment to live in or pass through, thereby supporting the idea of the SRI's savannahs was a necessary condition for farming expansion southward (Vansina, 1990, speaks of the "mythical jungles and true rainforests"). This led to published statements which were not fully supported by facts (e.g., Grollemund et al., 2015). Yet anyone who has done fieldwork in the *terra firma* forest knows that it is fairly easy to walk through, moving along crestlines, sometimes helped by rivers traversing the environment, without forgetting information obtained from encountered rainforest hunter-gatherers, and aided by existing wildlife tracks like elephant trails.

Settlement of the SRI by Pottery-Using Villagers

Pottery users settle north of the SRI by perhaps c. 2400 cal yr BP near Nangara-Komba (CAR). Others moved later into the Interval c. 2200–2100 cal yr BP. The paleoevidence points to a continuity of forest cover in the Interval since at least c.3300 cal yr BP, with only a limited spatial extension of savannahs or wooded savannahs. This picture contradicts earlier work (for example, see Russell et al., 2014; Grollemund et al., 2015; Bostoen et al., 2015; de Luna, 2017; Coupé et al., 2017; Maley et al., 2018). Our catalog of 160 Holocene radiocarbon dates (see Appendix), associated with a number of Iron Age sites, indicates a slow increase over time in the number of villages, with probably a low AI on the forest for horticulture, cooking, pottery, and iron making over several centuries. This conclusion is supported by the micro-charcoal records from several sites and forest transects. Further north, in the Ngotto forest area, there are no signs of widespread deforestation related to agriculture or iron production. Neumann and colleagues (2012) suggested that settlers may have exploited the secondary forest plant communities, which contain numerous useful fruit tree species and can be easily cleared. This scenario was included in a new model of a horticultural expansion (Coupé et al., 2017).

Based on the number of radiocarbon dates, some have argued that a major population decline occurred throughout Central Africa between 1400 and 1200 cal yr BP roughly contemporary with the MWP (de Saulieu et al., 2021). Others date the event to between 1550 and 1350 cal yr BP and suggest there was a regional population collapse (Seidensticker et al., 2021). Seidensticker and colleagues made use of (i) a biased number of ^{14}C dates; (ii) 115 ill-described styles of ancient pottery; and (iii) human genetics limited to Gabon. Our present paper and others (Clist et al., 2021a, 2021b, 2023; Giresse et al., 2021) do not support this conclusion. It has been adequately documented that such a population decline or collapse is based on biased evidence (see multiple examples in Clist et al., 2023). Though we see a decline in ^{14}C dates around 1000 cal yr BP, immediately followed by a period with clear evidence of increased human activity, we consider the number of radiocarbon dates is a better data set on which to understand a settlement than other forms of demographics (Clist et al., 2023). It has been stated "*archaeologists who spot pits, where ceramic material bears roulette decorations, do not systematically date them, because they are known to belong to the Late Iron Age, or even to the Modern and Contemporary periods; archaeologists therefore prefer to invest their scarce money in "old" dating, which leads to the under-representation of dates from recent contexts in a radiocarbon database*" (de Saulieu, 2020: 102) also leading to an overrepresentation of EIA sites. Instead, the data illustrate a continuous human presence in the SRI since c. 2200 cal yr BP. Our documentation thus supports K. Lupo and colleagues' proposal that low numbers of dates are better explained by a reduction in industrial activities such as iron-working that create charcoal (Lupo et al., 2018; Schmitt et al., 2019) and to a lack of field research in the SRI (Lupo et al., 2018; Morin-Rivat et al., 2017) and throughout Central Africa (Clist et al., 2023), which is also documented in the present study.

Local iron working was a late development in the Interval, dated c. 2000–1900 cal yr BP. Research in the northern SRI found that a major increase in smelting activities only took place after c. 1200 cal yr BP, as is documented by the greater number of LIA sites, ^{14}C dates (see Appendix), and by micro- and macro-charcoal analyses (Lupo et al., 2018). Similar evidence for high-intensity iron smelting activities in the rainforest has been found during the last centuries of the LIA in northern Gabon (Clist, 1993, 2022), eastern Cameroon (Gouem Gouem, 2019), and north-western Congo (Ndanga, 2008, 2013a, b). Such metallurgical activity now begins to look like a regional pattern that could serve as an indirect proxy for higher population densities and associated increased iron working in the rainforests of Cameroon, the CAR, Congo, Equatorial Guinea, and Gabon. This notion is supported by a peak in radiocarbon dates over the last 1000 years obtained from an increasing number of archaeological sites in western Central Africa (Clist, 2022; Clist et al., 2023; de Saulieu et al., 2021; Garcin et al., 2018a, 2018b, 2018c; Oslisly et al., 2013; Seidensticker et al., 2021; Wotzka, 2006) as illustrated for the SRI by our Fig. 7. The increase is irregular; it seems to start c. 900 cal yr BP in southern Cameroon and Congo, and c. 700 cal yr BP in the CAR, Gabon, and the DRC. These ideas are further supported by recent genomics studies that show population increases among LIA villages in Gabon (Seidensticker et al., 2021) and Cameroon (Padilla-Iglesias et al., 2022).

The Pikunda-Munda pottery group found by Eggert along the central Sangha River dates to c. 1900 cal yr BP, several generations after the initial arrival of villagers. Several sites 70 km from Ouesso seem to have Pikunda-Munda pottery (Seidensticker, 2021). It is possible this group represents a further wave of settlement into the Interval before they moved downstream to the Congo River, though it is understood its typochronological analysis supports an upstream movement from the Congo River (Seidensticker, 2021). It has been observed, while decoration and technology of the Pikunda-Munda Group are like pottery from the Inner Congo Basin, vessel shapes are different (Seidensticker, 2021). Small-scale iron working in the Interval is not present before c. 1900–1800 cal yr BP. The new picture for the SRI indicates that the initial diffusion of both villages and later, iron working is quite recent and illustrates a trajectory similar to the Bateke plateau in southern Congo, where the earliest settlements and iron workings are late c. 2000 cal yr BP (Dupré & Pinçon, 1997; Pinçon & Dechamps, 1991; Pinçon et al., 1995; Pinçon, 1988, 1990, 1991a, 1991b). Both the SRI and the Bateke plateau appear to have been ignored by the first wave of the horticultural expansion and settlement.

While we can with confidence link the Imbonga and Pikunda-Munda pot makers and users with probable Bantu-speakers due to their geographical setting and the position of language groups in recent times, we cannot be so sure for the Batalimo-Maluba group along the Ubangui River who could have been Ubanguian speakers like the inhabitants around the Nangara-Komba rock shelter.

Evidence from the Nangara-Komba rock shelter in the CAR, supported by limited information from the Mbol site in Cameroon, suggests a late existence of stone using FHG. They could have interacted with villagers to acquire pottery as early as 2400 years ago (Klieman, 2003; Lupo et al., 2021), perhaps via long-distance exchange networks that seemingly had already developed (Klieman, 2003; Padilla-Iglesias et al., 2022) and which may be partly materialized by the widespread distribution maps of polished stone adzes and axes in the forests, tools made by horticulturalists before contact with the early metallurgists (Clist, 2022). Of course, at this stage, one cannot rule out that they acquired the techniques for making pottery while maintaining their use of stone tools until quite recently.

Hunter-gatherers have inhabited the SRI from at least the Middle Stone Age and the Pleistocene (Lanfranchi, 1987, 1990, 1991, 1996; Lanfranchi & Manima Moubouha, 1989; Lanfranchi & Schwartz, 1990b; Padilla-Iglesias et al., 2023, 2024) until a few centuries ago when in Central Africa stone knapping was slowly terminated (Clist, 2006b; Coupé et al., 2017; Eggert, 2019; Lupo et al., 2021).

Genomics suggest that the ancestors of the FHG became separated from other human groups c. 70,000 cal yr BP, before branching into western and eastern FHG sub-groups c. 20,000 cal yr BP to the west and east of the Congo River. This appears to have taken place during the final Pleistocene (Patin et al., 2009) when MSA and LSA technological industries coexisted (Clist, 2022; Cornelissen, 2023). The western groups differentiated further after c. 3000 cal yr BP in Cameroon and Gabon (Patin et al., 2009; Van der Veen et al., 2009; Verdu, 2016; Verdu et al., 2009, 2013). This time frame is similar to our described archaeological sequence that pinpoints early villages in the forests of southern Cameroon before 3000 cal yr BP and centuries later in the northern Congo or the SRI.

Anthropogenic Impact (AI) in the SRI During the Iron Age

Light demanding tree or pioneer taxa occur and expand when nature or man clear primary forests (Aleman & Fayolle, 2020). These phenomena will be reflected in pollen diagrams. Multiple natural drivers exist of such openings leading to higher numbers of secondary forest pollen. Among the natural ones we considered climatic droughts, tornadoes, fires, and tree fall. Seeds present in the soils and wind-driven ones will bolster secondary vegetation. The wild fauna can also disseminate specific fruit bearing trees via their feces (e.g., Giresse et al., 2020, writing about chimpanzees spreading *E. guineensis*). Man will deposit charcoal by clearing forest land by fire to install a village or camp, to set up gardening plots, to eliminate pests, and to help hunters. Additional charcoal will come from pottery making and iron working activities. The latter further impacting on forest by the need for wood to create charcoal for iron smelting furnaces. To estimate the possible anthropogenic impact on the environment by an Iron Age community, we can also rely on regional ethnography and history (Bley & Pagezy, 2000; Clist, 1995; Nicolaï, 1961; Vansina, 1990) and archaeology (Clist et al., 2018a, 2018b; Denbow, 2014; Dubouloz, 2017; Neumann et al., 2012). They all give the same picture of settlements with a mean number of around 100 inhabitants (Vansina, 1990), creating a need, as in Gabon, for a horticultural space of only *c.* 4 km^2 (Pourtier, 1989). The small settlement size, the distance between each community, the discovery of Iron Age clusters of villages with large intermediate inhabited areas in the DRC (Clist, 2022) and in southern Cameroon (Morin-Rivat 2016: 10), as in modern times (Nicolaï, 1961), must have led to mean densities of 1 or 2 inhabitants per square kilometer, an ineffective figure to explain large-scale deforestation. Humans probably only acted as amplifiers of environmental change (Clist et al., 2018a, 2018b; Giresse et al., 2023; Kiahtipes, 2019). World-wide studies have found that after an initial settlement, horticultural villages show an increased demography, so indirectly leading to increased anthropogenic impact (Bellwood, 2013). This increased demography has always been followed by a decline documented by whatever proxy used, for example the number of radiocarbon data points (Clist et al., 2023: bias 15, "size of the radiocarbon data corpus and sub-regional radiocarbon date profile"). This pattern has been found across western Central Africa (de Saulieu et al. 2021; Seidensticker et al. 2021; Clist 2022; Clist et al. 2023) and the SRI from the EIA to the LIA (Fig. 7).

The marked demographic increase of the last few centuries compares well with existing evidence for increased human effects on the environment (Giresse et al., 2023).

To estimate correctly in the SRI the true anthropogenic impact in the "longue durée," we need to convincingly associate in space and time the presence of charcoals in soils and light demanding pollen with neighboring human settlements (e.g., Clist, 2022; Kiahtipes, 2019; Neumann et al., 2012). New lake and swamp sediments from the SRI, if they can be found, must be analyzed using a multi-proxy approach combining archaeology and paleoenvironmental specialists before one can more precisely date the LHRC, MWP, and LIceA events and measure their impact on vegetation.

The SRI in the Context of the Bantu-Speakers' Expansion

The available archaeological record does not register pottery using settlements in the Interval before c. 2200 cal yr BP. This is surprising when we consider past publications situating at the latest c. 2500 cal yr BP the use by bantu speakers of a savannah covered Interval during their first expansion through Central Africa (e.g., Grollemund et al., 2015; Bostoen et al., 2015; Grollemund et al., 2023; Koile et al. 2023). Looking at the drainage system of the Interval, we find rivers flowing from the north-west in Cameroon to the south-east in the DRC: the Dja River in Cameroon becomes the Ngoko River in Congo, then the Sangha River emptying into the Congo River. The existence of this river system through the forest, partly in the SRI, permitted the hypothesis that early villagers could have expanded downstream. We have indicated the SRI was dominated during the LHFC and later by forests, probably with very limited savannah patches on their periphery (see also Giresse et al., 2020, 2023). The oldest pottery using settlements at the periphery of the Interval, to the east downstream along the Sangha River towards the Congo River, or to the north in the CAR, or north-westwards in Cameroon, are not older than c. 2200–2000 cal yr BP (see ^{14}C dates in our Appendix). Looking further afield, around the headwaters of the Dja River in the rainforest of Cameroon, we find the same picture, though several dates from the Efoulan 1 and Nya Zanga sites push back to c. 2300 cal yr BP the start of such settlements (de Saulieu et al., 2015). Overall, these findings explain the late arrival of pottery using villagers into the SRI because they had not yet settled the lands between the Sanaga River and the Interval in Cameroon. Furthermore, mapping sites dated to c. 3000–2300 cal yr BP, one finds the thrust of expansion lies along the Atlantic Ocean coastline and the immediate forest hinterland, as hinted in the late 1980 s, leaving the SRI quite isolated and probably only inhabited by hunter-gatherers (Fig. 8). The main agriculturalist expansion from Cameroon began before c. 3000 cal yr BP as incomers moved south along the Atlantic coast, bypassing the SRI (Blench, 2012; Clist, 1989, 2022; Nlend Nlend, 2014; Oslisly, 2006; Vansina, 1990). While some settled the coast of Congo by c. 2500 cal yr BP (Denbow, 2012, 2014), others moved upstream along the Ogooué River to the Lopé savannahs in the center of Gabon (Assoko Ndong, 2002, 2003) and the savannahs at the border between Gabon and Congo (Clist, 2022; de Maret, 2018). By c. 2200 cal yr BP, when the SRI seems to have finally been settled, some migrants had already reached the savannahs or wooded savannahs of the border area between the DRC and Angola 800 km away (Clist et al., 2018a, b; Clist, 2006b, 2022; de Maret, 2018; Denbow, 2014), and perhaps even further south (Huffman, 2021).

Another and independent route probably ran through the forests from Cameroon to the Inner Congo Basin and the Congo River where Imbonga pottery is dated as early as c. 2400 cal yr BP (Eggert, 2005, 2016; Seidensticker, 2016, 2017, 2021; Wotzka, 1995). For the time being, this pottery style cannot be associated with any other to the north or the north-west that could link it to the expansion found in Cameroon. It must be noted archaeological fieldwork has been limited to rivers, where it is now known the density of identified sites is roughly ten times smaller than through land surveys (Clist et al., 2023: bias 3, "the impact of forests and rivers on surveys"). Imbonga seems to come out of the blue, though both the Okala Group in Gabon and the Imbonga Group in the DRC/Congo are the only pottery using flat decorated bases with rocking impressed combs or spatulas (Clist, 1989; Eggert, 1993; Wotzka, 1995). The Imbonga Group's Mobaka and Mitula sites on the lower Sangha River have already been discussed. They existed around c. 2300–2200 cal yr BP. This is later than ones on the Congo River to their east and suggesting they are the result of a late migration of Imbonga pottery users west of the Congo River or of a local community copying Imbonga production methods, meaning they were interacting along rather long distances. No other Imbonga-related sites have been found upstream along the rivers surveyed by M. Eggert, supporting the idea that the SRI, the Dja-Sangha, and Ubangui river systems did not contribute to the arrival of Imbonga pottery users.

Following archaeological data then available, the north to south rate of expansion through the equatorial forest

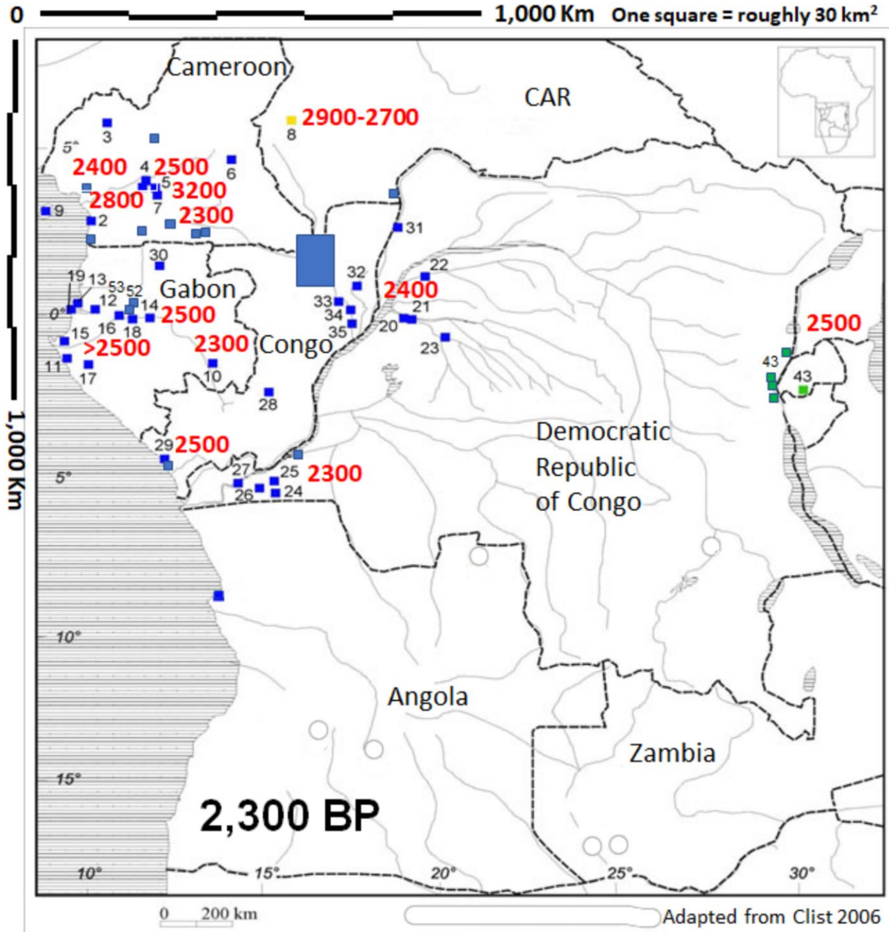


Fig. 8 The Sangha River Interval (blue rectangle) and the pottery-using archaeological sites dated to before 2300 cal yr BP. The yellow square is for megalith-builders of the Bouar area in the CAR, and the green squares of the Great Lakes area of East Africa are for the westernmost Urewe Industry-related sites

was estimated at 1.2 or 2 km per year (Clist, 1989: 80; 1995: 220; Vansina, 1990: 55), agreeing with other figures known at the time of small migrating groups (Collett, 1982; Van Bakel, 1981). Recently, using data from the Congo basin (Livingstone-Smith et al., 2017; Wotzka, 1995), pottery using communities west to east speed of expansion through forests along waterways has been estimated by B. Clist at 3 km/year along the Congo River between Mbandaka and Kisangani during the EIA (Second World of Iron conference, 2023, Nairobi). A much slower pace of 0.3 km/year along the secondary rivers like the Tshuapa during the EIA and LIA has been suggested from previous work (Wotzka, 1995). Thus, the rate of expansion varied according to the people involved, their environment, and the period considered as already proposed by Vansina (1990: 55–56). If we think of the first farming and metallurgical villagers reaching South Africa c. 1700 cal BP (Whitelaw & Van Rensburg, 2020: Silver Leaves Style Group, c. 1700–1500 cal BP), we calculate that the rate of expansion once the southern savannahs were reached increased tenfold. When South Africa was reached, only a small part of the Central African rainforest was colonized by putative Bantu speakers but still in very low numbers, leading to limited AI.

Conclusion

The present archaeological and paleoenvironmental picture admittedly draws from a limited dataset which is in urgent need of strengthening by fieldwork. This is especially true around Ouesso in Congo, where it is possible to set up a research base in the center of the Sangha River Interval leading to a PhD by a Congolese student.

Low-density stone using hunter-gatherer groups lived in the forested environment around the Nangara-Komba rock shelter in the Central African Republic. Pottery from the site strongly suggests that stone using hunter-gatherers were connected to horticulturalists for centuries. Villagers entered to the south, within the Sangha River Interval, c. 2200 cal yr BP, and began to work iron there c. 1900 cal yr BP. Our new understanding of the local impact on the environment of the Late Holocene Forest Crisis c. 2500–2000 cal yr BP negates the idea of a savannah corridor along the Sangha River. Later still, the rainforests seem to have been resilient during the "Medieval Warm Period" dated between c. 1200 and 800 cal yr BP and the "Little Ice Age" dated to c. 700–100 cal yr BP.

The intensity of iron metallurgy appears to correlate with a rising demography that peaked in the Late Iron Age after c. 1000 cal yr BP. Smelting activity needed wood charcoal and with an increasing need for larger horticultural plots and forest clearings for more numerous villages, it probably increased the AI on the environment.

We hypothesize that the Pikunda-Munda pottery style represents a specific expansion of villagers c. 1900 years ago moving along the Sangha River towards the Congo River. But this will require further confirmatory evidence.

Our study indicates that the SRI was never a major passageway for the expansion of the first villagers through the forests of Central Africa because when it was at last settled, other communities had reached the lower-Congo in the DRC and in northern Angola some 800 km away to the south. Rather, it was one of the areas where late settlements occurred in a forested environment that was much less impacted by the Late Holocene Forest Crisis than was previously thought.

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Author Contribution BC: Conceptualization of the research and compiling the archaeological data; JLD: modern environment description; PG and JM: palaeoenvironmental issues BC, JLD, PG and JM: writing the discussion and conclusion.

Data Availability Datasets related to this article can be found.

- for Cameroon at http://www.african-archaeology.net/biblio/bibliocam.html,

- for the CAR at http://www.african-archaeology.net/biblio/bibliorca.html, and

- for Congo at http://www.african-archaeology.net/biblio/bibliocon.html.

These bibliographies are open-source online data repositories hosted by the "African Archaeology" web site created in 2003 and since maintained by B. Clist.

Declarations

Competing Interests The authors declare no competing interests.

Appendix

One hundred sixty radiocarbon dates from the Sangha River Interval and its surroundings.

Type of material dated: Ch, wood charcoal; Cn, Canarium schweinfurthii nuts; En, Elaeis guineensis nuts; Fc, food crusts inside pottery; Hb, human bone; Po, pottery (TL); Sh, unspecified shell.

Type of cultural material: PO, pottery; IR, ironworking (slag, tewels); IQ, iron ore quarry; BU, burial; LI, Stone Age lithics.

Gray shading: In the date (bp) column, all radiocarbon dates with a standard error equal or exceeding 100 years have been flagged in gray.

Radiocarbon calibration: the Calib 8.20 program was used during August 2024 (http://calib.org/calib/) with the IntCal20 dataset for the northern hemisphere (Reimer et al., 2020), except for dates n°158 to 160 where it was the SHCal20 dataset for the southern hemisphere which was put to use (Hogg et al., 2020). All calibrations are at two sigma (95.4%) and the probabilities if at 10% or over indicated in column 6.

The median probability is tabulated in column 7 and appears in our text as c. xx yr cal BP.

Date no.	Site & (site no. on fig. 6)	Lab n°	Material dated/Type of cultural material	Date (bp)	BP calibration 95.4% (probability %)	Median prob. (cal BP)	Reference
1- North East of SRI (CAR, Congo): 16 ^{14}C dates							
1	Gobongo 1 (n°1)	Ly-12148	Ch / IR	1580 ± 40	1380-1534 (100)	1462	Ndanga 2008
2	Gobongo 1 (n°1)	Ly-12149	Ch / IR	1620 ± 45	1390-1589 (99.1)	1484	Ndanga 2008
3	Batalimo (n°2)	Bdy-462	Ch? / PO	240 ± 75	0-472 (100)	265	Koté 1992 [1]
4	Batalimo (n°2)	Bdy-465	Ch? / PO	1270 ± 125	928-1382 (100)	1225	Koté 1992
5	Batalimo (n°2)	OxTL-154a-4	Po / PO	1570 ± 220	-	1483	Aumassip 1975
6	Batalimo (n°2)	Gif-5894	Ch / PO	1590 ± 90	1307-1624 (96)	1474	de Maret 1985
7	Batalimo (n°2)	Bdy-304	Ch / PO	1730 ± 120	1364-1889 (100)	1624	Koté 1992
8	Batalimo (n°2)	Bdy-581	Sh / PO	1798 ± 101	1513-1942 (97.4)	1698	Koté 1992
9	Batalimo (n°2)	Bdy-301	Ch? / PO	1890 ± 130	1524-2147 (99.8)	1811	Koté 1992
10	Batalimo (n°2)	Bdy-306	Ch? / PO	1990 ± 210	1407-2375 (99)	1943	Koté 1992
11	Maluba (n°15)	KI-2444	Ch / PO	1930 ± 130	1541-2152 (98.6)	1859	Eggert 1993
12	Maluba (n°15)	GrN-13584	Ch / PO	1670 ± 110	1346-1752 (96.9)	1560	Eggert 1993
13	Maluba (n°15)	KI-2445	Ch / PO	2140 ± 200	1698-2547 (93.4)	2122	Eggert 1993
14	Maluba (n°15)	GrN-13585	Ch / PO	1990 ± 60	1744-2062 (98.7)	1921	Eggert 1993
15	Maluba (n°15)	Poz-62102	Hb / BU	580 ± 30	531-567 (32.5) 585-645 (67.5)	602	Seidensticker 2021
16	Maluba (n°15)	Poz-62103	Hb / BU	810 ± 80	649-913 (98.9)	736	Seidensticker 2021
2- Northern SRI (CAR): 67 ^{14}C dates							
17	CA3 (n°3)	D-AMS 27052	Ch / IR	101 ± 21	31-140 (73.3) 223-258 (26.7)	113	Schmitt et al. 2019
18	LE7 (n°3)	D-AMS 27061	Ch / IR	102 ± 24	26-142 (73.3) 221-261 (26.7)	112	Schmitt et al. 2019
19	Lingbangbo (n°2)	Bdy-464	Ch? / PO, IR	110 ± 80	0-156 (59.4) 164-287 (40.6)	137	Koté 1992
20	Limbumba (n°5)	Beta-234983	Ch / PO	120 ± 40	8-152 (66.1) 206-278 (28.4)	120	Lupo et al. 2018
21	OB05 (n°3)	AA-94546	Ch / PO, IR	131 ± 34	7-152 (64.5) 206-278 (28.4)	120	Lupo et al. 2015, 2018
22	OB06 (n°3)	AA-94547	Ch / IR	131 ± 34	7-152 (64.5) 206-278 (28.4)	120	Lupo et al. 2015, 2018

23	PO-2 (n°4)	AA-96498	Ch / PO	143 ± 34	4-47 (18.2) 50-121 (29.2) 123-153 (11.4) 170-281 (41.3)	135	Lupo et al. 2018
24	BB03 (n°3)	AA-94532	Ch / IR	148 ± 34	0-46 (19.2) 52-120 (26.1) 124-154 (11.1) 168-233 (26.4) 237-282 (17.1)	142	Lupo et al. 2015, 2018
25	OB01 (n°3)	AA-94543	Ch / IR	152 ± 35	0-46 (19.5) 52-120 (24.1) 124-155 (11.0) 167-233 (28.1) 237-284 (17.3)	146	Lupo et al. 2015, 2018
26	ND01 (n°3)	AA-94537	Ch / IQ	160 ± 35	0-45 (19.7) 57-119 (20.0) 125-157 (11.0) 164-232 (31.4) 239-288 (18.0)	155	Lupo et al. 2015, 2018
27	Limbumba (n°5)	Beta-234984	Ch / PO	160 ± 40	0-46 (19.2) 53-119 (21.1) 125-157 (11.3) 163-232 (30.3) 238-288 (18.1)	154	Lupo et al. 2018
28	BB01 (n°3)	AA-94530	Ch / IR	168 ± 35	0-44 (19.7) 59-118 (16.3) 132-230 (45.2) 241-291 (18.7)	171	Lupo et al. 2015, 2018
29	CA2 (n°3)	D-AMS 27051	Ch / IR	170 ± 21	0-35 (21.6) 138-156 (10.3) 164-226 (44.2) 255-287 (19.0)	183	Schmitt et al. 2019
30	MO6 (n°3)	D-AMS 27065	Ch / PO	175 ± 23	0-34 (20.9) 139-158 (10.5) 162-226 (45.1) 255-289 (19.6)	183	Schmitt et al. 2019
31	BB05 (n°3)	AA-94534	Ch / IR	187 ± 34	0-40 (18.9) 137-227 (51.6) 253-302 (22.0)	180	Lupo et al. 2015, 2018
32	OB05 (n°3)	AA-94545	Ch / PO, IR	188 ± 39	0-43 (18.4) 60-116 (10.6) 135-229 (48.8) 250-305 (22.3)	178	Lupo et al. 2015, 2018
33	Limbumba (n°5)	Beta-233555	Ch / PO	200 ± 40	0-41 (17.1) 136-228 (49.6) 252-310 (25.9)	182	Lupo et al. 2018
34	BB01 (n°3)	AA-94531	Ch / IR	207 ± 35	0-34 (15.9) 139-225 (52.6) 255-311 (29.3)	184	Lupo et al. 2015, 2018
35	OB02 (n°3)	AA-94544	Ch / IR	210 ± 34	0-34 (15.3) 139-225 (52.8) 256-312 (31.0)	185	Lupo et al. 2015, 2018
36	Limbumba (n°5)	Beta-233557	Ch / PO	210 ± 40	0-41 (15.7) 137-227 (49.2) 253-314 (29.6)	186	Lupo et al. 2018
37	BB01 (n°3)	AA-94529	Ch / IR	215 ± 34	0-33 (14.2) 139-225 (51.7) 256-314 (33.6)	187	Lupo et al. 2015, 2018
38	NG01 (n°3)	AA-94539	Ch / IR	217 ± 48	0-44 (14.4) 134-230 (43.5) 249-320 (29.7)	194	Lupo et al. 2015, 2018
39	PO-1 (n°4)	Beta-287971	Ch / PO	220 ± 40	0-35 (13.5) 138-226 (47.0) 255-317 (33.6)	195	Lupo et al. 2018
40	LE1 (n°3)	D-AMS 27053	Ch / IR	225 ± 23	150-188 (41.8) 269-309 (45.8)	196	Schmitt et al. 2019

41	BB05 (n°3)	AA-94533	Ch / IR	231 ± 34	145-219 (44.0) 265-315 (45.1)	209	Lupo et al. 2015, 2018
42	ND02 (n°3)	AA-94538	Ch / IR	242 ± 34	146-218 (34.3) 265-321 (47.5) 377-427 (11.6)	287	Lupo et al. 2015, 2018
43	LE6 (n°3)	D-AMS 27060	Ch / IR	246 ± 23	152-172 (25.2) 278-316 (67.4)	294	Schmitt et al. 2019
44	LE5 (n°3)	D-AMS 27059	Ch / IR	252 ± 23	153-170 (19.7) 280-317 (70.0)	298	Schmitt et al. 2019
45	LE2 (n°3)	D-AMS 27782	Ch / IR	325 ± 23	310-343 (21.1) 346-459 (78.9)	387	Schmitt et al. 2019
46	LE5 (n°3)	D-AMS 27781	Ch / IR	326 ± 23	310-344 (21.0) 346-460 (79.0)	387	Schmitt et al. 2019
47	Ngara (n°3)	Ly-5919	Ch / IR	330 ± 45	305-483 (98.7)	391	Ndanga 2008
48	LE3 (n°3)	D-AMS 27056	Ch / IR	347 ± 23	315-411 (61.4) 421-477 (38.6)	387	Schmitt et al. 2019
49	LE3 (n°3)	D-AMS 27055	Ch / IR	348 ± 25	315-412 (60.8) 421-479 (39.2)	389	Schmitt et al. 2019
50	LE5 (n°3)	D-AMS 27058	Ch / IR	356 ± 24	316-398 (53.1) 423-492 (46.9)	395	Schmitt et al. 2019
51	LL01 (n°3)	AA-94535	Ch / IR	412 ± 34	328-373 (17.8) 429-522 (82.2)	479	Lupo et al. 2018
52	Lingbangbo (n°2)	Bdy-255	Ch? / PO, IR	430 ± 180	240-677 (83.0)	454	Koté 1992
53	NZ03 (n°3)	AA-94541	Ch / PO, IR	494 ± 34	494-553 (100)	524	Lupo et al. 2015, 2018
54	Lingbangbo (n°2)	Bdy-582	Sh / PO, IR	559 ± 77	490-671 (99.9)	579	Koté 1992
55	NZ03 (n°3)	AA-94542	Ch / PO, IR	593 ± 34	537-573 (28.2) 579-650 (71.8)	603	Lupo et al. 2015, 2018
56	Sabélé I (n°6)	Ly-5921	Ch / IR	630 ± 45	548-665 (100)	604	Lanfranchi et al. 1998
57	NZ03 (n°3)	AA-94540	Ch / PO, IR	706 ± 35	560-592 (23.6) 630-689 (76.4)	660	Lupo et al. 2015, 2018
58	Sabélé II (n°6)	Ly-5922	Ch? / IR	715 ± 35	562-589 (17.0) 639-694 (79.6)	665	Lanfranchi et al. 1998
59	LE4 (n°3)	D-AMS 27057	Ch / IR	782 ± 22	675-726 (100)	700	Schmitt et al. 2019
60	Sikilongo (n°2)	Bdy-303	Ch? / IR	870 ± 210	508-1178 (97.9)	821	Koté 1992
61	Eyo (n°2)	Bdy-579	Ch? / PO	1020 ± 115	719-1176 (99.0)	928	Koté 1992
62	Z-13 (n°5)	Beta-282421	Ch / IR	1140 ± 40	957-1130 (92.7)	1036	Lupo et al. 2018
63	MO7 (n°3)	D-AMS 27062	Ch / IR	1144 ± 27	960-1079 (84.3)	1029	Schmitt et al. 219
64	MO9 (n°3)	D-AMS27063	Ch / IR	1146 ± 26	971-1080 (80.8) 1089-1123 (10.7)	1031	Schmitt et al. 2019
65	Bobélé II (n°2)	Bdy-583	Ch? / IR	1200 ± 100	953-1294 (97.9)	1118	Koté 1992
66	Eyo (n°2)	Bdy-461	Ch? / PO	1200 ± 120	905-1314 (98.1)	1114	Koté 1992
67	Z-05 (n°5)	Beta-287972	Ch / PO, IR	1230 ± 40	1062-1193 (67.6) 1198-1274 (32.4)	1152	Lupo et al. 2018
68	Z-13 (n°5)	AA-96499	Ch / IR	1264 ± 36	1118-1164 (18.1) 1175-1285 (76.5)	1215	Lupo et al. 2018
69	MO11 (n°3)	D-AMS 27780	Ch / ?	1508 ± 23	1344-1411 (97.4)	1377	Schmitt et al. 2019
70	PO-2 (n°4)	AA-96496	Ch / PO	1652 ±	1412-1462	1536	Lupo et al. 2018

				37	(19.1) 1468-1610 (75.6)		
71	PO-2 (n°4)	Beta-282420	Ch / PO	1690 ± 40	1516-1645 (77.4) 1651-1703 (20.8)	1583	Lupo et al. 2018
72	Bécaré II (n°6)	Beta-88067	Ch / IR	1870 ± 70	1608-1674 (10.6) 1688-1944 (88.0)	1784	Lanfranchi et al. 1998
73	MO9 (n°3)	D-AMS 27064	Ch / IR	1875 ± 27	1715-1832 (97.7)	1781	Schmitt et al. 2019
74	LE2 (n°3)	D-AMS 27054	Ch / IR	1898 ± 27	1733-1882 (100)	1800	Schmitt et al. 2019
75	MO8 (n°3)	D-AMS 27066	Ch / PO	1907 ± 34	1730-1893 (96.3)	1814	Schmitt et al. 2019
76	ML01 (n°3)	AA-94536	Ch / PO	1938 ± 36	1743-1943 (99.0)	1860	Lupo et al. 2018
77	Z-02 (n°4)	AA-96500	Ch / PO	2179 ± 37	2094-2317 (94.7)	2203	Lupo et al. 2018
78	Limbumba (n°5)	Beta-233556	Ch / PO	2380 ± 40	2336-2497 (88.9)	2416	Lupo et al. 2018
79	Cemetery 1 (n°6)	D-AMS 45991	Ch / IR	1659 ± 21	1516-1602 (91.9)	1544	Schmitt et al. 2023
80	Kadéi (n°6)	D-AMS 45992	Ch / PO	561 ± 21	528-558 (51.4) 594-627 (48.6)	559	Schmitt et al. 2023
81	Namboui 2 (n°6)	D-AMS 45993	Ch / IR	2551 ± 21	2536-2586 (19.4) 2615-2634 (11.5) 2699-2746 (67.0)	2718	Schmitt et al. 2023
82	Monkamboht 2 (n°6)	D-AMS 45994	Ch / IR	1695 ± 24	1534-1618 (83.1) 1670-1692 (16.9)	1581	Schmitt et al. 2023
83	Tanga 2 (n°6)	Poz-41930	Ch? / IR	1670 ± 30	1515-1621 (84.5) 1669-1692 (10.7)	1562	Schmitt et al. 2023
3- Nangara-Komba rockshelter, north of the SRI (CAR): 24 ^{14}C dates							
84	Layer IV (n°7)	D-AMS 32087	Cn / PO, LI	112 ± 24	22-147 (73.4) 217-266 (26.5)	109	Lupo et al. 2021
85	Layer IV, disturbed	D-AMS 32083	Cn / PO, LI	811 ± 25	676-740 (97.9)	710	Lupo et al. 2021
86	Layer III	D-AMS 32081	Ch / PO, LI	157 ± 26	0-44 (21.0) 59-117 (19.0) 134-155 (10.1) 166-230 (32.9) 242-284 (17.0)	155	Lupo et al. 2021
87	-60 cm, disturbed	D-AMS 27068	Ch / PO, LI	170 ± 22	0-35 (21.4) 138-156 (10.3) 164-226 (43.4) 255-287 (18.8)	183	Lupo et al. 2021
88	Layer III	D-AMS 32080	Ch / PO, LI	276 ± 20	288-326 (53.8) 375-428 (44.9)	316	Lupo et al. 2021
89	Rock art	D-AMS 32079	?	488 ± 38	489-554 (98.1)	522	Lupo et al. 2021
90	Layers II/III	D-AMS 37363	Ch / PO, LI	1508 ± 23	1344-1411 (97.4)	1377	Lupo et al. 2021
91	-35 cm, testing	D-AMS 27079	Ch / LI	1657 ± 26	1513-1605 (81.7)	1543	Lupo et al. 2021
92	Feature 1/II	D-AMS 37361	Ch / PO, LI	2351 ± 28	2331-2439 (95.9)	2356	Lupo et al. 2021
93	Feature 1/II	D-AMS	Ch / PO, LI	2409 ±	1711-2018	2429	Lupo et al. 2021

		37358		28	(100)		
94	Feature 2/II	D-AMS 37359	Cn / PO, LI	2830 ± 26	2855-3003 (100)	2931	Lupo et al. 2021
95	Layer II	D-AMS 32084	Cn / ?, LI	2991 ± 31	3068-3253 (93.5)	3174	Lupo et al. 2021
96	Layer II	D-AMS 32088	Cn / ?, LI	3082 ± 37	3207-3378 (98.2)	3291	Lupo et al. 2021
97	Layers I/II	D-AMS 32089	Cn / ?, LI	2484 ± 33	2426-2723 (99.7)	2582	Lupo et al. 2021
98	Layers I/II	D-AMS 32718	Ch / LI	3049 ± 41	3150-3367 (99.5)	3259	Lupo et al. 2021
99	-180 cm, disturbed	D-AMS 37366	Cn / LI	3645 ± 30	3876-4016 (76.8) 4026-4085 (23.2)	3961	Lupo et al. 2021
100	-46 cm, testing	D-AMS 27067	Ch / LI	4880 ± 28	5581-5658 (98.5)	5603	Lupo et al. 2021
101	Layer I	D-AMS 37364	Ch / LI	4963 ± 28	5600-5742 (100)	5677	Lupo et al. 2021
102	Layer I	D-AMS 32085	Cn / LI	5019 ± 38	5656-5895 (98.6)	5762	Lupo et al. 2021
103	Layer I	D-AMS 37365	Ch / LI	5750 ± 31	6480-6640 (95.2)	6548	Lupo et al. 2021
104	Layer I	D-AMS 32086	Cn / LI	5824 ± 36	6536-6736 (97.4)	6635	Lupo et al. 2021
105	Layer I	D-AMS 32082	Ch / LI	6072 ± 34	6837-7008 (91.1)	6927	Lupo et al. 2021
106	Layer I	D-AMS 37362	Ch / LI	6084 ± 31	6848-7014 (91.3)	6944	Lupo et al. 2021
107	Layer I	D-AMS 32090	Cn / LI	6099 ± 34	6853-7029 (82.2) 7110-7156 (14.2)	6967	Lupo et al. 2021
4- North West of the SRI (Cameroon): 22 ^{14}C dates							
108	Bourland Site 2 (n°14)	KIA-38938	Ch / PO	2150 ± 451	1242-3235 (99.3)	2135	Bourland et al. 2015
109	Bourland site 3 (n°14)	KIA-38934	Ch / PO	205 ± 30	0-30 (15.9) 141-222 (55.4) 259-307 (28.7)	183	Bourland et al. 2015
110	Ndama (n°11)	Poz-38701	Ch / PO	2260 ± 30	2155-2260 (62.0) 2298-2343 (38.0)	2231	Morin-Rivat et al. 2014
111	Mindourou 1 (n°10)	KIA-45497	En / PO	1630 ± 25	1412-1464 (36.1) 1466-1546 (63.9)	1489	Morin-Rivat et al. 2014
112	Bali river 2 (n°9)	Poz-41775	Ch / PO	590 ± 30	539-571 (27.4) 582-6487 (72.6)	604	Morin-Rivat et al. 2014
113	Messok 3 (n°12)	KIA-38934	Ch / PO	205 ± 30	0-30 (15.9) 141-222 (55.4) 259-307 (28.7)	183	Morin-Rivat et al. 2014
114	Mbol (n°13)	Poz-41773	Ch/LI	1870 ± 30	1711-1833 (97.4)	1778	Morin-Rivat et al. 2014
115	Transect 4, puit n°2 (n°10)	Poz-62626	En / PO	1810 ± 30	1614-1672 (37.1) 1690-1751 (54.4)	1709	Morin-Rivat et al. 2016
116	Transect 4, puit n°2	Poz-62625	En / PO	1750 ± 30	1568-1711 (99.0)	1640	Morin-Rivat et al. 2016
117	Transect 5, puit n°8 (n°11)	Poz-49339	Ch / PO	1915 ± 30	1738-1893 (95.4)	1828	Morin-Rivat et al. 2016
118	Transect 5, puit n°9	Poz-49340	Ch / PO	2745 ± 30	2764-2883 (94.7)	2826	Morin-Rivat et al. 2016

119	Transect 5, puit n°9	Poz-49341	En / PO	1670 ± 35	1512-1624 (78.6) 1666-1694 (11.8)	1562	Morin-Rivat et al. 2016
120	Transect 6, puit n°9 (n°12)	Poz-49342	En / PO	2190 ± 30	2114-2317 (100)	2231	Morin-Rivat et al. 2016
121	Transect 6, puit n°9	Poz-49343	En / PO	2165 ± 30	2049-2182 (54.9) 2226-2306 (42.1)	2163	Morin-Rivat et al. 2016
122	Transect 6, puit n°9	Poz-49344	En / PO	2250 ± 35	2151-2268 (68.4) 2293-2343 (31.6)	2229	Morin-Rivat et al. 2016
123	Transect 6, puit n°9	Poz-49325	En / PO[2]	9400 ± 50	10499-10757 (99.7)	10628	Morin-Rivat et al. 2016
124	Transect 6, puit n°9	Poz-49345	En / PO	2275 ± 30	2157-2245 (49.6) 2299-2348 (49.6)	2257	Morin-Rivat et al. 2016
125	Bagofit (n°8)	Erl-12252	Ch / PO	268 ± 39	272-342 (40.7) 348-457 (46.3)	322	Meyer et al. 2009
126	Bagofit (n°8)	Erl-12253	Ch / PO, IR	1923 ± 39	1733-1940 (100)	1840	Meyer et al. 2009
127	Bagofit (n°8)	Erl-12254	Ch / PO	2559 ± 40	2494-2599 (37.8) 2612-2645 (13.6) 2682-2756 (48.6)	2640	Meyer et al. 2009
128	Mampang (n°8)	Erl-12257	Ch / PO	1761 ± 38	1547-1719 (100)	1647	Meyer et al. 2009
129	Mampang (n°8)	Erl-12258	Ch / PO	1761 ± 38	1547-1719 (100)	1647	Meyer et al. 2009
	5- Central SRI (Congo): 10 ^{14}C dates						
130	Bomassa 2 (P3) (n°16)	KIA-39606	En / PO [3]	1715 ± 25	1538-1628 (73.8) 1660-1697 (26.2)	1600	Gillet 2013
131	Ndoki river (P5) (n°16)	KIA-39607	En / PO [3]	1715 ± 25	1538-1628 (73.8) 1660-1697 (26.2)	1600	Gillet 2013
132	Landjoué (n°20)	Poz-41782	En / PO	2130 ± 30	1999-2153 (88.5) 2265-2295 (11.5)	2098	Morin-Rivat et al. 2014
133	Ngombé (n°18)	Poz-38702	En / PO	1765 ± 30	1571-1719 (100)	1651	Morin-Rivat et al. 2014
134	Mambili river (n°20)	Poz-38700	Ch / PO, IR	1590 ± 30	1403-1532 (100)	1467	Morin-Rivat et al. 2014
135	Ngombé (n°18)	Poz-38703	Ch / PO, IR	675 ± 30	560-593 (41.9) 629-673 (58.1)	641	Morin-Rivat et al. 2014
136	Pikounda 2 (n°19)	Poz-41772	En / PO	520 ± 30	506-555 (92.5)	535	Morin-Rivat et al. 2014
137	Djaka river (n°17)	Poz-38696	Ch / PO	335 ± 35	309-477 (100)	391	Morin-Rivat et al. 2014
138	Ebaleki river (n°16)	Poz-38697	Ch / PO	315 ± 30	304-461 (100)	389	Morin-Rivat et al. 2014

139	Landjoué (n°20)	Poz-41781	En / PO	290 ± 30	289-335 (32.2) 349-452 (67.1)	385	Morin-Rivat et al. 2014
6- South east of the SRI (Congo): 21 ^{14}C dates							
140	Pikunda (n°21)	KI-2891	Ch / PO	600 ± 75	513-672 (100)	597	Seidensticker 2021
141	Pikunda (n°21)	KI-2877	Ch / PO	1980 ± 100	1698-2152 (97.4)	1915	Eggert 1993
142	Pikunda (n°21)	KI-2892	Ch / PO	840 ± 41	675-795 (94.7)	741	Seidensticker 2021
143	Pikunda (n°21)	RICH-30864	Fc / PO	1850 ± 24	1711-1823 (100)	1734	Seidensticker 2024
144	Munda (n°22)	KI-2882	Ch / PO	1110 ± 110	793-892 (11.1) 896-1193 (80.0)	1030	Seidensticker 2021
145	Munda (n°22)	KI-2883	Ch / PO	870 ± 180	530-1131 (98.7)	814	Seidensticker 2021
146	Munda (n°22)	KI-2884	Ch / PO	250 ± 40	144-219 (27.2) 264-331 (42.4) 358-441 (24.8)	296	Seidensticker 2021
147	Munda (n°22)	KI-2890	Ch / PO, IR	1680 ± 90	1363-1743 (100)	1569	Eggert 1993
148	Munda (n°22)	KI-2889	Ch / PO, IR	1650 ± 80	1354-1715 (100)	1533	Eggert 1993
149	Munda (n°22)	KI-2885	Ch / PO, IR	1800 ± 80	1531-1889 (99.9)	1698	Eggert 1993
150	Munda (n°22)	KI-2887	Ch / PO, IR	2020 ± 120	1707-2185 (90.2)	1969	Eggert 1993
151	Munda (n°22)	KI-2881	Ch / PO	1990 ± 45	1820-2008 (95.3)	1900	Eggert 1993
152	Munda (n°22)	KI-2886	Ch / PO	1910 ± 80	1691-2003 (94.3)	1829	Eggert 1993
153	Munda (n°22)	KI-2888	Ch / PO	1990 ± 65	1743-2071 (97.8)	1922	Eggert 1993
154	Munda (n°22)	KI-2876	Ch / PO	1980 ± 41	1820-2002 (97.9)	1910	Eggert 1993
155	Munda (n°22)	RICH-30865	Fc / PO	192 ± 22	0-26 (18.1) 142-220 (59.4) 262-292 (22.5)	190	Seidensticker 2024
156	Munda (n°22)	RICH-30866	Fc / PO	328 ± 22	311-344 (20.0) 346-460 (79.1)	388	Seidensticker 2024
157	Likwala-aux-Herbes (n°23)	KI-2893	Ch / PO	1960 ± 90	1699-2123 (98.9)	1889	Eggert 1993
158	Mitula (n°25)	KI-2895	Ch / PO	2230 ± 100	1922-2371 (98.4)	2219	Eggert 1993
159	Mobaka (n°24)	KI-2894	Ch / PO	2270 ± 160	1888-2714 (100)	2282	Eggert 1993
160	Ngombe (n°25	RICH-30867	Fc / PO	841 ± 24	672-739 (98.9)	706	Seidensticker 2024

[1]Apart from dates processed from shell samples, the 17 others obtained by L. Koté (1992) were on “charbons de bois ou des graines calcinées” (= charcoal or carbonized seeds) (Koté, 1992: 117) or “charbon ou noix de palme” (= charcoal or palm nuts) (Koté, 1992: 119).

[2]Ceramics in association with E. guineensis dating to the early Holocene suggests the deposits are mixed, the charcoals being possibly in secondary deposits. This is confirmed by Poz-49345 dated to 2275 bp sampled from a lower level.

[3]Knotted fiber roulette decorated pottery.

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