



**HAL**  
open science

# Climatic and cultural changes in the west Congo Basin forests over the past 5000 years

Richard Oslisly, Lee White, Ilham Bentaleb, C. Favier, Michel Fontugne,  
Jean-François Gillet, David Sebag

► **To cite this version:**

Richard Oslisly, Lee White, Ilham Bentaleb, C. Favier, Michel Fontugne, et al.. Climatic and cultural changes in the west Congo Basin forests over the past 5000 years. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 2013, 368 (1625), pp.20120304-20120304. 10.1098/rstb.2012.0304 . hal-01970011

**HAL Id: hal-01970011**

**<https://hal.science/hal-01970011>**

Submitted on 28 Apr 2021

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



**Cite this article:** Oslisly R, White L, Benteleb I, Favier C, Fontugne M, Gillet J-F, Sebag D. 2013 Climatic and cultural changes in the west Congo Basin forests over the past 5000 years. *Phil Trans R Soc B* 368: 20120304. <http://dx.doi.org/10.1098/rstb.2012.0304>

One contribution of 18 to a Theme Issue 'Change in African rainforests: past, present and future'.

**Subject Areas:**

environmental science, health and disease and epidemiology, ecology

**Keywords:**

Holocene, archaeology, Congo–Ogooué basin, palaeoenvironment, climatic change, vegetation

**Author for correspondence:**

Richard Oslisly  
e-mail: [richard.oslisly@ird.fr](mailto:richard.oslisly@ird.fr)

# Climatic and cultural changes in the west Congo Basin forests over the past 5000 years

Richard Oslisly<sup>1</sup>, Lee White<sup>2,3,4</sup>, Ilham Benteleb<sup>5</sup>, Charly Favier<sup>5</sup>, Michel Fontugne<sup>6</sup>, Jean-François Gillet<sup>7</sup> and David Sebag<sup>8</sup>

<sup>1</sup>Institut de Recherche pour le Développement, UMR 208 IRD/MNHN, Patrimoines Locaux, Agence Nationale des Parcs Nationaux, BP 20379 Libreville, Gabon

<sup>2</sup>Agence Nationale des Parcs Nationaux, BP 20379 Libreville, Gabon

<sup>3</sup>Institut de Recherche en Ecologie Tropicale, BP 13354 Libreville, Gabon

<sup>4</sup>University of Stirling, Stirling FK9 4LA, UK

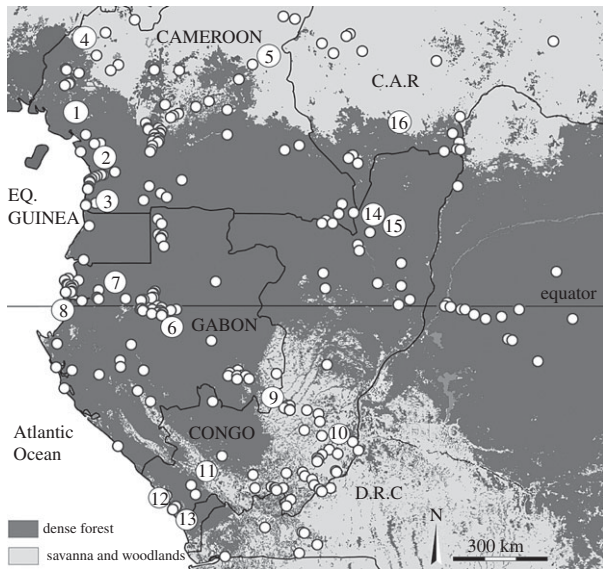
<sup>5</sup>Université de Montpellier 2, CNRS, ISEM, Place Eugene Bataillon, 34095 Montpellier, France

<sup>6</sup>Laboratoire des Sciences du Climat et de l'Environnement, UMR 8212 CNRS/CEA/UVSQ, Domaine du CNRS, 91198 Gif-sur-Yvette Cedex, France

<sup>7</sup>Université de Liège, Gembloux Agro-Bio Tech, Laboratoire de foresterie des régions tropicales et subtropicales, Passage des Déportés 2, 5030 Gembloux, Belgium

<sup>8</sup>Institut de Recherche pour le Développement, HydroSciences Montpellier, Université de Ngaoundéré, BP 454, Cameroon

Central Africa includes the world's second largest rainforest block. The ecology of the region remains poorly understood, as does its vegetation and archaeological history. However, over the past 20 years, multidisciplinary scientific programmes have enhanced knowledge of old human presence and palaeoenvironments in the forestry block of Central Africa. This first regional synthesis documents significant cultural changes over the past five millennia and describes how they are linked to climate. It is now well documented that climatic conditions in the African tropics underwent significant changes throughout this period and here we demonstrate that corresponding shifts in human demography have had a strong influence on the forests. The most influential event was the decline of the strong African monsoon in the Late Holocene, resulting in serious disturbance of the forest block around 3500 BP. During the same period, populations from the north settled in the forest zone; they mastered new technologies such as pottery and fabrication of polished stone tools, and seem to have practised agriculture. The opening up of forests from 2500 BP favoured the arrival of metallurgist populations that impacted the forest. During this long period (2500–1400 BP), a remarkable increase of archaeological sites is an indication of a demographic explosion of metallurgist populations. Paradoxically, we have found evidence of pearl millet (*Pennisetum glaucum*) cultivation in the forest around 2200 BP, implying a more arid context. While Early Iron Age sites (prior to 1400 BP) and recent pre-colonial sites (two to eight centuries BP) are abundant, the period between 1600 and 1000 BP is characterized by a sharp decrease in human settlements, with a population crash between 1300 and 1000 BP over a large part of Central Africa. It is only in the eleventh century that new populations of metallurgists settled into the forest block. In this paper, we analyse the spatial and temporal distribution of 328 archaeological sites that have been reliably radiocarbon dated. The results allow us to piece together changes in the relationships between human populations and the environments in which they lived. On this basis, we discuss interactions between humans, climate and vegetation during the past five millennia and the implications of the absence of people from the landscape over three centuries. We go on to discuss modern vegetation patterns and African forest conservation in the light of these events.



**Figure 1.** The study area (Central Atlantic Africa) showing the location of 328 archaeological sites and 16 lake coring sites in the dense forest and forest/savanna mosaic (references are cited in the main text): 1, Barombi Mbo; 2, Ossa; 3, Nyabesan; 4, Bambili; 5, Mbalang; 6, Kamalété; 7, Nguène; 8, Maridor; 9, Bilanko; 10, Ngamaka; 11, Sinnda; 12, Kitina; 13, Coraf/Songolo; 14, Mopo Bai; 15, Goulougo; 16, Bodingué.

## 1. Introduction

Geological and biological studies carried out over the past 40 years have dispelled the illusion of the ‘eternal rainforest’ in equatorial Africa. Indeed, it is clear that during the last glacial maximum severe climatic conditions restricted dense equatorial forests in Africa into a small number of larger refuge areas and a complex mosaic of ‘micro-refugia’, where favourable conditions persisted [1–5].

The Holocene marked the return to milder conditions in Central and West Africa, and forests quickly regained lost ground, as evidenced by increasing levels of rainforest pollen in lake sediments across the region [6,7]. Several records from marine [8–10] and terrestrial climate archives [4,11] also suggest humid conditions interspersed by numerous climate fluctuations [12] during the Early and Middle Holocene followed by a dry Late Holocene.

In Central Africa, there is strong evidence for a significant forest regression event between 3000 and 2000 years BP. The Warm African monsoon declined from about 3500 years BP, causing a serious disturbance of the forest massif, as attested by many palynological and geological studies undertaken on sedimentary deposits of lakes (figure 1) in the Congo basin [3,13–27].

Pollen profiles show that humid forest trees were replaced by light-demanding pioneer and herbaceous species, characteristic of degraded forests and savannas between 3000 and 2500 BP [21].

The fragmentation of the Congolese forests, at a time when there were variations in the levels of many lakes in the region and corresponding changes of average surface water temperatures in the Gulf of Guinea [10], has been interpreted as a response to a generalized arid period in Central Africa [14,28], related to a weakening of the Atlantic monsoon. The palynological and geochemical data and diatoms at the site of Mbalang in Cameroon [22,29] demonstrate

significant environmental change from 3200 years BP, linked to different hydrological conditions.

The consensus that has developed is that climatic conditions with a long dry season combined with more severe storm events resulted in severe erosion. A recent study [30] suggested that this can be explained by anthropogenic soil erosion, but others [31,32] argue that climate was the main driver. A large-scale spread of Bantu iron workers occurred only around 1900–1700 BP. It seems likely therefore that the first Bantu farmers opportunistically followed forest fragmentation to penetrate the forest zone.

These studies also demonstrate that the medieval period in the Northern Hemisphere (1100–800 years BP) is characterized by decadal fluctuations in the lake levels in Atlantic Central Africa [33], coinciding with the opening up of the canopy of mature forests in peripheral areas adjoining the forest block [14,20] as well as forest recovery in the central Gabon [34]. During the Little Ice Age (500–200 years BP), lake levels were low [16,33], cover of rainforests decreased and there was a change in the type of vegetation from evergreen to deciduous forests [16].

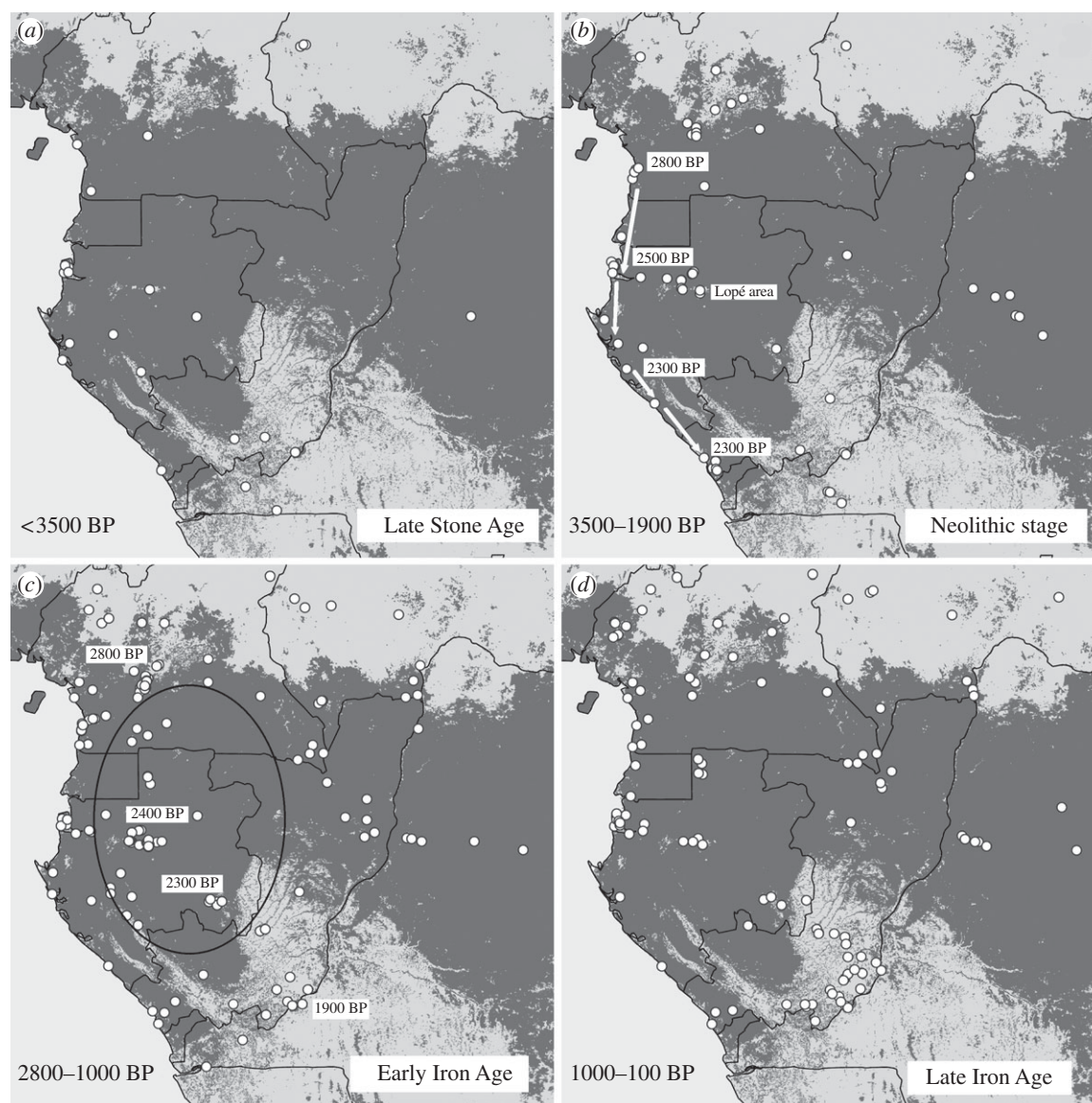
Archaeological studies have demonstrated that cultural and technological evolution occurred in parallel to these regional environmental changes. Here, we consider the distribution of archaeological sites discovered over the past 30 years in Cameroon and especially Gabon to evaluate the interactions between humans and the environment. Following a number of pioneering studies in the 1960s [35,36], systematic surveys were undertaken between 1980 and 1990. These early studies identified the major stages of cultural change in the region [37]. Subsequent studies in the period 1990–2000 focused on a number of major sites, providing a regional chronological reference for cultural changes [38–40]. More recently, the focus has been on interactions between man and the environment, focusing particularly on the impact of man on his habitat and the impacts of climate change on human societies [41–43]. In this synthesis, we assemble a database of 328 archaeological sites known in West Central Africa and analyse their distribution, in an attempt to better understand the relationships between climate, human demography and forest distribution through the Holocene.

## 2. Study area and methods

This is the first study to compile data on all known archaeological sites in the Central African rainforest region. The area under study includes six countries of Atlantic Central Africa (the southern half of Cameroon, mainland Equatorial Guinea (the island of Bioko has a different history), Gabon, Republic of Congo, the western part of the Democratic Republic of Congo and the southwest of the Republic of Central Africa). We divide the region into two generic biomes: forest and savanna/savanna–forest mosaic (figure 1).

We identified 328 archaeological sites with at least one reliable carbon date from the last 5000 years. Of these, 32% (106 of 328) were sites where one of the authors had been involved in research, including 20 sites for which no data have previously been published; the remainder were from the literature [38,40,43–91]. Oslisly *et al.* [92] provide additional details of dating methods, materials and precision.

We compiled all known published and unpublished radiocarbon dates for the 328 archaeological sites [92]. Of a total of



**Figure 2.** Location of 328 archaeological sites in Atlantic Central Africa for (a) the Late Stone Age, (b) the Neolithic stage, (c) the Early and (d) the Late Iron Ages.

733 dates, 16 were rejected by researchers as being spurious, either owing to contamination or sampling error, 25 were modern, 94 were considered duplicates (very similar dates in the same site) and 12 were from Bioko island [93] (Equatorial Guinea), where there is an unbroken culture of pottery and polished stone tools from 700 AD until the arrival of Europeans in the eighteenth century. Dates on the same site a century or more apart were retained. A total of 586 dates were retained for this analysis, from a total of 328 sites.

Our method assumes that relative population numbers are related to the number of radiocarbon dates. However, caution is necessary, because sampling remains patchy reflecting the concentration of research activity and possible impacts of prevailing environmental conditions on charcoal preservation. It is also possible that the economic pursuits of pre-historic populations leave differential amounts of dateable material (i.e. iron-working versus mobile hunter–gatherers).

### 3. Results

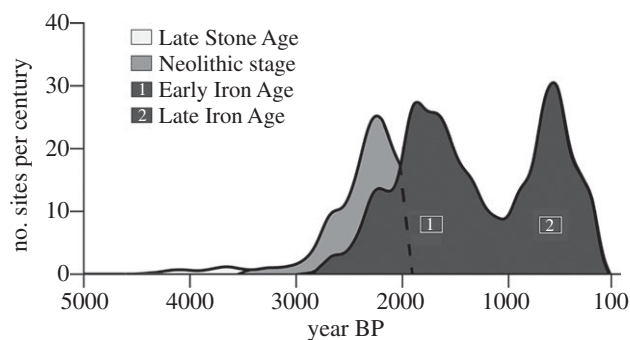
Figure 2 shows the distribution of archaeological sites across the region divided between four cultural sequences: Late Stone Age; Neolithic stage; Early Iron Age and Late Iron Age.

Two-thirds of the sites are located in the modern forest/savanna mosaic. These areas are easier to prospect and archaeological sites often show up as sites with active erosion. Forest sites were generally discovered in places where artificial openings were made during construction of roads, railways, pipelines, dams and power plants, or during mining and forestry exploitation. Given the state of research today, it is not possible to say whether distribution of sites reflects the actual spatial distribution of archaeological sites or is simply an effect of patchy sampling.

Of 586 radiocarbon dates analysed, 33 were associated with Late Stone Age sites, 97 with Neolithic sites and 456 were Iron Age remains. The distribution of 586 carbon dates from 328 archaeological sites across the region is plotted by number of sites per century in figure 3. Figure 3 shows that few sites have been found dating prior to 3000 years BP. The Late Stone Age in the region ends around 3500 years BP. Neolithic sites increase in numbers from about 3000 years BP onwards, peaking at 2300 BP and petering out at 1900 years BP (except in Bioko island, which never had an Iron Age).

Map (a) shows the disparate nature of sites at the end of the Late Stone Age.

Map (b) shows the migration of the Malongo peoples from Cameroon to Congo over a period of 700 years.



**Figure 3.** Graph of 586 radiocarbon dates for Atlantic Central Africa, distinguished on the basis of the character of associated archaeological remains.

Map (c) shows a north–south spread of iron smelting with older dates in the north and more recent dates in the south. The oval represents the region with the most iron-rich deposits.

Map (d) shows a gradual repopulation after the crash.

3500 years ago, a radical change is observed as groups of stone working hunter–gatherers give way across the region to new migrants, who settle the land and begin the first forms of rudimentary slash and burn agriculture [94]. Probably originating from northern Sahelian areas, these populations settled firstly along the edge of the forest block and benefited from forest fragmentation to penetrate further. They created small villages on hilltops and dug rubbish pits close to their houses, unlike Late Stone Age peoples who left their waste on the surface [39]. They mastered new technologies such as pottery and stone polishing and seem to have practised early forms of agriculture, as shown by the presence of stone hoes. This period, known as the ‘Neolithic stage’, occurs in the forest zone between 3500 and 2000 BP. People settle on hilltops and in dominant positions close to rivers.

Beginning approximately 3200 years BP, a migratory wave travelled south from Cameroon along the Atlantic coast, taking advantage of the presence of a continuous string of narrow savannas that range from Equatorial Guinea to the mouth of the Congo. This tradition, defined by a common ‘Malongo’ pottery style, lasts from 2700 to 2000 years BP [75]. Their pottery containers were decorated with large zigzag patterns produced by a series of pivoting combs (figure 4). The edges of the vases are generally straight, thickened externally with a fluted lip with settings spanning from the neck to the base. The first Malongo pottery was dated at 2700 years BP at Bissiang [63] (figure 2). Homogeneous pottery remains found in the coastal areas of Kribi in Cameroon (2600–2000 BP) [75], near Kogo in Equatorial Guinea [95], at Libreville (2400–2000 years BP) [43], at Iguela and Mayumba in Gabon (2300–2100 years BP) and at Tchissanga in the Republic of Congo (2500–2000 years BP) [53,96] indicate that this was one cultural group that migrated southwards from Cameroon.

A second much more important current begins approximately 2800–2500 years BP in the hinterlands, and corresponds to the Early Iron Age. The first signs of iron smelting date back to 2800 years BP, at Oliga, in southern Cameroon [61]. The number of Iron Age sites rises rapidly from 2600 years BP onwards, peaking 1900 years BP. From 1600 to 1000 years BP, there is a drastic drop, suggesting that Atlantic Central Africa was almost devoid of people during this period.

Figure 2c shows the spread of iron smelting to the south over a period of 900 years. Note that the dates on the map

indicate an initial spread from north to south in inland areas where geological formations rich in iron occur; and a second phase along the coast, indicating it was principally a result of commercial exchanges, although some iron furnaces have been found.

These metal workers demonstrated a very good knowledge of geological formations and established their settlements on hilltops [41].

They made a range of forms and decorative styles of ceramics that differ markedly from those of the Neolithic cultures, suggesting that they replaced or displaced peoples. Bi-lobed and careened pots decorated using comb swivels disappear in favour of generalized closed vessels with open edges, with more intricate decorations: concentric circles and bands of incised parallel lines mainly in the upper part of the body, where handles and gripping appendices were fitted.

In the middle valley of the Ogooué, corresponding rock engravings are found that include comparable geometric shapes with those found on the pottery as well as animal figures [39]. Oslisly [41] has mapped the southwards spread of characteristic pottery styles associated with these populations, demonstrating their gradual migration to the south. The distinct lack of any hybrid forms and decorations suggests that the populations that moved in displaced those already there.

Increasing densities of archaeological sites around 2000–1900 years BP demonstrate a demographic explosion of metal working populations (figures 2c and 3). Using iron tools, these peoples had the potential to profoundly affect the forest by slash and burn forms of agriculture and it is likely that they also managed forest–savanna mosaics using fire as a hunting strategy. They also produced great quantities of charcoal during iron reduction operations and would have maintained savannas through the lighting of bush fires [74,97].

In addition to evidence of gathering of rainforest fruits and seeds, such as *Antrocaryon klaineianum*, *Canarium schweinfurthii* and *Coula edulis* [41,42], there is also evidence of extensive use of oil palm beginning from 3000 years BP in the Yaoundé area [94] and at 2800 years BP at Otoumbi in central Gabon [38]. There is also an isolated record around 2200 BP of cultivation of pearl millet, *P. glaucum*, in the modern forest zone of southern Cameroon [98]. This observation is consistent with suggestions that it was generally drier at this time, with longer, more pronounced dry seasons.

Figure 5 presents four maps showing the distribution of archaeological sites in four periods:

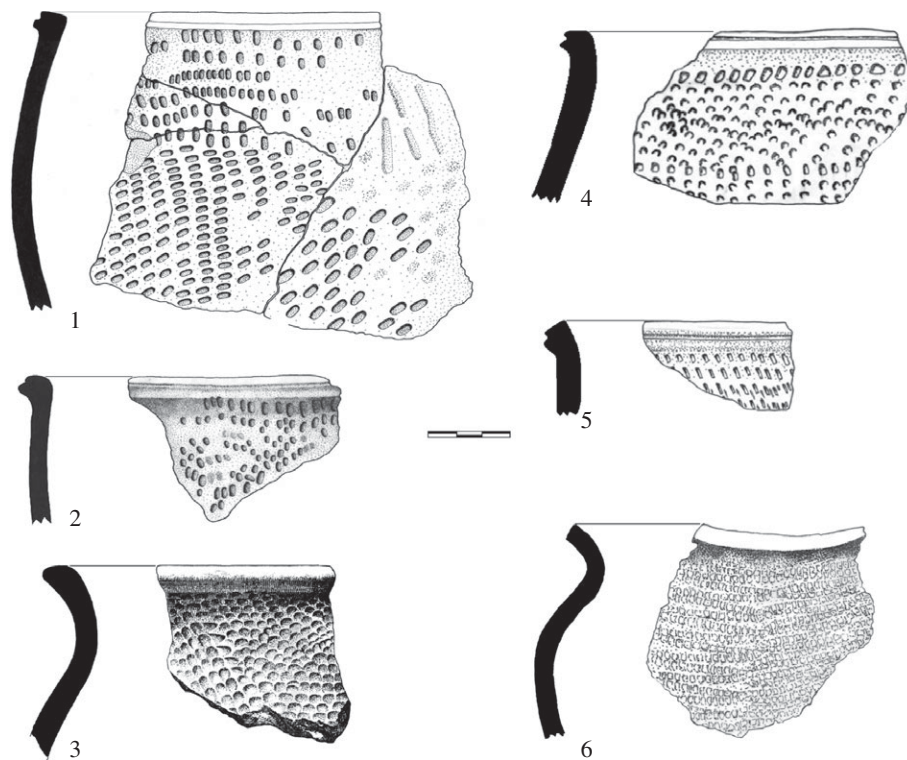
Map (a): the period from 2100 to 1700 years BP indicates that there were many sites of Iron Age and Neolithic stage in Cameroon and Gabon.

Map (b): the period from 1600 to 1400 years BP shows a slight iron age population deflation.

Map (c): the period from 1300 to 900 years BP reveals a total absence of dates in the forest hinterland South Cameroon/Centre and North of Gabon/North of Congo and little human presence in the peripheral areas of the forestry block. There was a clearly defined ‘population crash’ from 1300 to 900 years BP in the central Gabon [41].

Map (d): the period from 800 to 400 years BP shows that the forest block has been recolonized by Late Iron Age populations.

From 1000 years BP, new populations of metalworkers settled in the region, achieving their greatest numbers around 500 BP, in the pre-colonial period. The division in terms of abundance of sites is corroborated in some regions by cultural differences. For example, in central Gabon, iron ore reduction



**Figure 4.** Typical Malongo tradition pottery: profile and vase fragments of fluted edges decorated with collars and swivel impressions. 1 and 2, Malongo (Cameroon); 3, Kogo (Equatorial Guinea); 4 and 5, Okala (Libreville) and 6, Tassi (Loango National Park) in Gabon (scale bar, 3 cm).

structures built above ground with clay in the Early Iron Age disappear in favour of pits, and the ceramic traditions are totally different, later styles being characterized by frequent use of recurrent patterns created using wooden roulettes, with no evidence of cultural exchange [41].

The metallurgists of the Late Iron Age resettled along hilltops and practised shifting cultivation [39]. Ceramics of this period include large and small pots of flattened spherical shape with out-curved apexes and pots of uneven curvature, as well as clay pipes indicating smoking of tobacco. The decoration of these pots is unique, with small circular motifs made with knotted strips of plant material forming herringbone patterns. The designs on pots form a band of variable width high on the sphere, and similar patterns are found on the clay bowls of pipes.

The maximum expansion of the new metallurgists peaks around 500 years BP (figure 3) and then decreases to around 100 years BP. While the end of this last phase coincides with the end of the Little Ice Age, other factors are probably important. This period was marked by the first contacts with Europeans, which caused a radical shift in Aboriginal culture: the traditional pottery was supplanted by colonial pots. The 'cultural shift' is not the only impact: these contacts also saw the development of the slave trade, which had a profound impact on populations. It is very difficult to assess the impacts of the slave trade, because data are scarce and difficult to verify. Some data exist for Sao Tomé and for the Kongo Empire but few are available for Gabon. Picard-Tortorici & François [99] put forwards a figure of 18 000 slaves leaving the Gabonese coast, which had an estimated population of 100 000. This suggests that the consequences on human population densities may have been significant. Slave trails penetrated far into the interior, reaching Lopé in the Central Gabon [100] and further southeast. Data on vegetation composition and structure in Lopé have allowed for

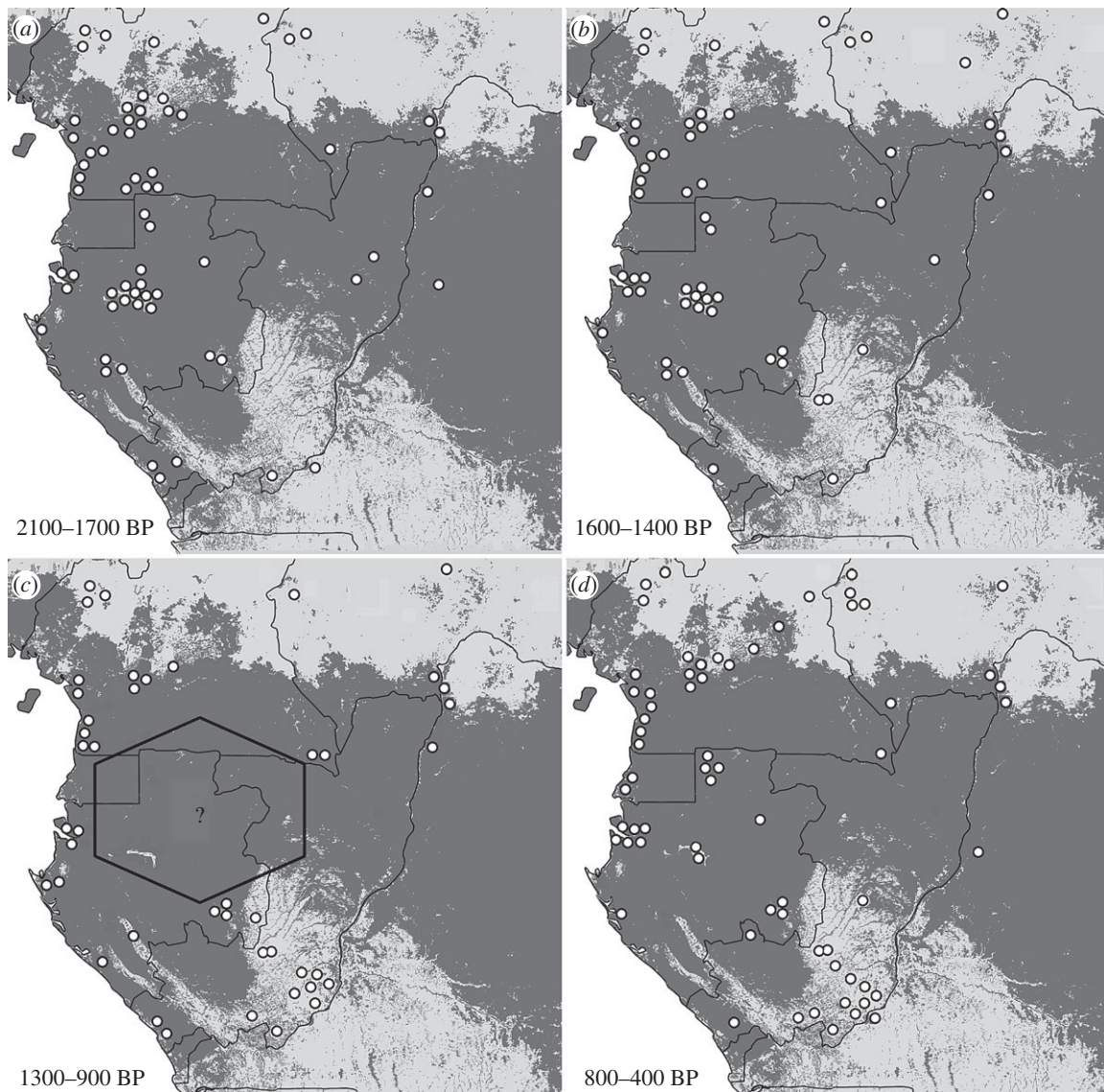
modelling of vegetation change over the past 2000 years, indicating that a spurt of savanna colonization corresponds to the period covered by the slave trade [101]. It seems likely that depopulation in the Lopé region resulted in reduced frequencies of savanna fires, allowing forest expansion, and reduced intensity of agriculture, resulting in forest succession from young to more mature formations.

However, the subject has received little attention and deserves further study by archaeologists, historians and geographers, although, from about 500 years BP onwards, the archaeological data are of limited value owing to the fact that archaeologists rarely radiocarbon date sites that they know on the basis of stratigraphy and pottery to belong to the relatively recent past. Hence, for this period, we have to rely on historical documents or undertake new detailed archaeological surveys.

#### 4. Discussion and conclusion

In the early part of the Holocene Stone Age, human settlements seem to be few and far between in the forest belt of West Central Africa and there is little to suggest that man played an overly determinant role in the ecosystem. The Late Stone Age, which started at about 40 000 years BP [102], ended approximately 3500 years BP, when Neolithic cultures migrated from Cameroon into Gabon and Congo along the coast. These peoples were the first to make pottery, which would have greatly increased their ability to store and preserve foodstuffs, and their polished stone hoes indicate an early form of agriculture.

With the arrival of iron smelting and working, which moved into the region from the Sahel and central Sahara around 2800 years BP, human impacts on the rainforest would have increased significantly. During the same period,



**Figure 5.** Maps showing distribution of dated archaeological sites in the periods: (a) 2100–1700 years BP; (b) 1600–1400 years BP; (c) 1300–900 years BP; (d) 800–400 years BP. The relations between these populations are described in detail in [39].

approximately 3000–2000 years BP, Central Africa was also affected by a worsening climate that contributed to the fragmentation of the forest block and probably also to the accelerated expansion of Bantu peoples towards the south.

The increase in numbers of archaeological sites from 2000 years BP through to about 1600 years BP (figure 3) suggests that human population numbers increased greatly through this period. Despite somewhat fragmented evidence it seems safe to conclude that the reduction of forest cover at this time, through a combination of changes in the hydrological cycle and increased anthropogenic pressure, may have resulted in a deforestation peak on a scale similar to that which has affected West Central Africa over the last century or so [103].

To date, there is little evidence of what was being cultivated. De Maret records oil palm, *Elaeis guineensis*, for the first time in the region 3000 years BP in the Yaoundé area [94] and Oslisly [38] and Fay [104] record it, respectively, 2850 years BP in the Lopé region of Central Gabon and from 2400 years BP in the Nouabalé Ndoki region of northern Congo. In some areas of coastal Cameroon, there is evidence of extensive oil palm groves [75], and extensive forest fires in the valley of the Lélédi and Offoué in the Central Gabon at around 1800 years BP [97] are consistent with agriculture

on a comparable scale with that recorded in Okomu in southwest Nigeria around 700 years BP, continuous over at least 1000 km<sup>2</sup> [105–107].

It will require further archaeological exploration across Central Africa in order to fully document and understand the implications of pre-historic man on vegetation patterns across the African rainforest zone, but recent studies in Central Africa as well as other studies further afield [108] suggest that humanity's impact in the recent past may have been significant. Indeed, the region known as the Sangha interval, a low biodiversity corridor separating richer forests of the Ogooué and Congo basins [109], has been revealed in recent years to contain numerous archaeological sites, as well as vast deposits of oil palm seeds dating to the period between 2400 and 1000 BP (peaking at 1700 BP). The forests in this region remain dominated by species indicative of old secondary vegetation (*Entandrophragma*, *Triplochiton*, etc.) as well as extensive formations with a dense understorey dominated by species of Marantaceae, indicative of cultivation, savanna colonization or forest fires [104,110,111], and it is possible that their low diversity is a result of severe disturbance by humans over the past three millennia, particularly considering that their actions have been coupled with phases of climate stress.

The decrease in abundance between 1600 and 900 years BP and possible disappearance of humans from large parts of the landscape between 1350 and 900 years BP would have had an equally marked, if different, impact on vegetation (figure 5c). Palaeoenvironmental data reveal that from 1400 years BP a stronger monsoon would have favoured forest regeneration [21], so reduced frequencies of anthropic fires at this time would have created conditions favourable to wide-scale forest regeneration [74,97].

It is interesting to hypothesize about the cause of the human population decline. If the population rise was built on cultivation of pearl millet (*P. glaucum*) [98] during a period of climatic stress for rainforest vegetation and from 1400 years BP conditions became too humid for this species, then it would have been difficult to maintain high populations, and people may have migrated away in search of a climate appropriate for millet cultivation. If Mbida's report of banana cultivation [112] in the Yaoundé area proves reliable this hypothesis would seem less likely, because bananas would have thrived in the new climate, but if no alternative was available, then this hypothesis seems plausible.

An alternative hypothesis, which remains impossible to test due to the fact that acidic soils preclude the discovery of human bodies dating to this time, is that the risk of epidemics would have increased as the human population density increased. Old literature on epidemics in Atlantic Central Africa shows that sleeping sickness seems to have been the disease that most affected the populations of the forest, owing to its high mortality rate. At the end of the nineteenth century, the French colonial administration reported a major outbreak of trypanosomiasis, which resulted in the disappearance of populations in eastern Gabon and northern Congo [113]. Around the year 1920, when Dr Eugene Jamot fought against human African trypanosomiasis in South Cameroon, he found that 116 000 persons out of 664 000 examined (17%, with peaks at 30% in some places) were infected with sleeping sickness, a deadly disease with no traditional cure [114].

Recently, apes that had risen to unusually high densities in old secondary vegetation in northeast Gabon and northwest Congo following displacements of human populations died of Ebola in density-dependent epidemics [115] that might mirror what happened to people some 1400 years BP.

Another possibility is that the extreme weather events of AD 535–536, known to be the most severe and protracted short-term episodes of cooling in the Northern Hemisphere in the past 2000 years [116], had an impact in Central Africa. The event is thought to have been caused by an extensive atmospheric dust veil, possibly resulting from a large volcanic eruption in the tropics [117]. Its effects were widespread, causing unseasonal weather, crop failures and famines worldwide.

These hypotheses can be confirmed or refuted only by further research. While we attempt to demonstrate that the number of radiocarbon dates is related to demographic changes, other questions related to shifts in human activities across the landscape require further studies.

Irrespective of the cause, the evidence for the population decline seems sound, and the implications of the rise and subsequent fall of human populations for vegetation are likely to be significant. In more recent times, the impacts of the slave trade and the subsequent forced relocation of

rural populations to roads and urban centres by colonial authorities, leaving vast areas in Gabon and Congo devoid of people [118], also had significant impacts on vegetation, such as the distribution of Okoumé trees (*Aucoumea klaineana*) in Gabon [101].

The pattern that emerges over the past 5000 years is a complex interaction of variations in climate and in human population density, distribution and ability to impact on forest vegetation. While it is clear from botanical work that these changes have not overwhelmed the signature of longer-term climate change resulting in the cyclical retraction of forests into refuges and expansion across the Congo basin [5,119], no scientific study of vegetation, including work on the dynamics of carbon stocks, should ignore the possibility of disturbance linked to human activities over the past two millennia having a significant bearing on the results. Archaeologists have developed methods of mapping past human activity using trees such as *A. klaineana*, *Lophira alata* and *Bailonella toxisperma*, all of which are associated with old village sites [120]. Furthermore, many of the forests with the highest densities of large mammals, which tend to be prioritized for conservation, are in areas that have been significantly impacted by humans over the past 1000 years or so [103].

This synthesis of 30 years of archaeological studies allows us to describe the main stages in cultural development, as well as key changes in climatic conditions through the past 5000 years. The picture we have painted is not without analogy to the current situation, where human populations are growing in the context of increasing climatic stress. Currently, it seems unlikely that we will avoid the large-scale deforestation that such circumstances have caused repeatedly in the past. The combination of climate change and increased logging pressure is likely to result in increased frequencies of forest fires [110], whereas the global appetite for productive agricultural land is likely to see more and more of the Central African forests converted to large-scale oil palm plantations and other commercial crops [121]. The REDD+ process seemed for a while to offer some potential for preservation of extensive tracts of forests, but interest in this process seems to be stagnating, with very few concrete success stories to bolster flagging enthusiasm of political leaders.

The archaeological data presented in this paper suggest that several waves of forest disturbance and oil palm cultivation have affected the Congo Basin over the past three millennia and that the forest has been relatively resilient. Were the conditions to be put in place to favour forest growth, it is likely that regeneration would be rapid. In the meantime, conservationists should look to mirror the patterns of forest survival that have made it possible for forests to recover quickly once given the chance.

**Acknowledgements.** We want to thank C. Moreau and J-P. Dumoulin of LMC14 ARTEMIS Facility (Saclay, France), and three anonymous referees for commenting on the manuscript.

**Funding statement.** This research was funded by the ERA-Net BiodivERSA (CoForChange project), with the national funders ANR (France) and NERC (UK), part of the 2008 BiodivERSA call for research proposals. Other funding was also provided by the EU programme ECOFAC (1992–1998), IRD Projects (ECOFIT 1992–1996, PALEOFORGA 1997–1999, ADHENTRO 2000–2005, PALOC since 2008, PPR-FTH since 2011) and CNRS projects (PNEDC PRIMUS 2002–2004 and ECLIPSE REGAB 2005–2009). L.W. was supported by the Wildlife Conservation Society and the Centre International de Recherches Médicales de Franceville.



## References

- Talbot MR, Livingstone DA, Palmer PG, Maley J, Melack JM, Delibrias G, Gulliksen S. 1984 Preliminary results from sediment cores from Lake Bosumtwi, Ghana. *Palaeoecol. Africa* **16**, 173–192.
- Giresse P, Maley J, Brenac P. 1994 Late Quaternary paleoenvironments in the lake Barombi Mbo (Cameroon) deduced from pollen and carbon isotopes of organic matter. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* **107**, 65–78. (doi:10.1016/0031-0182(94)90165-1)
- Maley J. 1996 The African rain forest: main characteristics of changes in vegetation and climate from the Upper Cretaceous to the Quaternary. In *Essays on the ecology of the Guinea–Congo rain forest*. Proc. Royal Society of Edinburgh Section B, vol. 1048 (eds IJ Alexander, MD Swaine, R Watling), pp. 31–73. Edinburgh, UK: Royal Society of Edinburgh.
- Maley J, Brenac P. 1998 Vegetation dynamics, palaeoenvironments and climatic changes in the forests of West Cameroon during the last 28,000 years. *Rev. Palaeobot. Palynol.* **99**, 157–188. (doi:10.1016/S0034-6667(97)00047-X)
- Leal ME. 2009 The past protecting the future: locating climatically stable forests in West and Central Africa. *Int. J. Clim. Change Strateg. Manag.* **1**, 92–99. (doi:10.1108/17568690910934426)
- Hamilton AC. 1988 Guenon evolution and forest history. In *A primate radiation: evolutionary biology of the African guenon* (ed. A Gautier-Hion), pp. 13–34. Cambridge, UK: Cambridge University Press.
- Hamilton AC, Taylor D. 1991 History of climate and forests in tropical Africa during the last 8 Million years. *Clim. Change* **19**, 65–78. (doi:10.1007/BF00142215)
- deMenocal P, Ortiz J, Guilderson T, Adkins J, Sarnthein M, Baker L, Yarusinsky M. 2000 Abrupt onset and termination of the African humid period: rapid climate responses to gradual insolation forcing. *Quat. Sci. Rev.* **19**, 347–361. (doi:10.1016/S0277-3791(99)00081-5)
- Kuhlmann H, Meggers H, Freudenthal T, Wefer G. 2004 The transition of the monsoonal and the N Atlantic climate system off NW Africa during the Holocene. *Geophys. Res. Lett.* **31**, L22204. (doi:10.1029/2004GL021267)
- Weldeab S, Schneider RR, Kolling M, Wefer G. 2005 Holocene African droughts relate to eastern equatorial Atlantic cooling. *Geology* **33**, 981–984. (doi:10.1130/G21874.1)
- Shanahan TM, Overpeck JT, Wheeler CW, Beck JW, Pigati JS, Talbot MR, Scholz CA, Peck JK. 2006 Paleoclimatic variations in West Africa from a record of late Pleistocene and Holocene lake level stands of Lake Bosumtwi, Ghana. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* **242**, 287–302. (doi:10.1016/j.palaeo.2006.06.007)
- Weldeab S, Lea DW, Schneider RR, Andersen N. 2007 Centennial scale climate instabilities in a wet early Holocene West African monsoon. *Geophys. Res. Lett.* **34**, L24702. (doi:10.1029/2007GL031898)
- Elenga H, Vincens A, Schwartz D, Bertaux J, De Namur C, Martin L, Wirmann D, Servant M. 1996 Diagramme Holocène du lac Kitina (Congo): mise en évidence de changements paléobotaniques et paléoclimatiques dans le massif forestier du Mayombe. *C.R. Acad. Sci. Paris* **323**, 403–410.
- Elenga H, Maley J, Vincens A, Farrera I. 2004 Palaeoenvironments, palaeoclimates and landscape development in Central Equatorial Africa: a review of major terrestrial key sites covering the last 25 kys. In *Past climate variability through Europe and Africa* (eds RW Battarbee, F Gasse, C Stickley), pp. 181–196. Berlin, Germany: Springer.
- Vincens A, Schwartz D, Bertaux J, Elenga H, De Namur C. 1998 Late holocene climatic changes in western equatorial Africa inferred from pollen from Lake Sinnda, southern Congo. *Quat. Res.* **50**, 34–45. (doi:10.1006/qres.1998.1979)
- Ngomanda A, Jolly D, Bentaleb I, Chepstow-Lusty A, Makaya M, Maley J, Fontugne M, Oslisly R, Rabenkogo N. 2007 Lowland rainforest response to hydrological changes during the last 1500 years in Gabon, Western Equatorial Africa. *Quat. Res.* **67**, 411–425. (doi:10.1016/j.yqres.2007.01.006)
- Ngomanda A, Neumann K, Schweizer A, Maley J. 2009 Seasonality change and the third millennium BP rainforest crisis in southern Cameroon (Central Africa). *Quat. Res.* **71**, 307–318. (doi:10.1016/j.yqres.2008.12.002)
- Giresse P, Mvoubou M, Maley J, Ngomanda A. 2009 Late-Holocene equatorial environments inferred from deposition processes, carbon isotopes of organic matter, and pollen in three shallow lakes of Gabon, west-central Africa. *J. Paleolimnol.* **41**, 369–392. (doi:10.1007/s10933-008-9231-5)
- Reynaud-Farrera I, Maley J, Wirmann D. 1996 Végétation et climat dans les forêts du Sud-Ouest Cameroun depuis 4770 ans BP: analyse pollinique des sédiments du Lac Ossa. *C. R. Acad. Sci. Paris* **322**, 749–755.
- Wirmann D, Bertaux J. 2001 Late Holocene paleoclimatic changes in Western Central Africa inferred from mineral abundance in dated sediments from Lake Ossa (Southwest Cameroon). *Quat. Res.* **56**, 275–287. (doi:10.1006/qres.2001.2240)
- Ngomanda A, Chepstow-Lusty A, Mvoubou M, Favier C, Schevin P, Maley J, Fontugne M, Oslisly R, Jolly D. 2009 Western equatorial African forest-savanna mosaics: a legacy of late Holocene climatic change? *Clim. Past* **5**, 647–659. (doi:10.5194/cp-5-647-2009)
- Vincens A, Buchet G, Servant M, Ecofit Mbalang collaborators. 2010 Vegetation response to the 'African humid period' termination in Central Cameroon (7°N) – new pollen insight from Lake Mbalang. *Clim. Past* **6**, 281–294. (doi:10.5194/cp-6-281-201)
- Assi-Kaudjhis C. 2011 Dynamique des écosystèmes et biodiversité des montagnes du Cameroun au cours des derniers 20 000 ans. Analyse palynologique d'une série sédimentaire du lac Bambili. Thesis. Université Liège et Université de Versailles Saint-Quentin.
- Brncic TM, Willis KJ, Harris DJ, Washington R. 2007 Culture or climate? The relative influences of past processes on the composition and the lowland Congo rainforest. *Phil. Trans. R. Soc. B* **362**, 229–242. (doi:10.1098/rsth.2006.1982)
- Brncic TM, Willis KJ, Harris DJ, Telfer MW, Bailey RM. 2009 Fire and climate change impacts on lowland forest composition in Northern Congo during the last 2580 years from Palaeoecological analyses of a seasonally flooded swamp. *The Holocene* **19**, 79–89. (doi:10.1177/0959683608098954)
- Kiahtipes CA, Lupo KN, Schmitt DN, Ndanga J-P, Jones JG, Lee R. 2011 Prehistory and the present: palaeoenvironments in the northern Congo Basin. In *Proc. Int. Conf. Congo Basin Hunter–Gatherers (ICCBHG 2010), Montpellier, France, 22–24 September 2010. Before Farming 2011/2*, no. 4.
- Neumer M, Becker E, Runge J. 2008 Palaeoenvironmental studies in the Ngotto forest: alluvial sediments as indicators of recent and holocene landscape evolution in the Central African Republic. *Palaeoecol. Africa* **28**, 121–137.
- Vincens A *et al.* 1999 Forest response to climate changes in Atlantic Equatorial Africa during the last 4000 years BP and inheritance on the modern landscapes. *J. Biogeogr.* **26**, 879–885. (doi:10.1046/j.1365-2699.1999.00333.x)
- Nguetsop F, Bentaleb I, Favier C, Martin C, Servant M, Servant-Vildary S. 2011 Past environmental and climatic changes during the last 7200 cal yrs BP in Adamawa plateau (Northern-Cameroun) based on fossil diatoms and sedimentary 13C isotopic records from Lake Mbalang. *Clim. Past* **7**, 305–345. (doi:10.5194/cp-7-1371-2011)
- Bayon G, Dennielou B, Etoubeau J, Ponzevera E, Toucanne S, Bermell S. 2012 Intensifying weathering and land use in iron age Central Africa. *Science* **335**, 1219–1221. (doi:10.1126/science.1215400)
- Maley J, Giresse P, Doumenge C, Favier C. 2012 Comment on intensifying weathering and land use in iron age Central Africa. *Science* **337**, 1040. (doi:10.1126/science.1221820)
- Neumann K *et al.* 2012 Comment on 'intensifying weathering and land use in iron age Central Africa'. *Science* **337**, 1040. (doi:10.1126/science.1221747)
- Nguetsop F, Servant-Vildary D, Servant M. 2004 Late Holocene climatic changes in West Africa: a high resolution diatom record from equatorial Cameroon. *Quat. Sci. Rev.* **23**, 591–609. (doi:10.1016/j.quascirev.2003.10.007)
- Ngomanda A, Chepstow-Lusty A, Mvoubou M, Schevin P, Maley J, Fontugne M, Oslisly R,

- Rabenkogo N, Jolly D. 2005 Vegetation changes during the past 1300 years in western equatorial Africa: a high resolution pollen record from Lake Kamalété, Lopé Reserve, Central Gabon. *The Holocene* **15**, 1021–1031. (doi:10.1191/0959683605hl875ra)
35. Farine B. 1965 Recherches préhistoriques au Gabon. *Bull. Soc. Préhist. Protohist. Gabonaise* **3**, 68–85.
36. Blankoff B. 1969 L'état des recherches préhistoriques au Gabon. In *Actes du premier colloque international d'archéologie africaine, Fort-Lamy, République du Tchad, 11–16 Décembre, 1966*. Institut national tchadien pour les sciences humaines, mémoire no. 1, 62–79.
37. Peyrot B, Oslisly R. 1986 Recherches récentes sur le paléoenvironnement et l'archéologie au Gabon: 1982–1985. *L'Anthropologie* **T90**, 201–216.
38. Oslisly R. 1993 *Préhistoire de la moyenne vallée de l'Ogooué au Gabon*. Bondy, France: Orstom.
39. Oslisly R. 1998 Hommes et milieux à l'Holocène dans la moyenne vallée de l'Ogooué au Gabon. *Bull. Soc. Préhist.* **95**, 93–105. (doi:10.3406/bspf.1998.10737)
40. Clist B. 1995 *Gabon: 100.000 ans d'histoire*. Saint Maur des Fossés, France: Sépia Editions.
41. Oslisly R. 2001 The history of human settlement in the middle Ogooué valley (Gabon): implications for the environment. In *African rain forest ecology and conservation* (eds B Weber, L White, A Vedder, L Naughton-Treves), pp. 101–118. New Haven, CT: Yale University Press.
42. Oslisly R, White L. 2007 Human impact and environmental exploitation in Gabon and Cameroon during the Holocene. In *Rethinking agriculture; archaeological and ethnoarchaeological perspectives* (eds T Denham, I Iriarte, L Vrydaghs), pp. 345–358. Walnut Creek, CA: Left Coast Press Inc.
43. Clist B. 2005 Des premiers villages aux premiers européens autour de l'estuaire du Gabon. Quatre millénaires d'interactions entre l'homme et son milieu. PhD thesis. Université Libre de Bruxelles, Belgium.
44. Assoko Ndong A. 2001 Archéologie du peuplement Holocène de la réserve de faune de la Lopé, Gabon. *L'Anthropologie* **106**, 135–158. (doi:10.1016/S0003-5521(02)01083-X)
45. Atangana C. 1992 Les fosses d'Okolo (Sud Cameroun); fouilles et axes de recherches. *Nyame Akuma* **38**, 7–13.
46. Claes P. 1992 A propos des céramiques de Mimboman et d'Okolo. In *L'archéologie au Cameroun* (ed. JM Essomba), pp. 215–227. Paris, France: Karthala.
47. De Maret P. 1982 New survey of archaeological research and dates for West-Central and North-Central Africa. *J. Afr. History* **23**, 1–15. (doi:10.1017/S0021853700020223)
48. De Maret P. 1985 Recent archaeological research and dates from Central Africa. *J. Afr. History* **26**, 129–148. (doi:10.1017/S0021853700036902)
49. De Maret P. 1986 The Ngovo group: an industry with polished stone tools and pottery in lower Zaïre. *Afr. Archaeol. Rev.* **4**, 103–133. (doi:10.1007/BF01117037)
50. De Maret P. 1990 Le 'Néolithique' et l'âge du fer ancien dans le sud-ouest de l'Afrique centrale. In *Paysages quaternaires de l'Afrique Centrale Atlantique* (eds R Lanfranchi, D Schwartz), pp. 447–457. Bondy, France: Orstom.
51. De Maret P, Van Noten F, Cahen D. 1977 radiocarbon dates from west central Africa: a synthesis. *J. Afr. History* **18**, 481–505. (doi:10.1017/S0021853700015681)
52. Delneuf M, Essomba J-M, Froment A (eds) 1998 *Paléo-anthropologie en Afrique centrale. Un bilan de l'archéologie au Cameroun*, p. 368. Paris, France: L'Harmattan.
53. Denbow J. 1990 Congo to Kalahari: data and hypotheses about the political economy of the western stream of the Early Iron Age. *Afr. Archaeol. Rev.* **8**, 139–175. (doi:10.1007/BF01116874)
54. Dupré MC, Pinçon B. 1997 *Métallurgie et politique en Afrique Centrale, deux mille ans de vestiges sur les plateaux Bateke (Gabon, Congo, Zaïre)*. Paris, France: Khartala.
55. Eggert M. 1987 Imbonga and Batalimo: ceramic evidence for early settlement of the equatorial rain forest. *Afr. Archaeol. Rev.* **5**, 129–145. (doi:10.1007/BF01117088)
56. Eggert M. 1992 The central African rain forest: historical speculations and archaeological facts. *World Archaeol.* **24**, 1–24. (doi:10.1080/00438243.1992.9980190)
57. Eggert M. 1993 Central Africa and the archaeology of the equatorial rainforest: reflections on some major topics. In *The archaeology of Africa: food, metals and towns* (eds T Shaw, P Sinclair, B Andah, A Okpoko), pp. 289–329. London, UK: Routledge.
58. Eggert M. 2004 The Bantu problem and African Archaeology. In *African archaeology: a critical introduction* (ed. A Stahl), pp. 301–326. London, UK: Blackwell Studies in Global Archaeology.
59. Eggert M, Hohn A, Kalheber S, Meister C, Neumann K, Schweitzer A. 2006 Pits, graves, and grains: archaeological and archaeobotanical research in southern Cameroon. *J. Afr. Archaeol.* **4**, 273–298. (doi:10.3213/1612-1651-10076)
60. Elouga M. 1998 Recherches archéologiques au Cameroun méridional: résultats des prospections et hypothèses sur les phases de peuplement. In *Paléo-anthropologie en Afrique centrale: un bilan de l'archéologie au Cameroun* (eds M Delneuf, JM Essomba, A Froment), pp. 213–224. Paris, France: L'Harmattan.
61. Essomba J-M. 2004 Status of iron age archaeology in southern Cameroon. In *The origins of iron metallurgy in Africa: new light on its antiquity*, pp. 135–147. Paris, France: UNESCO.
62. Lanfranchi R, Clist B (eds) 1991 *Aux origines de l'Afrique Centrale*. Saint Maur des Fossés, France: Sepia Editions.
63. Lavachery P, MacEachern S, Bouïmon T, Mbida Mindzie C. 2010 *Komé–Kribi: rescue archaeology along the Chad–Cameroon oil pipeline, 1999–2004*. J. Afr. Archaeol. Monograph Series, vol. 4. Frankfurt am Maine, Germany: Africa Magna Verlag.
64. Livingstone-Smith A, Assoko Ndong A, Cornelissen E. 2007 Prospection archéologique dans le sud du Gabon. *Nyame Akuma* **67**, 26–35.
65. Mbida Mindzie C. 1992 Ndindan: archaeological synthesis of a site dating back to three millennia ago in Yaounde (Cameroon). *L'Anthropologie* **106**, 159–172. (doi:10.1016/S0003-5521(02)01082-8)
66. Mbida Mindzie C, Asombang R, Delneuf M. 2001 Rescue archaeology in eastern Cameroon. *Antiquity* **75**, 805–806.
67. Meister C. 2007 Recent archaeological investigations in the tropical rain forest of south-west Cameroon. In *Dynamics of forest ecosystems in Central Africa during the Holocene. Past–present–future*. (ed. J Runge), pp. 43–58. London, UK: Taylor & Francis.
68. Meister C. 2010 Remarks on Early Iron Age burial sites from Southern Cameroon. *Afr. Archaeol. Rev.* **27**, 237–249. (doi:10.1007/s10437-010-9081-1)
69. Meister C, Eggert M. 2008 On the Early Iron Age in Southern Cameroon: the sites of Akonétye. *J. Afr. Archaeol.* **6**, 183–202. (doi:10.3213/1612-1651-10109)
70. Meyer S, Meister C, Eggert M. 2009 Preliminary report on the excavations at Bagofit and Mampang, East Province, Cameroon. *Nyame Akuma* **72**, 67–73.
71. Moga J. 2008 La métallurgie du fer en Centrafrique: premiers éléments de synthèse. *Revue Centrafricaine d'Anthropol.* **1**. <http://recaa.mmsh.univ-aix.fr/>.
72. Ndanga A. 2008 La chaîne opératoire des ateliers paléométallurgiques de Pendere-Sengue (RCA). *Revue Centrafricaine d'Anthropol.* **1**. <http://recaa.mmsh.univ-aix.fr/>.
73. Nlend P. 2001 *Inventaire des sites archéologiques de Kribi à Campo: étude préliminaire des sites Malongo 1, Nlendé-Dibé et Boussibiliga*, Mémoire de Maîtrise, Université de Yaoundé 1.
74. Oslisly R. 1999 Contribution de l'Anthracologie à l'étude de la relation homme/milieu au cours de l'Holocène dans la vallée de l'Ogooué au Gabon. *Ann. Sci. Econ.* (MRAC – Tervuren), Belgique **25**, 185–193.
75. Oslisly R. 2006 Les traditions culturelles de l'Holocène sur le littoral du Cameroun entre Kribi et Campo. In *Grundlegungen. Beiträge zur europäischen und afrikanischen Archäologie für Manfred K.H. Eggert* (ed. H-P Wotzka), pp. 303–317. Tübingen, Germany: Francke Attempto Verlag GmbH and Co.
76. Oslisly R, Dechamps R. 1994 Découverte d'une zone d'incendie dans la forêt ombrophile du Gabon ca 1500 BP: essai d'explication anthropique et implications paléoclimatiques. *C. R. Acad. Sci. Paris* **318**, 555–560.
77. Oslisly R, Mbida C. 2001 Surveillance archéologique de l'axe routier Lolodorf-Kribi-Campo. Rapport final. Coopération Cameroun–Union Européenne. Yaoundé, Cameroon: Ministère des Travaux Publics.
78. Oslisly R, Assoko Ndong A. 2006 *Archéologie de sauvetage sur la route Médoumane-Lalara, vallée de l'Okano, Gabon*. Libreville, Gabon: Wildlife Conservation Society.
79. Oslisly R, Mbida C, White L. 2000 Les premiers résultats de la recherche archéologique dans le sanctuaire de Banyang Mbo (Sud-Ouest du Cameroun). *L'Anthropologie* **104**, 341–354. (doi:10.1016/S0003-5521(00)80049-7)
80. Oslisly R, Pickford M, Dechamps R, Fontugne M, Maley J. 1994 Sur une présence humaine

- mi-holocène à caractère rituel en grottes au Gabon. *C.R. Acad. Sci. Paris* **319**, 1423–1428.
81. Oslisly R, Kinyock P, Nlend Nlend P, Ngouoh F, Nkonkonda O. 2008 Etude Archéologique du site de Dibamba, Rapport final KPDC/AES Sonel.
  82. Pinçon B. 1990 La métallurgie du fer sur les plateaux Teke (Congo). Quelles influences sur l'évolution des paysages au cours des deux derniers millénaires. In *Paysages quaternaires de l'Afrique Centrale Atlantique*, (eds R Lanfranchi, D Schwartz), pp. 479–492. Bondy, France: Orstom.
  83. Schwartz D, Dechamps R. 1991 Nouvelles céramiques découvertes à Pointe-Noire au Congo (1600 BP) au cours d'une fouille de sauvetage. *Nsi* **8/9**, 16–23.
  84. Schwartz D, Dechamps R, Fournier M. 1991 Un site de fonte du fer récent (300 BP) et original dans le Mayombe congolais: Ganda-Kimpese. *Nsi* **8/9**, 33–40.
  85. Tamura T. 1984 Some regolith-stratigraphic data on late Quaternary environmental changes in the West Cameroon Highlands. In *Natural and man-induced environmental changes in tropical Africa* (ed. H Kadomura), pp. 45–59. Sapporo, Japan: Hokkaido University.
  86. Wirmann D, Elouga M. 1998 Lake Ossa: a new Iron Age site in the Cameroonian littoral province. *Nyame Akuma* **49**, 16–26.
  87. Wotzka H-P. 1995 Studien zur Archäologie des zentralafrikanischen Zaire-Beckens und ihre Stellung im Kontext der Bantu-expansion. *Africa Prehistorica* 6. Heinrich-Barth Institut, Köln.
  88. Wotzka HP. 2006 Records of activity: radiocarbon and the structure of iron age settlement in central Africa. In *Grundlegungen. Beiträge zur europäischen und afrikanischen Archäologie für Manfred K.H. Eggert* (ed. HP Wotzka), pp. 271–289. Tübingen, Germany: Francke Attempto Verlag GmbH and Co.
  89. Zangato E. 1993 In *La question des datations des mégalithes de Centrafrique: nouvelles perspectives* (eds D Barreateau, C Von Graffenried), pp. 51–75. Bondy, France: Orstom.
  90. Zangato E. 1995 Variantes architecturales des Tazunu du nord-ouest de la République Centrafricaine et évolution chrono-culturelle régionale. *J. Africanistes* **65**, 125–143. (doi:10.3406/jafr.1995.2435)
  91. Zangato E. 1996 Etude du mégalithisme en République centrafricaine: nouvelles découvertes de monuments à chambre dans le secteur de Ndio. *Cahiers Orstom sciences humaines* **32**, 361–377.
  92. Oslisly R, Bentaleb I, Favier C, Fontugne M, Gillet J-F, Morin-Rivat J. 2013 West Central African peoples: survey of radiocarbon dates over the past 4000 years. *Radiocarbon* **55**, 3–4. (doi:10.2458/azu\_js\_rc.55.16385)
  93. Clist B. 1998 Nouvelles données archéologiques sur l'histoire ancienne de la Guinée-Equatoriale. *L'Anthropologie* **102**, 213–217.
  94. Maret de P. 1992 Sédentarisation, agriculture et métallurgie du Sud-Cameroun: Synthèse des recherches depuis 1978. In *L'Archéologie au Cameroun* (ed. J-M Essomba), pp. 247–262. Paris, France: Karthala.
  95. Perramon R. 1968 *Contribucion a la prehistoria y protohistoria de Rio Muni*. Publicaciones del Instituto Claretiano de Africanistas, 26. Santa Isabel de Fernando Poo, W. Africa: Imp. Misioneros.
  96. Denbow J. 2012 Pride, prejudice, plunder and preservation: archaeology and there-envisioning of ethnogenesis on the Loango coast of the Republic of Congo. *Antiquity* **86**, 383–408.
  97. Oslisly R, White L. 2000 La relation Homme/milieu dans la réserve de la Lopé (Gabon) au cours de l'Holocène; les implications sur l'environnement. In *Dynamique à long terme des écosystèmes forestiers intertropicaux* (eds M Servant, S Servant-Vildary), pp. 241–250. Paris, France: UNESCO.
  98. Kahlheber S, Bostoen K, Neumann K. 2009 Early plant cultivation in the Central African rain forest: first millenium BC pearl millet from South Cameroon. *J. Afr. Archaeol.* **9**, 253–272. (doi:10.3213/1612-1651-10142)
  99. Picard-Tortorici N, François M. 1993 *La traite des esclaves au Gabon du XVII<sup>e</sup> au XIX<sup>e</sup> siècle*. Florianopolis, Brazil: CEPED.
  100. Brunschwig H. 1972 *Brazza, explorateur (1875–1879)*. Paris, France: Mouton.
  101. White L, Oslisly R, Abernethy K, Maley J. 2000 L'Okoumé (*Aucoumea Klaineana*) expansion et déclin d'un arbre pionnier en Afrique centrale atlantique au cours de l'Holocène. In *Dynamique à long terme des écosystèmes forestiers intertropicaux* (eds M Servant, S Servant-Vildary), pp. 399–411. Paris, France: UNESCO.
  102. Oslisly R, Doutrelepon H, Fontugne M, Giresse P, Hatté C, White L. 2006 Premiers résultats d'une stratigraphie vieille de plus de 40.000 ans du site de Maboué 5 dans la réserve de la Lopé. In *Actes du XIV Congrès de l'UISPP, Liège 2–8 September 2001, Préhistoire en Afrique*, BAR International Series, vol. 1522, pp. 189–198.
  103. White LJT. 2001 Past and present trends in the African rain forest: overview. In *African rain forest ecology and conservation* (eds B Weber, L White, A Vedder, L Naughton-Treves), pp. 47–49. New Haven, CT: Yale University Press.
  104. Fay JM. 1997 The ecology, social organization, populations, habitat and history of the western lowland gorilla (*Gorilla gorilla gorilla* Savage and Wyman 1847). PhD thesis, Department of Anthropology, Washington University.
  105. Jones EW. 1955 Ecological studies of the rain forest of southern Nigeria IV. The plateau forest of the Okomu. Forest Reserve. I. The environment, the vegetation types of the forest, and the horizontal distribution of species. *J. Ecol.* **43**, 564–594. (doi:10.2307/2257012)
  106. Jones EW. 1956 Ecological studies of the rain forest of southern Nigeria IV. The plateau forest of the Okomu Forest Reserve. II. The reproduction and history of the forest. *J. Ecol.* **44**, 83–117. (doi:10.2307/2257155)
  107. White L, Oates J. 1999 New data on the history of the plateau forest of Okomu, southern Nigeria: an insight into how human disturbance has shaped the African rain forest. *Glob. Ecol. Biogeogr.* **8**, 355–361. (doi:10.1046/j.1365-2699.1999.00149.x)
  108. Hart TB, Hart JA, Dechamps R, Fournier M, Ataholo M. 1996 Changes in forest composition over the last 4000 years in the Huri basin, Zaire. In *The Biodiversity of African plants* (eds LJG van der Maesen, XM van der Burgt, JM van Medenbach de Rooy), pp. 545–563. Dordrecht, The Netherlands: Kluwer Academic Publications.
  109. White F. 1986 *La végétation de l'Afrique*. Mémoire accompagnant la carte de végétation de l'Afrique. Paris, France: Orstom–UNESCO.
  110. White LJT. 2001 Forest–savanna dynamics and the origins of 'Marantaceae Forest' in the Lopé Reserve, Gabon. In *African rain forest ecology and conservation* (eds B Weber, L White, A Vedder, L Naughton-Treves), pp. 165–182. New Haven, CT: Yale University Press.
  111. Foresta H de. 1990 Origine et évolution des savanes intra-mayombiennes (R.P. du Congo). II. Apports de la botanique forestière. In *Paysages quaternaires de l'Afrique Centrale atlantique* (eds R Lanfranchi, D Schwartz), pp. 326–335. Paris, France: Orstom.
  112. Mbida Mindzie C, Doutrelepon H, Vrydaghs L, Swennen R, Beeckman H, De Langhe E, De Maret P. 2001 First archaeological evidence of banana cultivation in central Africa during the third millennium before present. *Vegetation History Archaeobot.* **10**, 1–6. (doi:10.1007/PL00013367)
  113. Sautter G. 1966 *De l'Atlantique au fleuve Congo. Une géographie du sous-peuplement (République du Congo, République Gabonaise)*. Paris, France: La Haye, Mouton.
  114. Lapeyssonie I. 1987 *Moi, Jamot. Le vainqueur de la maladie du sommeil*. Plaisir, France: Les Presses de l'Inam, Editions Louis Musin.
  115. Walsh PD, Biek R, Real LA. 2005 Wave-like spread of Ebola Zaire. *PLoS Biol.* **3**, e371. (doi:10.1371/journal.pbio.0030371)
  116. Baillie MGL. 1994 Dendrochronology raises questions about the nature of the AD 536 dust-veil event. *The Holocene* **4**, 212–217. (doi:10.1177/095968369400400211)
  117. Larsen B et al. 2008 New ice core evidence for a volcanic cause of the A.D. 536 dust veil. *Geophys. Res. Lett.* **35**, L04708. (doi:10.1029/2007GL032450)
  118. Pourtier R. 1989 *Le Gabon*. Paris, France: L'Harmattan.
  119. Sosef M. 1994 Refuge begonias: taxonomy, phylogeny and historical biogeography of Begonia sect. Loasibegonia and sect. Scutobegonia in relation to glacial rain forest refuges in Africa. *Wageningen Agricultural University Papers* 94-1, 1–306.
  120. Oslisly R, White L. 2003 Etude des traces de l'impact de l'homme sur l'environnement au cours de l'holocène dans deux régions d'Afrique centrale forestière: la réserve de la Lopé (Gabon) et le sanctuaire du Banyang Mbo (Cameroun). In *Peuplements anciens et actuels des forêts tropicales* (eds A Froment, J Guffroy), pp. 77–87. Montpellier, France: IRD Editions.
  121. The Rain Forest Foundation. 2013 *Industrial oil palm in the Congo basin: potential impacts on forest and people*. 72 pp. New York, NY: The Rain Forest Foundation.