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Archaeological Evidence for Population Rise and Collapse between ~2500 and ~500 cal. yr BP in Western Central Africa

Preuve archéologique de l'augmentation et de l'effondrement de la population entre ~2500 et ~500 ans cal. BP en Afrique centrale occidentale

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Traduction(s) :

Preuve archéologique de l'augmentation et de l'effondrement de la population entre ~2500 et ~500 ans cal. BP en Afrique centrale occidentale [fr]

Résumés

s antérieures ont montré que des changements majeurs de la
sont produits en Afrique centrale à partir de l'Holocène moyen (ex.
ıtre elles mettent en évidence une origine humaine et supposent que
, les innovations techniques (par exemple, la technologie de la fonte
lans les pratiques agricoles, conduisant à la déforestation et au
es changements. Cependant, à ce stade, l'absence de reconstitution
ıutenir pleinement ces hypothèses. Notre étude utilise une base de
ées pour déduire la dynamique des populations et l'évolution des
rale occidentale au cours des 5000 dernières années. Cette base de
ɔrées au 14C provenant de 425 sites – localisés dans le sud du
du Congo, en Guinée équatoriale et dans la partie occidentale de la
–, remontant à un maximum de 5000 ans cal. BP. La modélisation
croissance de la population entre ~2500 et ~1500 ans cal. BP,
échelle régionale de techniques et de pratiques spécifiques.
ɔsses dépotoirs, des vestiges d'utilisation de palmier à huile *Elaeis*
es de millet *Pennisetum glaucum* et la montée en puissance des
ı lieu pendant la seconde moitié du Néolithique, à partir d'environ
ôtières, la croissance de la population concerne le Néolithique et le
ıs cal. BP et 2000-1500 ans cal. BP), tandis que dans l'Hinterland
plus tardive (2400 et 1300 ans cal. BP). Il n'est pas possible
de diffusion à partir d'un seul centre. Les innovations techniques et

les nouvelles pratiques semblent plutôt s'être répandues à travers un large réseau d'interactions culturelles qui a favorisé la formation des sociétés d'Afrique centrale occidentale au cours du troisième millénaire avant notre ère.

Palaeocological studies show that major vegetation and environmental changes occurred in Central Africa from the mid-Holocene (e.g. Maley & Brenac 1998). Several suggest a human origin and assume that large population migration, technical innovations (e.g. iron-smelting technology) and/or change in agricultural practice, leading to deforestation and land clearance, are the drivers of these changes. However, at this stage, the lack of demographic reconstruction does not fully support these hypotheses. Here, a georeferenced archaeological database is used to infer population dynamics and the evolution of cultural practices in Western Central Africa over the last 5000 years. This database includes 1139 ^{14}C calibrated dates from 425 sites throughout southern Cameroon, Gabon, the Republic of Congo, Equatorial Guinea and the western part of the Democratic Republic of Congo, dating back a maximum of 5000 cal. yr BP. Data modelling indicate possible population growth from 2500 to 1500 cal. yr BP, coinciding with the occurrence at a regional scale of specific techniques and practices. The concomitant increase of refuse pits, palm oil Elaeis guineesis and iron metallurgy (plus rare remains of millet Pennisetum glaucum) took place during the second half of the Neolithic, beginning around 2800 cal. yr BP. In the coastal regions, the population growth concerns the Neolithic and the Early Iron Age (2500–2000 cal. yr BP and 2000–1500 cal. yr BP), while in the Hinterland population growth seems slightly later (2400 and 1300 cal. yr BP). It is not possible to identify a common diffusion phenomenon from a single homeland. Rather, technical innovations and new practices appear to have spread through a wide network of cultural interactions, which fostered the formation of Western Central African societies during the third millennium.

Entrées d'index

Mots-clés : Holocène tardif, archéologie, démographie préhistorique, analyse spatiale, datation radiocarbone

Keywords: Late Holocene, Archaeology, prehistoric demography, spatial analysis, radiocarbon dating

Index géographique : Cameroun/Cameroon, Gabon, Congo, R. D. Congo/Congo D. R., Guinée équatoriale/Equatorial Guinea, Afrique centrale occidentale/Western Central Africa

Texte intégral

ıf rescue archaeology and the funding of international ıl. 2010), archaeological research in Western Central Africa ›uthern Cameroon, Gabon, the Republic of Congo, Equatorial the Democratic Republic of Congo, has made qualitative and quantitative progress since the 1990s. On the one hand, archaeology-only studies now include both site-specific analyses (e.g. Eggert & Seidensticker 2016) as well as regional syntheses (e.g. Bostoen et al. 2015; Bostoen 2018). On the other hand, there are a number of projects integrating archaeological data with palaeological (palaeoecological, palaeoclimatological, palaeoenvironmental), linguistic and genetic approaches (Quintana Murci et al. 2008; Berniell-Lee et al. 2009; de Filippo et al. 2012; Grollemund et al. 2015; Patin et al. 2017; Garcin et al. 2018; Lipson et al. 2020). The archaeological data accumulated in recent years cover several specific issues, including information on the first cultigens (palm oil, millet) (e.g. Neumann et al. 2012; Kahlheber et al. 2014), the evolution of regional cultures/ceramic styles (e.g. Wotzka 1995) and/or technological developments, such as the appearance, mastery and diffusion of iron metallurgy at a regional scale (e.g. Clist 2012).

2 Although the archaeological sites investigated are unequally distributed in WCA, the accumulated dataset of ^{14}C dates associated with archaeological evidence is now sufficient to infer regional population dynamics and to provide answers to specific questions regarding cultural dynamics (e.g. on ceramic styles, technology, etc.). Given the lack of human remains and ancient DNA in WCA, however, such an archaeological approach cannot easily distinguish between the spatial dynamics necessarily involving the movement of people (migration, colonization) and those without such a necessity (expansion/retreat of cultural styles, techniques and practices). Notwithstanding, through geochronological dating techniques (e.g. ^{14}C), archaeology can distinguish between various phenomena. First of all, there are centrifugal dynamics (of people, of practices or both) that, for convenience, will be called in this paper *diffusion*. For instance, the diffusion of the Neolithic culture in Europe is illustrated by a clear ^{14}C age distribution indicating the movement of pioneer populations (Ammerman & Cavalli-Sforza 1971, 1979; Bocquet-Appel et al. 2009; Dubouloz 2017). At the regional scale, a time lag between various related occurrences arranged on a gradient in both time and space would strongly suggest diffusion of populations or cultural traits.

3 By contrast, a lack of spatial dynamics is more difficult to account for. Firstly, we cannot rule out that the methods available until now have been too imprecise to reveal any time lag. Secondly, it can also suggest that the modality of the cultural phenomenon in question is based on social interactions that are not yet understood. In this case, only local qualitative analyses may help to disentangle between diffusion and migration/colonization processes (e.g. Eggert and Seidensticker 2016; Wotzka 1995).

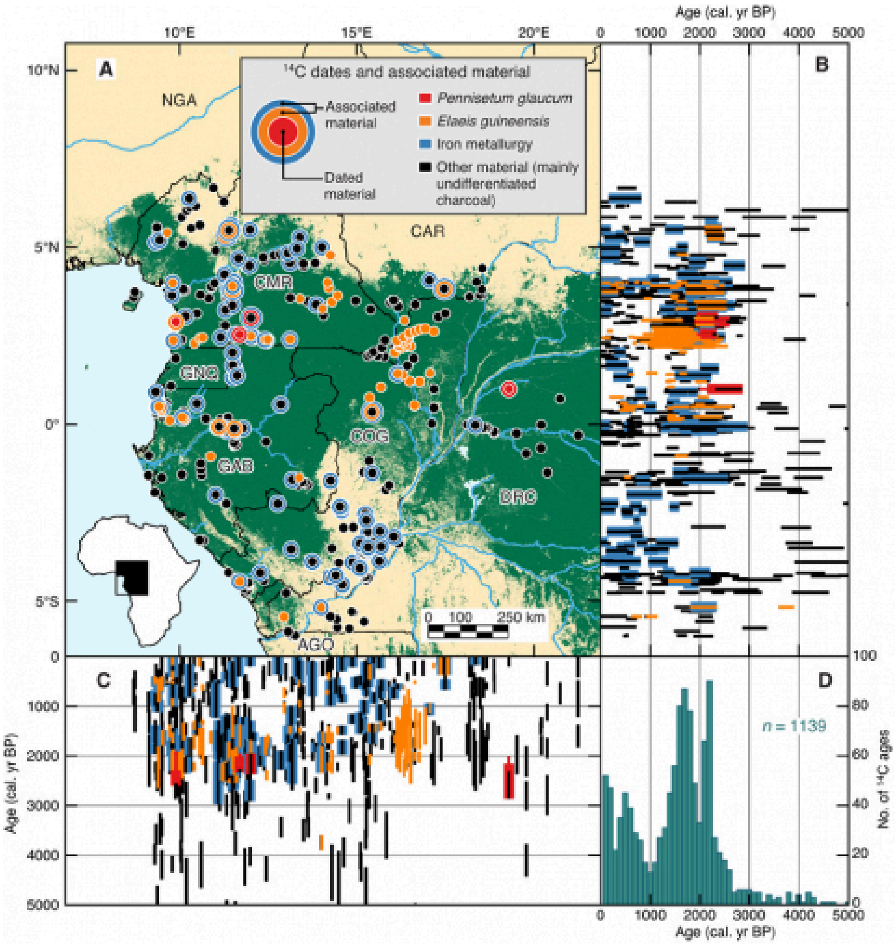
4 Working from both demographic and cultural perspectives, this study compiles a regional dataset based on a comprehensive review of the archaeological literature concerning WCA during the last 5000 years. The review aims to (i) identify the key periods of regional population shifts through archaeological data, (ii) place the inferred population dynamics within a chronology of cultural and technical innovations and (iii) test the synchronicity of these innovations at a regional scale to show evidence of possible cultural diffusion processes. As a result, this study will provide an initial archaeological synthesis, independent of, but complementary to, current linguistic and genetic data, of a period of African prehistory in which the interplay between environmental changes, climate variability and human activities is still debated by scholars (Bayon et al. 2012; Clist et al. 2018; Garcin et al. 2018; Giresse et al. 2018; Maley et al. 2012; Neumann et al. 2012).

...ntral African Archaeological ...tatistical Methods

...and use

...referenced database including 425 sites and 1139 published ...es in WCA ranging between 5000 and 15 ^{14}C yr BP (Fig. 1). ... *Elaeis guineensis*, iron metallurgy, and pit features, were ...ed that the age of a given material is equal to ages of nearby ...k has already been partially published in a companion paper ...sed on the respective roles of climate variability and human ...orest Crisis[1]. Radiocarbon dates and associated errors were ...tion proposed by Stuiver and Polach (1977).

Figure 1 – Spatiotemporal distribution of sample sites covering the past 5000 years.



(A) Current spatial distribution of the rainforest shown in green, taken from the Collection 5 MODIS Global Land Cover Type product (www.landcover.org). Countries: AGO–Angola; CAR–Central African Republic; CMR–Cameroon; COG–Congo; DRC–Democratic Republic of Congo; GAB–Gabon; GNQ–Equatorial Guinea; NGA–Nigeria. Overlain are ^{14}C-dated archaeological sites in WCA with dated and associated material.
(B) and (C) time-latitude and time-longitude distribution of the calibrated radiocarbon dates, respectively. Horizontal and vertical bars show the 95% ranges of analytical error on the ^{14}C dates.
(D) Histogram of the calibrated radiocarbon age (median) distribution of archaeological sites shown with 100-year bins for WCA.

6 The analysed samples straddle the Equator, extending from ~10°N to ~5°S, a zone which experiences seasonal variations in atmospheric CO_2. Consequently, the ^{14}C calibration curve to apply can be either the IntCal20 (Reimer et al. 2020) for the Northern Hemisphere, or the SHCal20 (Hogg et al. 2020) for the Southern Hemisphere, or a mix of both curves depending on the sample location. The distinction between the Northern and Southern Hemisphere atmospheres is not trivial and the boundary between them is set by the thermal Equator or the Intertropical Convergence Zone (ITCZ) at the time when the sample was formed (i.e. during the growing seasons in question), rather than by the geographic Equator ... et al. 2020). In the absence of any precise paleo-ITCZ ... all dates were calibrated with SHCal20, based on the ... curve for areas south of ITCZ in December-February ... ently dominate WCA. The long-term hemispheric offset is ... is IntCal20), which may create additional uncertainties in ... 2020). Radiocarbon calibration and summed probability ... ted using the freely available R statistical computing package, ... nd all ages are shown as calendar years before AD 1950

... ned probability distributions (SPDs) and other statistical ... were binned to correct for investigator bias and oversampling ... Shennan et al. 2013; Timpson et al. 2014). To account for the ... y across the study area, closely distanced radiocarbon dates ... rbitrary 10-km radius, with the ArcGIS 10.2.1 (ArcGIS, 2010) ... tial binning before calculating SPDs has been done to avoid ... d regions having been thoroughly excavated and studied (like ..., the impact of such binning is fairly limited: the amplitude of

SPDs deviations is slightly less important than what it is without binning. Radiocarbon dates were further binned in time by clustering the mean 14C yr using a threshold of 200 yr.

8 Human activity was inferred from the SPDs of 14C-dated and/or associated material, including occurrences of *Pennisetum glaucum* (pearl millet), *Elaeis guineensis* (palm oil), iron metallurgy and pit features. The age of any associated material was assumed to be the same as that of the nearby dated material.

Statistical Methods

9 Summed 14C dates (Fig. 1D) have often been used as a proxy for ancient demography, including Central Africa (Oslisly et al. 2013; Wotzka 2006), based on the idea that a larger amount of archaeological material and sites in an area reflects the presence of more people at the time (Oslisly et al. 2013). However, this method has evident weaknesses, mostly related to sampling bias, taphonomic loss and fluctuations in the radiocarbon calibration curve, such as that caused by the presence of a plateau (e.g. the Hallstatt plateau, Van der Plicht 2005), all of which reduce the reliability of demographic inference. To avoid the evident limitations of previous attempts and to produce a new and more credible representation of the region, we used recently developed demographic proxies based on the SPDs of calibrated 14C dates. This approach has been used in similar studies for Europe (Shennan et al. 2013; Timpson et al. 2014), Western Africa (Manning & Timpson 2014), South America (Goldberg et al. 2016; Riris & Arroyo-Kalin 2019), South West Asia (Roberts et al. 2018) and East Asia (Crema et al. 2016; Oh et al. 2017; Zahid et al. 2016). The method is now well established and was previously applied to Western Central Africa (Garcin et al. 2018). Seidensticker et al. (2021) recently used this method focusing on the post-1600 cal. yr BP period. In contrast, we focus here on the pre-1600 cal. yr BP period corresponding to the initial settlement history.

10 The usage of SPDs as a population proxy has been widely debated (see for example Contreras & Meadows 2014; Torfing 2015; Williams 2012; Lupo et al. 2018). If the shape of the SPDs is not overemphasized, this method provides valuable insight into palaeodemographic dynamics (Timpson et al. 2015; Crema & Bevan 2021).

11 Population dynamics were reconstructed from the SPDs of 14C dates compared with formal statistical models using the hypothesis-testing approach introduced in Shennan et al. (2013), further developed in Timpson et al. (2014) and provided in R (R Core Team 2017), statistical computing language, by Crema et al. (2016). In summary, the SPDs are first fitted to a generalized linear model. Then, random calendar year dates are created via Monte Carlo simulation. Finally, random calendar year dates are "back calibrated" into radiocarbon dates to generate null SPDs. This method provides both statistically significant local deviations (compared to the null model) and a global significance test (Timpson et al. 2014; Crema et al. 2016).

12 Here, the SPDs of 14C dates compiled in the database were calculated after correction for oversampling biases (see above). The results of the preparative binning process are shown in Table 1. In order to avoid edge effects related to the abrupt decline of radiocarbon date
day, as other dating techniques such as historical
simulation results, which started from 5150 cal. yr BP were

alysis of each of the three regions of Western Central Africa

(n)	Binned sites (n)	Binned dates (n)
	84	215
	66	137
	96	226

r the exponential model and pair-wise permutation tests
01)

		Pairwise permutation test	

	Exponential null model test	*Vs. North Coast*	*Vs. Hinterland*	*Vs. South Coast*
North Coast	**<0.0001**	-	**0.0019**	0.4174
Hinterland	**<0.0001**	**0.002**	-	**0.1595**
South Coast	**<0.0001**	0.3401	0.12	-

Table 3 – Data used for the construction of Fig. 1

	North Coast	**Hinterland**	**South Coast**
Millet			
Samples (*n*)	16	2	0
Sites (*n*)	4	2	0
Binned sites (*n*)	3	1	0
Binned dates (*n*)	4	1	0
Elaeis guineensis			
Samples (*n*)	118	121	42
Sites (*n*)	46	44	20
Binned sites (*n*)	28	27	13
Binned dates (*n*)	58	55	25
Iron metallurgy			
Samples (*n*)	89	18	83
Sites (*n*)	50	13	63
Binned sites (*n*)	35	6	40
Binned dates (*n*)	52	7	60

13 To assess whether the SPDs of 14C dates showed statistically relevant fluctuations, the SPDs were compared with an exponential model (based on 10,000 Monte Carlo simulation) used as a conservative null hypothesis reflecting long-term prehistoric human population growth and taphonomic losses, as already proposed elsewhere (Crema et al. 2016; Shennan et al. 2013; Timpson et al. 2014). This method resolves numerous biases related to sampling error and
ı curve. Significant deviations (negative or positive) from the
lation dynamics that were significantly stronger than in other
ɔns are not interpreted in terms of absolute demographic
hanges in different geographic sub-regions, a nonparametric
performed, specifically a permutation test, allowing the
nore sets of 14C dates (Crema et al. 2016). In this method the
are equal in the regions compared if the sample dates are
d population curves (Fig. 6 and Table 2). Three regions were
ıst and Hinterland) based on their geographical coordinates
ering analysis in Euclidean space calculated with Ward's
5 and R code in the Supplementary Materials). Had further
: of dates per region would have dropped significantly (values
th Coast: 526–215, Hinterland: 241–137, South Coast: 372–
uent reducing may hamper the statistical significance of
ı) however showed that the method remains robust even for
may not be fully suited to detecting rapid demographic
ndred years with reduced datasets. Supplementary Materials

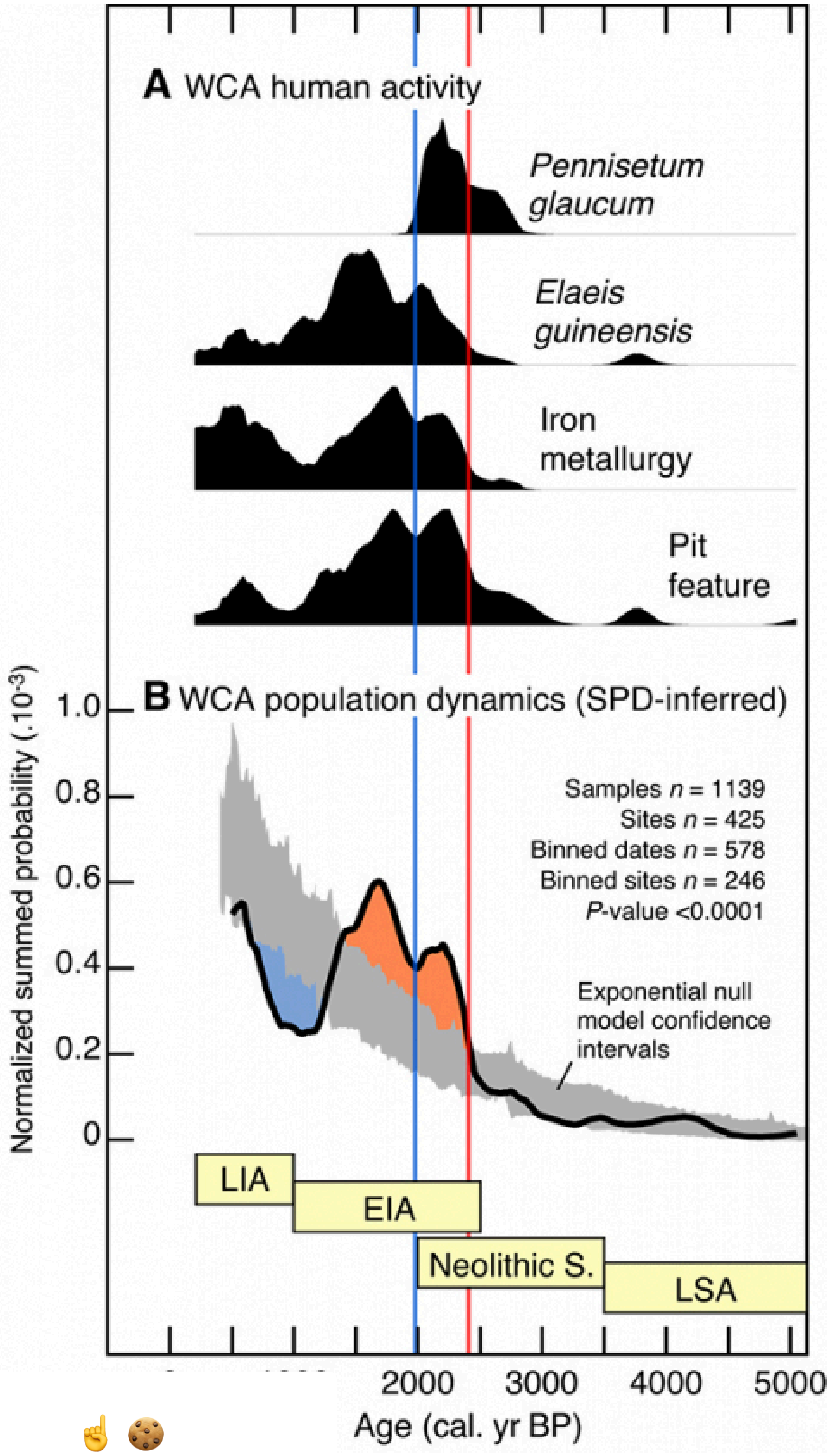
including Supplementary Tables and Figures, the archaeological database and the R codes used in this study are publicly available in the online repository DataSuds (https://doi.org/10.23708/XB8LHG).

Results

SPD deviation of archaeological remains through time

14 In WCA, the SPD deviation of archaeological finds increased from 2800 cal. yr BP until around 1500 cal. yr BP when the curve suddenly fell, confirming the empirical observations of Oslisly et al. (2013) (Fig. 2B). Based on the SPDs of calibrated ^{14}C dates for the entire WCA dataset (at 95% confidence interval), a significant change in the archaeological record is inferred, highlighting a major positive deviation in the SPD curve from 2500 to 1500 cal. yr BP. This positive deviation is marked by two distinct increases (Fig. 2B) with maximum values at 2300 cal. yr BP (interval ~2500–2000 cal. yr BP) and 1700 cal. yr BP (2000–1500 cal. yr BP).

Figure 2 – Archaeological synthesis of Western Central Africa during the past 5000 years.



the SPDs of calibrated ^{14}C dates that were binned in space using 10-km
s were plotted with a 200-yr moving average to prevent over-interpretation of

A inferred from the occurrence of remains of millet (*Pennisetum glaucum*),
gy and pit features in archaeological context.
PD of ^{14}C dates (thick line) was compared against an exponential model
ee text for explanation). The dark grey area represents the 95% confidence
areas represent intervals with significant positive and negative deviations
Regional cultural timeline (2) shown at the bottom (LSA–Late Stone Age;
on Age; LIA–Late Iron Age).
ue and red vertical lines indicate the limit of the Late Holocene Rainforest
eroon).

400 cal. yr BP, the SPD curve shows clearly a global negative
mented in all archaeological contexts as shown in previous
ieu et al. 2017). Since the dataset has been binned to avoid
and since this decrease is documented across the whole
sis, sampling bias can be ruled out.

16 However, it is important to note that the decrease of the values initiated earlier, from 1500 up to 1200 cal. yr BP. After this decline, a stabilization of the curve occurred between 1200 and 800 cal. yr BP. Finally, values recovered from 800 to 400 cal. yr BP without reaching the exponential null model.

Archaeobotanical finds and changes in cultivation practices

17 Throughout the period considered, the archaeological contexts remained homogeneous, consisting mostly of pit features (Fig. 2A). These features are about one metre in diameter and more than a metre depth and are generally filled with black earth containing charcoal and calcined fruits, sherds, stones and sometimes iron tools. The purpose of these features is still debated (Eggert et al. 2006; Mbida 2003; Mbida & Mvondo Ze 2016; Saulieu et al. 2017), but there are several lines of evidence that pits are associated with domestic sites, and likely correspond to refuse chutes (Oslisly et al. 2013; Saulieu et al. 2017).

18 While pottery and pits in the domestic context in WCA first appeared around 2800 cal. yr BP (Figs. 2 and 3), recurrent archaeological elements—such as traces of *Pennisetum glaucum*, *Elaeis guineensis* nuts and iron metallurgy—arose simultaneously in different sites around ~2500 cal. yr BP and then increased sharply afterwards (Fig. 2A). Iron metallurgy is probably older in other parts of Africa (Clist 2012), notably in Nigeria (Eggert 2014). The expansion seen here therefore appears to be related to its initial introduction into the region.

19 The occurrence of cultigens in WCA reveals different chronological patterns. Remains of both *Pennisetum glaucum* (charred grains) and *Elaeis guineensis* (charred nuts) appeared during the first part of the positive deviation (~2500–2000 cal. yr BP). *Elaeis guineensis*, a sun-loving tree, is fundamental to the diet in Central Africa for the proteins it provides and the fermented drink made from it. But the origin of its use is problematic, exactly the same way as for the other important tree in the region, *Canarium schweinfurthii*, present in archaeological contexts from the early Holocene. In archaeology, it is difficult to prove that a plant that is not domesticated (in the genetic sense of the term) was really cultivated. The remains of its charred endocarp that frequently appear in sites from the second half of the Holocene are therefore not necessarily proof of true domestication. Thus, there is a long-standing debate between those who interpret the visible variations of *Elaeis* in pollen diagrams, such as that of Lake Barombi (Maley & Brenac 1998), as natural phenomena, notably climatic (*idem*, Maley & Chepstow-Lusty 2001), and those who maintain that this tree was rationally exploited and disseminated by humans and was even a marker of the anthropization of landscapes (Warnier 1984; Sowunmi 1998). The statistical results presented here do not allow the debate to be resolved, but combined with the other trends, they could show how landscapes seem to be increasingly anthropised.

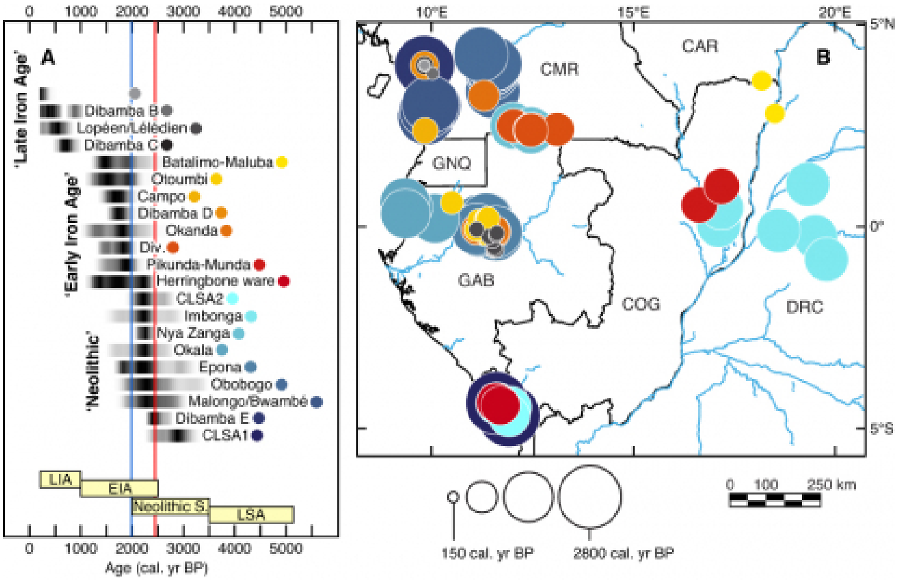
20 Rare *Pennisetum glaucum* remains, a cereal domesticated in northern Mali and Mauritania about 4900 years ago (Burgarella et al. 2018), are only present for a short time period prior
2014). Noteworthy and as expected, its occurrence in WCA
Nigeria (the Nok Culture) by the first half of the first
uller 2018). Unfortunately, instances are too scattered and
spread in WCA. This low occurrence of *Pennisetum glaucum*
to the lack of studies using dedicated isolation methods (e.g.
tzka 2019). Moreover, the populations of the Congo Basin,
s, only sporadically consumed this cereal, and in a very
egion (Bleasdale et al. 2020). Despite its low occurrence, the
ns an important cultural fact.

…gical occurrence and cultural

amic traditions were compared using SPDs, for which more
lable (Fig. 3). These have been chosen from the contexts that
apparent major bioturbation, homogeneous archaeological
ned in space and time in the same way than the complete

radiocarbon dataset (see p. 14). We chose to use SPDs for cultural chronology in coherence with the method chosen for our population modelling. The positive SPD deviation curve corresponds with a specific cultural period. The first half of the positive deviation, between ~2500 and ~2000 cal. yr BP, takes place within a ceramic horizon, which lasts from ~2800 to ~2000 cal. yr BP (Figs. 3 and 4). The ceramic styles predominant in this first period share numerous formal and decorative peculiarities present at a large regional scale. This period has different names in the literature: *Neolithic* or *Neolithic Stage* (Denbow 1990; Neumann et al. 2012; Oslisly et al. 2013), *Stone to Metal Age* in de Maret (1982, 1994) or *Ceramic Later Stone Age* (Denbow 2012, 2013). To avoid entering into a terminology debate that is beyond the aims of this article, the period is referred to here, for convenience, as *Neolithic*.

Figure 3 – Pottery traditions and main Periods of Western Central Africa.

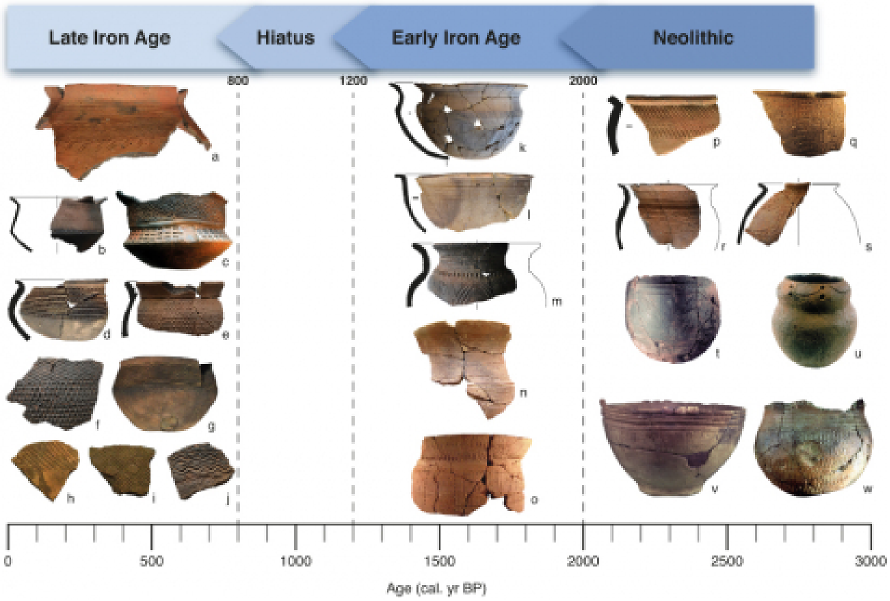


(A) Data shown in time. All archaeological data presented rely on the SPDs of calibrated ^{14}C dates that were binned in space using 10-km radii and time using 200-yr intervals. SPDs were plotted with a 200-yr moving average to prevent over-interpretation of smaller scale variability and are shown as a greyscale (black represents maximum probability; white represents null probability). Coloured dots refer to sites on the map in (B). Regional cultural timeline shown at bottom (LSA–Late Stone Age; Neolithic S.–Neolithic Stage; EIA–Early Iron Age; LIA–Late Iron Age). The blue and red vertical lines indicate the limit of the Late Holocene Rainforest Crisis (LHRC) at Lake Barombi (SW Cameroon).

(B) Location and age of sample sites. Larger dots represent older samples and smaller dots represent younger samples. Colours refer to pottery traditions highlighted in (A).

22 Despite some strong similarities, at least six distinct ceramic styles (Dibamba E, Malongo, Obobogo, Epona, Okala, Nya Zanga) occurred between ~2500 and ~2000 cal. yr BP. First described in Obobogo (Yaoundé, Cameroon; Fig. 3), ceramics are characterised by simple shapes: ovoid or spherical short-necked jars, usually with flat bases (Oslisly et al. 2013; Saulieu et al. 2017). Techniques, decorative arrangements and decorative motifs are [illegible]ressions (from vertical and/or rocker stamping) and shallow [illegible]general, the decoration is not very neat, and the firing [illegible]ave been conducive to oxidizing. The lips of containers are [illegible]s coeval ceramic styles in the Republic of Congo (Denbow's [illegible], Denbow 2013) and in the Democratic Republic of Congo [illegible]e occasional similarities and seem to be part of a common

Central Africa with Pottery traditions.



Late Iron Age: (a, b) Dibamba A–Cameroon; (c) Lopé region from 11th to 18th centuries–Gabon, (d, e) Dibamba B–Cameroon, (f) Oku–Cameroon, (g) Dibamba C–Cameroon, (h, i) Lobéké–Cameroon, (j) Kovifem–Cameroon.
Early Iron Age: (k, l) Campo–Cameroon, (m) Akom near Mintom–Cameroon, (n) Lalara–Gabon, (o) Otoumbi–Gabon.
Neolithic: (p) Dibamba E–Cameroon, (q) Mpolongwé–Cameroon, (r, s) Nya Zanga–Cameroon, (t, u) Epona–Gabon, (v) Imbonga–Democratic Republic of Congo (w), CLSA from Madingo-Kayes–Republic of Congo.

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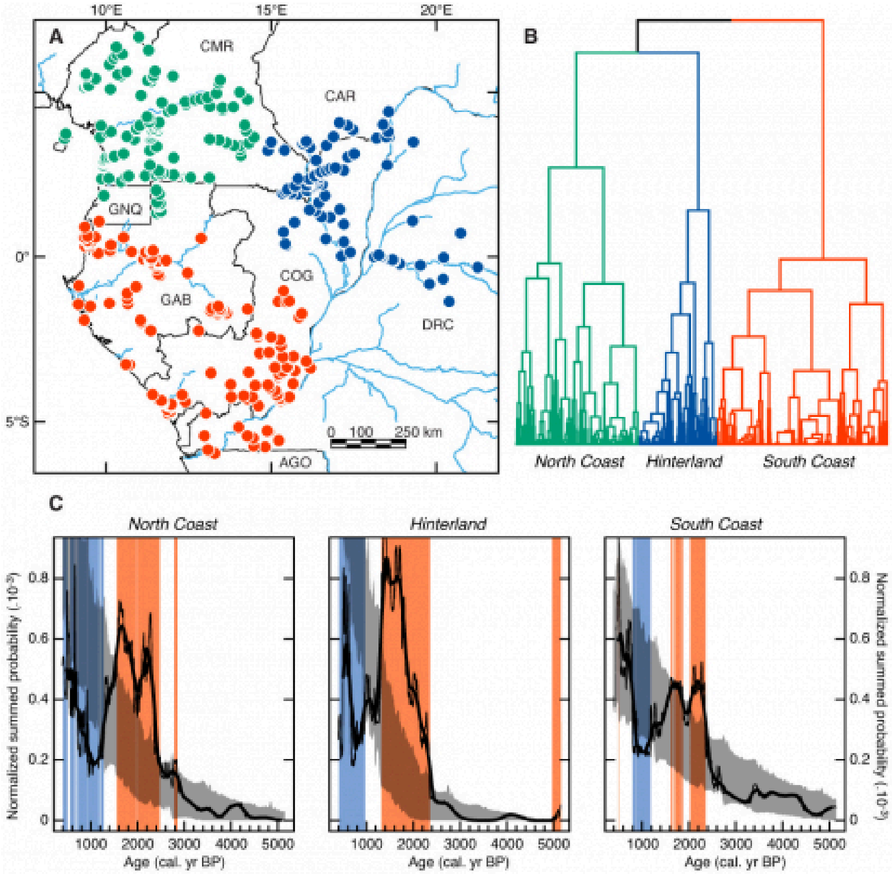
23 The second half of the positive deviation[2], occurring between ~2000 and ~1500 cal. yr BP, coincides with what some authors call the *Early Iron Age*. This period is characterised by a considerable amount of iron artefacts in archaeological contexts along the coastal regions (Table 3). Yet iron artefacts in the eastern regions of WCA are rare and of later date (Fig. S1C and Table 3) (Wotzka 1995, 2006). Regardless, the ceramic styles between ~2000 and ~1500 cal. yr BP (Fig. 4, *k-o*) are diverse but they share numerous similarities (Saulieu et al. 2017). They comprise flat-bottomed vessels and containers with composite shapes. These usually high-necked, high-shouldered pots, sometimes carinated, and various other containers such as bowls with direct or composite walls, are characterised by a particularly rich decoration, reminiscent of the earlier Imbonga ceramic style, made with combs (sometimes broadly grooved) and sticks. The patterns (parallel lines, hatching, dots, herringbone) are very dense and often deeply imprinted in the clay. In some areas *appliqué* was used. The decorations cover the whole exterior of the jar and, often, also the inner surface of its flared edges, always with great care. Thus, ceramic styles from this second period (Figs. 3, 4) share many formal and decorative traits at a wider regional scale.

Spatial occurrence of archaeological remains

24 At the scale of the studied region (1500 km by 1500 km), the dates of the Neolithic ceramic
distributed in a clear spatiotemporal gradient that would be
Indeed, in the case of a diffusion from a homeland, we may
region characterized by the oldest dates, with younger and
ving away from this centre. However, in order to avoid
for a possible spatial dynamic, a clustering analysis of
dertaken. The dated items were split into the three distinct
ıely 'North Coast', 'South Coast', and 'Hinterland' (Fig. 5).
Ds for each region (Fig. 5) and permutation tests of SPDs
ɔ observations.

ɔpulation dynamics of Western Central Africa.

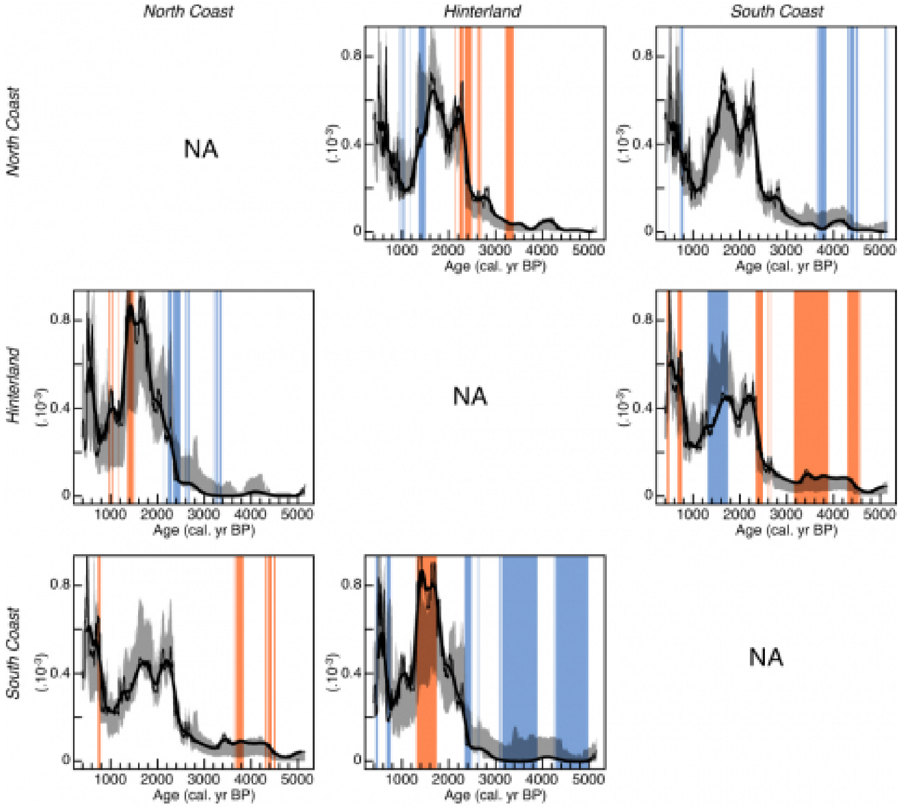


(A) Map of Western Central Africa. Dots indicate archaeological site locations and colours delineate the three regions used to estimate population changes.
(B) Definition of the three regions based on a hierarchical clustering analysis in Euclidean space.
(C) SPD of the three regions (thin line) against an exponential model. The thick lines show the 200-yr rolling mean and the grey area represents the 95% confidence interval for the model. Red and blue vertical bands represent periods with significant positive and negative deviations, respectively.

25 Firstly, the permutations demonstrate that the North and South Coast regions are statistically indistinguishable for both cultural periods: the positive deviations are synchronous with the inceptions (~2500 cal. yr BP), terminations of significant archaeological occurrences (1500 cal. yr BP) and present similar general shapes. This suggests that the North and South Coast actually formed a single homogeneous cultural region between ~2500 and ~1500 cal. yr BP.

26 Secondly, the Hinterland shows a different pattern. The 14C SPD curve does not show the typical bimodal distribution of both coastal areas. On the contrary, it shows a single principal peak whose inception shows a slight lag of ~170 yr compared with the coastal regions, which, however, is not statistically significant. This peak is stronger and lasts longer (Fig. 6), overlapping the second peak identified in the coastal zones. Finally, the 14C SPD curve dips drastically at ~1300 cal. yr BP, ~200 years later than for the coastal regions (Figs. 5, 6). These … the coastal regions and the Hinterland (discernible from … *neensis* and from the shapes of regional 14C SPD curves, see … ng the Early Iron Age.

the three regions based on permutation tests.



Each row shows an observed SPD (black thick line with its model in grey) of a region compared against another in the column. Red and blue vertical bands indicate periods with significant positive and negative deviations, respectively, from the model of the combined set of each of pair.

Discussion

Evidence for a possible population growth between ~2500 and ~1500 cal. yr BP

27 The SPD curves (Fig. 2) highlight one positive deviation between ~2500 and ~1500 cal. yr, followed by a negative deviation between ~1500 and ~ 400 cal. yr BP. This study, therefore, suggests a significant population growth (between ~2500 and ~1500 cal. yr BP) followed by a widespread demographic decline (between ~1200 and ~400 cal. yr BP) in WCA.

28 Aside from the main trends in population dynamics identified, there are also regional differences. The first part of the population growth (~2500–2000 cal. yr BP) appears marked in the two coastal regions, while the second part (~ 2000–1500 cal. yr BP), affecting all regions, is more prominent in the Hinterland (Fig. 5).

cal changes tied to the population

:ms to correspond with cultural and technical changes, which :s:

ulation growth (~2500–2000 cal. yr BP), present only in the during the second half of the Neolithic period (~2800– ıcides with the appearance of the cultigen / iron metallurgy

ıopulation growth (~2000–1500 cal. yr BP) corresponds with three regions. It is worth highlighting that this period is change in ceramic styles in the two coastal regions.
ıe two parts of the population growth are associated with the ılithic and the Early Iron Age respectively. Conversely, in the

Hinterland, the main population increase occurred during the Early Iron Age. These observations are consistent with archaeological data from the Democratic Republic of Congo showing the important diffusion of related ceramic styles eastwards along the tributaries of the Congo River and suggesting a colonization movement (Wotzka 1995, 2006).

Unresolved question of the environmental impact of the population growth

30 The first part of the population growth (~2500–2000 cal. yr BP) seems coeval with environmental and vegetation changes recorded in sedimentary archives from WCA, at least at the local scale. Indeed, various palynological records show that roughly between 3000 and 2000 cal. yr BP, rainforests were replaced in many places by a forest-savannah mosaic (e.g. Vincens et al. 1999). The timing of this vegetation disturbance, referred to as the Late Holocene Rainforest Crisis (LHRC), is poorly constrained, mostly because of the low-scale time resolution of the sedimentary archives that were investigated and the presence of sedimentary hiatuses (Bonnefille 2011). A recent study (Garcin et al. 2018) confirms a prominent and abrupt appearance of C4 plants (i.e. some light demanding plants such as *poaceae* relying on the Hatch–Slack (C4) carbon fixation pathway) in the Lake Barombi catchment, at ~2600 cal. yr BP, followed by an equally sudden return to rainforest vegetation at ~2020 cal. yr BP. Based on changes in carbon and hydrogen isotope compositions of plant waxes, it also shows that there was no simultaneous hydrological change during this event. This local and well-dated record suggests the concomitance between the LHRC and the first part of the SPDs positive deviation interpreted as a regional population growth (~2500–2000 cal. yr BP). However, the question of the spatial scale of this impact remains open. Kiahtipes (2019) outlined that local human disturbances near the Atlantic coast might have amplified a long-term forest fragmentation during the Late Holocene, when the climate was drier than in the earlier Holocene.

The Bantu expansion issue

31 It is questionable whether these results can be straightforwardly integrated with current data on genetics and historical linguistics, notably with the spread of Bantu languages. This expansion is generally assumed to have taken place between 5000 and 2000 cal. yr BP (Bostoen 2018; Bostoen et al. 2015; de Maret 2013; Vansina 1984, 1990). The population growth highlighted from ~2500 cal. yr BP onward is difficult to link with the expansion of languages in Central Africa for two main reasons. The first is that there is no ancient DNA for the populations concerned by this demographic phenomenon. The available DNA data (Lipson et al. 2020) are from the Shum Laka site located in the grassland of Western Cameroon, the supposed homeland of the Bantu languages and concern the immediately preceding period (8000–3000 cal. yr BP). Genome-wide DNA analyses clearly indicate that
the current Bantu populations and the four individuals
ckshelter (Ribot et al. 2001; Lavachery 2001). The second
alysis of the archaeological data does not prove that this
accompanied by a large migratory movement throughout the
the cultigen/iron metallurgy package co-occurring with the
ed by refuse pits and accompanied by a population growth
is very similar in the coastal regions. Here, it is difficult to
use there is not one central region where all these phenomena
he role of a homeland. This can be explained in several ways.
ethod of analysis is not precise enough to identify diffusion. It
mparison of regional curves for periods of less than two
ed to avoid chronological bias), is not statistically significant.
over such a time scale, it would not solve the interpretation
been demic (i.e. resulting from population displacements) or
displacement) dissemination of cultural traits or techniques
the North Coast to the South Coast region would imply the
lations over 1000 km in less than 200 years. Knowing the

quantity of archaeological remains involved, and taking seriously into account the distances (without a navigable rivers), this does not seem to be a realistic hypothesis: the shifts would be detectable. Conversely, the dissemination of technical practices or cultural traits over such distances in less than 200 years *without* population displacement is conceivable under certain conditions. Both social anthropology (e.g. Kopytoff 1987) or analytical sociology (e.g. Hedström 2006) can provide models or examples of transmission along social networks. However, these are currently impossible to demonstrate based on available archaeological evidence. Nonetheless, if this hypothesis is retained, then it follows that the social networks that enabled the rapid diffusion of these technical practices and/or cultural traits were already in place and mature before 2500 cal. yr BP.

Population decline between ~1200 and ~ 400 cal. yr BP

32 The negative deviation of the curve (1200–400 cal. yr BP) corresponding to a possible global decline in occupation levels is widespread and follows a millennium long trend of population growth and probable technologically-driven modification of the environment through, for example, iron metallurgy. This regional decrease may not be clearly reflected in all local archaeological records. Even if in some regions human settlements seem to be maintained (Lupo et al. 2018; Oslisly et al. 2013), there seems to be a gap in the cultural chronologies of the Lopé region of central Gabon (Oslisly 1993; Oslisly 2001; Assoko Ndong 2002) and the Dibamba site on the Cameroonian coast (Saulieu et al. 2017).

33 Changes in population dynamics in both coastal regions of WCA and in the Hinterland were asynchronous (Fig. 5). The permutation test (Fig. 6) indicates that during the first population growth the Hinterland response lagged behind the coastal regions by ~170 years (which is not statistically significant), and the population decline arrived ~200 years later. This confirms the particular status of the Hinterland region, in contrast to the two coastal regions. The latter are actually very similar as demonstrated by the permutation test.

34 It must also be emphasised that the negative deviation of the curve observed between ~1200 and 400 cal. yr BP is coeval with the proposed substantial gene admixture between the rainforest hunter-gatherers ('pygmies') and the ancestors of the modern Bantu-speaking peoples, estimated between 1000 and 800 cal. yr BP (Patin et al. 2014, 2017). This raises a multitude of questions regarding when these different populations settled in Central Africa, as well as when and how the very particular relations that they maintain today came about. The well-known complementarity between these different populations (Bahuchet 1991; Testart 1982) could therefore have been established at that time, attributing to the pygmies the activities related to the deep forest.

35 The cause of this population decline is unknown. A sanitary or epidemic regional crisis could be envisaged, similar to the hypothesis of the second plague pandemic impacting societies in the Ife political sphere of influence, and many other urban sites in West and East Africa starting in the 14th century (Chouin 2013, 2018; Green 2018). The demographic decline should probably be seen as the result of multiple rather than single factors, as it is deep and long term. What initiated the decline and what prolonged it? The chronological framework we
…ology of the 'First plague pandemic' (540–850 CE) as already
…017). This hypothesis seems to be unsubstantiated for the
…graphic crisis is very long, it is not impossible that this event
… the depopulation, particularly environmental ones (e.g.
…nental transformations triggered by these sedentary human
…d epidemiological boundaries. We could also make the
…ties could have adopted new practices that brought them into
… pathogenic vectors. However, the insufficient accuracy of the
…e of human remains do not allow further insight.

…ned probability distributions of 14C dates from archaeological
… population growth between ~2500 and ~1500 cal. yr BP. The
…pits, *Elaeis guineensis* and iron metallurgy along with rare
… took place during the second half of the Neolithic, beginning

around 2800 cal. yr BP. Regional differences were demonstrated by splitting the data into to three geographical clusters (‘North coast’, ‘South coast’ and ‘Hinterland’). In the coastal regions, the population growth appears in two successive parts during the Neolithic and the Early Iron Age (~2500–2000 cal. yr BP and ~2000–1500 cal. yr BP) while in the Hinterland the shape and timing of the curve is slightly different (~2400–1300 cal. yr BP). However, it is not possible to identify a common diffusion phenomenon from a homeland. While the specificities of the SPD curve for the Hinterland region can probably be explained by colonization in the Congo Basin (Wotzka 1995, 2006), the two coastal regions evolve in an identical way, to the extent that it seems unlikely that the archaeological proxies and the SPD curve are here indicators of a population displacement. On the contrary, it suggests a wide-ranging interaction network, already in place when new innovations arrived around 2500 cal. yr BP, causing population growth. A decline in settlements at the regional level after ~1500 cal. yr BP is also evident and detailed at a sub-regional scale. This decline can be compared with the long-term local archaeological chronology observed at the Lopé (Oslisly 1993, 2001; Assoko Ndong 2002) or Dibamba (Saulieu et al. 2017) sites. However, the causes are yet to be elucidated.

37 This study establishes for the first time a plausible picture of the population dynamics and the evolution of cultural traits and technical innovation in WCA over the last five millennia, based on a comprehensive and statistically-binned archaeological database. These results provide a robust archaeological timeframe that may contribute to the refinement of phylogenetic and linguistic models in the area. Together with ancient DNA data (Lipson et al. 2020), this study aims to contribute also to the debates regarding the cultural and linguistic history of Central African populations as well as the long-term changes in land use that affected this region during the Late Holocene.

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39 Author contributions: G.S., Y.G., D.S. and R.O. conceptualized the paper. R.O., G.S., Y.G., and P.N. built the archaeological dataset. Y.G., D.S. and G.S. performed analyses. All authors assisted with data interpretation and paper preparation. D.Z. and P.C. provided feedback on the concepts, data interpretation and paper preparation. G.S., D.S. and Y.G. wrote the paper.

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Notes

1 The 'Late Holocene Rainforest Crisis' is a vegetation disturbance that is recorded in palaeoenvironmental proxies, mostly pollen, from several sites in Western Central Africa between 2800 and 2000 cal. yr BP (Ngomanda et al. 2009). It was originally described in the sediments of Lake Barombi in south-west Cameroon (Maley & Brenac 1998). Here, the crisis is recorded by a greater openness of the forest environment, an increase in the relative importance of *poaceae* and pioneer tree taxa, a relative decline in old-growth forest taxa, and an increase in pollen from the oil palm *Elaeis guineensis*—an heliophilic taxon commensal with humans.

2 *Positive deviation*: when the statistical curve is greater than the null model. The deviation is *negative* when the curve is smaller than the null model.

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patiotemporal distribution of sample sites covering the past
›patial distribution of the rainforest shown in green, taken from the MODIS Global Land Cover Type product (www.landcover.org). GO–Angola; CAR–Central African Republic; CMR–Cameroon; ›; DRC–Democratic Republic of Congo; GAB–Gabon; GNQ–uinea; NGA–Nigeria. Overlain are ^{14}C-dated archaeological sites dated and associated material. (B) and (C) time-latitude and time-›tribution of the calibrated radiocarbon dates, respectively. ıd vertical bars show the 95% ranges of analytical error on the ^{14}C ıstogram of the calibrated radiocarbon age (median) distribution of ›al sites shown with 100-year bins for WCA.
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Titre Figure 2 – Archaeological synthesis of Western Central Africa during the past 5000 years.

Légende All archaeological data presented rely on the SPDs of calibrated ^{14}C dates that were binned in space using 10-km radii and time using 200-yr intervals. SPDs were plotted with a 200-yr moving average to prevent over-interpretation of smaller scale variability. (A) Evidence of human activity in the WCA inferred from the occurrence of remains of millet (*Pennisetum glaucum*), palm oil (*Elaeis guineensis*), iron metallurgy and pit features in archaeological context. (B) SPD-inferred population dynamics: SPD of ^{14}C dates (thick line) was compared against an exponential model used as a conservative null hypothesis (see text for explanation). The dark grey area represents the 95% confidence interval for the null model. Red and blue areas represent intervals with significant positive and negative deviations from the exponential model, respectively. Regional cultural timeline (2) shown at the bottom (LSA–Late Stone Age; Neolithic S.–Neolithic Stage; EIA–Early Iron Age; LIA–Late Iron Age). (A) and (B) are adapted from (*14*). The blue and red vertical lines indicate the limit of the Late Holocene Rainforest Crisis (LHRC) at Lake Barombi (SW Cameroon).

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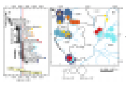
Titre Figure 3 – Pottery traditions and main Periods of Western Central Africa.



Légende (A) Data shown in time. All archaeological data presented rely on the SPDs of calibrated ^{14}C dates that were binned in space using 10-km radii and time using 200-yr intervals. SPDs were plotted with a 200-yr moving average to prevent over-interpretation of smaller scale variability and are shown as a greyscale (black represents maximum probability; white represents null probability). Coloured dots refer to sites on the map in (B). Regional cultural timeline shown at bottom (LSA–Late Stone Age; Neolithic S.–Neolithic Stage; EIA–Early Iron Age; LIA–Late Iron Age). The blue and red vertical lines indicate the limit of the Late Holocene Rainforest Crisis (LHRC) at Lake Barombi (SW Cameroon). (B) Location and age of sample sites. Larger dots represent older samples and smaller dots represent younger samples. Colours refer to pottery traditions highlighted in (A).

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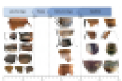
Titre Figure 4 – Chronology of Western Central Africa with Pottery traditions.



Légende Late Iron Age: (a, b) Dibamba A–Cameroon; (c) Lopé region from 11th to 18th centuries–Gabon, (d, e) Dibamba B–Cameroon, (f) Oku–Cameroon, (g) Dibamba C–Cameroon, (h, i) Lobéké–Cameroon, (j) Kovifem–Cameroon. Early Iron Age: (k, l) Campo–Cameroon, (m) Akom near Mintom–Cameroon, (n) Lalara–Gabon, (o) Otoumbi–Gabon. Neolithic: (p) Dibamba E–Cameroon, (q) Mpolongwé–Cameroon, (r, s) Nya Zanga–Cameroon, (t, u) Epona–Gabon, (v) Imbonga–Democratic Republic of Congo (w), CLSA from Madingo-Kayes–Republic of Congo.

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Titre Figure 5 – Regional variability in population dynamics of Western Central Africa.

Western Central Africa. Dots indicate archaeological site locations delineate the three regions used to estimate population changes. of the three regions based on a hierarchical clustering analysis in pace. (C) SPD of the three regions (thin line) against an exponential hick lines show the 200-yr rolling mean and the grey area e 95% confidence interval for the model. Red and blue vertical sent periods with significant positive and negative deviations,

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omparison of SPDs of the three regions based on permutation

ows an observed SPD (black thick line with its model in grey) of a ared against another in the column. Red and blue vertical bands ods with significant positive and negative deviations, respectively, del of the combined set of each pair.

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Référence papier
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