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## An update to the African palms (Arecaceae) floristic and taxonomic knowledge, with emphasis on the West African region

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### ABSTRACT

The present contribution is the product of palm research on continental African taxa started 7 years ago and represents an update to our taxonomic and floristic knowledge. Current estimates indicate that this palm flora is represented by 68 species, grouped in 18 genera attributed to three subfamilies (Calamoideae, Coryphoideae and Arecoideae). Although much less species rich when compared with other palm floras, African palms are extremely interesting from different perspectives, including phylogenetics, economic botany, ecology and conservation, all of them briefly discussed in this paper. A historical background on palm studies in Africa is provided, whereas current efforts on our multi-disciplinary research efforts in West Africa and future perspectives are depicted.

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## 1. Introduction

Continental African palms, in particular the ones native to the 17 countries of the western region, are currently the subject of research in the Conservatory and Botanic Gardens of Geneva. The most accurate estimates for the continent indicate that the region hosts 68 species, grouped in 18 genera and attributed to three subfamilies (Calamoideae, Coryphoideae and Arecoideae) of the five currently circumscribing the family. Taking into account generic and specific taxonomic richness, the native palm flora in this continent is regarded as much less important when compared with other large regions or continents of the world: Pacific: 30 gen./128 spp., America: 66 gen./750 spp., Europe: 2 gen./2 spp., mainland Asia: 43 gen./354 spp., western Indian Ocean, including Madagascar: 25 gen./193 spp., Malesia: 50 gen./992 spp. and Oceania (Australia): 21 gen./57 spp. (data based on Dransfield 1988, 2008; Henderson et al. 1995; Pintaud et al. 2008; Henderson 2009; Stauffer et al. 2014; Govaerts et al. 2017). The low taxonomic richness reported for the African palm flora is clearly in contrast to the high economic and ecological importance and their accurate inventory is critical for their conservation and sustainable use.

In spite of their recognized importance, many taxa remain incompletely known and/or only fragmentarily sampled. Historical collectors visiting Africa, especially

those during the eighteenth century (i.e. Palisot de Beauvois, Thoning, Gardner) (Figure 1), and others visiting the continent from the early to the mid nineteenth century in the frame of the inventory of biological resources of European colonies (i.e. Chevalier, Gossweiler, Welwitsch, Zimmerman), gathered palm specimens from several regions. The European explorers were not only astonished by the impressive morphology or growth form displayed by some palm species but also amazed about the wide range of uses that locals attributed to the different palms. The specimens shipped to European institutions often had notes on the common names and the different uses that the local ethnic groups made of almost all organs of the palms. Once in Europe those specimens were described by renowned palm botanists such as O. Beccari, O. Drude, N. von Jacquin, G. Man, C. von Martius and H. Wendland (Figure 2), among others.

Unfortunately, a modern taxonomic interpretation of the palms gathered by means of the study of the original type material represents in many cases a very frustrating task. Many type specimens are no longer extant (i.e. due to bombing during World War II) or when present they are fragmentary and poorly informative. Other complete and more informative type material has ended up in carpological collections given their bulky nature. Unfortunately, with some exceptions (Figure 3)



**Figure 1.** Holotype specimen of *Raphia vinifera* P. Beauv. deposited in the herbarium of the Conservatory and Botanical Gardens of Geneva (G) [G00301631]. This specimen was collected by the French explorer Palisot de Beauvois during the late eighteenth century in present-day Nigeria–Benin.

the collections of bulky specimens in worldwide herbaria are much less curated than traditional flat specimens and access to them is strongly hindered if not impossible for the palm researchers.

Modern standards of palm collecting were applied by most botanists during the twentieth century. Indeed, good examples of palm collecting can be identified when studying the specimens gathered by P. B. Tomlinson (palms from Ghana), J. P. Profizi (palms from West Africa), E. de Wildeman (palms from Central Africa), J. Dransfield (palms from East Africa), C. Jonkind (palms from West Africa), T. Sunderland (African rattans), J. van Valkenburg and T. Couvreur (palms from Cameroon and Gabon), among others. Good quality collections are,

in the case of the palm family, of particular importance for an accurate taxonomic identification and this is only possible when extensive field work is associated with a proper sampling of the specimens (Figure 4). All in all, the interpretation of available specimens has played a major role for the publication of monographic treatments for the family. In the case of African palms these efforts include the publications of Dransfield (1986) on the palms of East Africa, or more taxonomically oriented monographs (i.e. Furtado 1967: *Hyphaene*; Otedoh 1982: *Raphia*; Barrow 1998: *Phoenix*; Bayton 2007: *Borassus*; Van Valkenburg and Sunderland 2008; Van Valkenburg et al. 2007, 2008: *Podococcus* and *Sclerosperma*; and Sunderland 2007, 2012: the African rattan genera



**Figure 2.** Some of the most prominent authors describing the taxonomic diversity of African palm taxa. **(A)** Carl von Martius, photo courtesy of Botanische Staatssammlung München. **(B)** Hermann Wendland, photo courtesy of Landeshauptstadt Hannover, Fachbereich Herrenhäuser Gärten. **(C)** Odoardo Beccari, photo courtesy of Riccardo Baldini (Florence Herbarium). **(D)** Caetano Xavier Furtado.

*Calamus*, *Eremospatha*, *Laccosperma* and *Oncocalamus*). The only continental publication effort is restricted to the book of Tuley (1995) and some taxonomic updates, including short descriptions of the genera and species

and distribution maps, were proposed in the publication of Stauffer et al. (2014).

The fossil history of the continental African palm flora, in particular the complex factors explaining its dramatic decline and its present-day low diversity, has been the subject of several studies. According to Pan et al. (2006) the earliest purported African palms are Aptian [125–112 million years ago (Mya)], with the particular example of *Hyphaeneocarpon aegyptiacum*. The same author has also explained that Tropical West Africa has been sampled most consistently as a result from pollen from drill cores (Late Cretaceous–Early Miocene) whereas East Africa is relatively well sampled for macrofossils (mostly Neogene). A first decline in the African palm flora is associated with the Cretaceous–Palaeogene global extinction event (65 Mya), in which the disappearance of 47% of palm pollen species was recorded among fossil genera in West Africa. A second decline revealing extinctions and appearances at or near the Eocene–Oligocene boundary indicates a significant change in the African flora. At least six palm pollen genera disappeared from the African fossil record between 36 and 34 Mya.

Classical authors (i.e. Moore 1973) argued that the late Quaternary climate shifts could be identified among the major causes explaining the low species-level richness observed in African palms; however, as indicated before, fossil evidence suggests that palm extinctions date back to the Palaeogene and Neogene periods and new studies also highlight the impact of pre-Quaternary historical drivers (Pan et al. 2006; Kiessling et al. 2012). Blach-Overgaard et al. (2013) analysed a continental data-set on African palms to explore the importance of palaeoclimatic effects on current gradients associated with their richness patterns. These authors found that



**Figure 3.** Important herbaria storing samples of African palm taxa. **(A)** Herbarium of the Royal Botanic Gardens, Kew (K); this collection is in particular rich in East and South African taxa. **(B)** Fruit collection of the herbarium of Florence (FI), hosting many type specimens described by Odoardo Beccari.



**Figure 4.** Floristic inventory of the palms in Ghana. *Borassus aethiopum* is a massive palm for which bulky specimens have to be collected to obtain accurate morphological data. Doudjo Ouattara, Fred Stauffer and Patrick Ekpe collected male and female individuals of this species in different regions of the country.

African palm diversity patterns show important historical legacies related to long-term climatic changes, in particular pre-Pleistocene precipitation variables differentially affected current diversity patterns of palms grouped by contrasting habitat requirements.

The present contribution, representing an expanded version of the conference given in the frame of the Tropical Botany Conference (Florence, October 2016), aims to provide a general and updated picture on the palm floristic and taxonomic studies on African palms, focusing in particular on the recent efforts undertaken in four West African countries (Côte d'Ivoire, Ghana, Togo and Benin). In each of these countries the main goals of the projects included: (1) a comprehensive floristic inventory (including complete herbarium and DNA sampling), (2) taxonomic definition of native palms and a record of their morphological diversity, (3) an update of distribution maps, (4) an inventory of the main uses and common names, (5) conservation status assessment following IUCN guidelines (country level assessment as a first approach to a species level assessment), and (6) morpho-anatomical studies on vegetative and/or reproductive organs in poorly known or economically important taxa. Although probably incomplete and lacking much more updated field data, we believe that the present paper does contribute to a better understanding of the palm family in Africa and may raise some interest among the botanical research community.

## 2. Material and methods

The general taxonomic analysis on Continental African palms is based on the complete or partial study of specimens deposited in the European herbaria of BR, BRU, COI, FI, G, K, LISC, LISU and P, and the West African herbaria of GC and the herbarium of the Swiss Research

Centre in Abidjan (Holmgren et al 1990). We have largely benefited from the well-curated African database of the WAG herbarium, as well as the complete database of African plants from the Conservatory and Botanical Garden of Geneva (<https://www.ville-ge.ch/musinfo/bd/cjb/africa/index.php?langue=fr>). Taxonomic identification of specific palm groups was based on the publications of Furtado (1967, *Hyphaene*), Barrow (1998, *Phoenix*), Bayton (2007, *Borassus*), Dransfield (1986, 2010, East African palms), Otedoh (1982, *Raphia*), Sunderland (2012, African rattan genera), Van Valkenburg and Sunderland (2008, *Podococcus*), Van Valkenburg et al. (2008, *Sclerosperma*), Van Valkenburg and Dransfield (2004, *Hyphaene*), and for other palm groups we based our identifications on the general publication of Tuley (1995). The general taxonomy and distribution of the palms is based on the work of Stauffer et al. (2014).

For strictly practical reasons associated with our analysis, some important geopolitical issues had to be defined: Western Sahara was included under Morocco and South Sudan was included in Sudan. Although our study is restricted to Continental Africa and therefore excludes Madagascar, some islands close to the continent were included in our analysis. Hence, we have taken into account the islands of Cape Verde, home of the endemic *Phoenix atlantica* (Henderson et al. 2006), Sao Tomé & Príncipe and Bioko (Equatorial Guinea), in the Guinea Gulf and Pemba Island (Tanzania), home of the endemic *Dypsis pembana*. Our analysis also takes into account the palm genus *Nypa*; although this palm is well-known to be native in South Eastern Asia (Dransfield et al. 2008) it is nowadays spreading from Lagos to the Woury Estuary near Douala.

The taxonomic, floristic, morphological, ecological and ethnobotanic data associated with West African palms is based on the results of three master projects undertaken in the Conservatory and Botanic Gardens of Geneva and the University of Geneva (Doudjo Ouattara: palms of Côte d'Ivoire and Ghana), Simona da Giau (palms of Côte d'Ivoire) and Loïc Michon (palms of Togo and Bénin). Extensive field work associated with palm research in West Africa was carried out in Senegal (2014), Côte d'Ivoire (2012–2015), Ghana (2013–2015), Benin (2014) and Togo (2015). Issued from these field activities more than 150 fully informative herbarium specimens are now deposited at G. For the ethnobotanical survey several interviews were carried out with locals and village markets were visited; calculation of the Relative Importance value for each species followed the guidelines proposed by Bennett and Prance (2000) and Albuquerque et al. (2006) and standardized forms were inspired in Brokamp et al. (2010) and Paniagua-Zambrana et al. (2010). We visited endangered or heavily exploited palm populations and a preliminary conservation status assessment at country level for each species was proposed based on Gärdenfors (2001) and IUCN

(2003). For the structural studies we have employed the classical histological methods proposed in the laboratory of Micro-Morphology of the Conservatory and Botanic Gardens of Geneva and scanning electron microscope-based analyses by mean of the microscope of the Natural History Museum of Geneva.

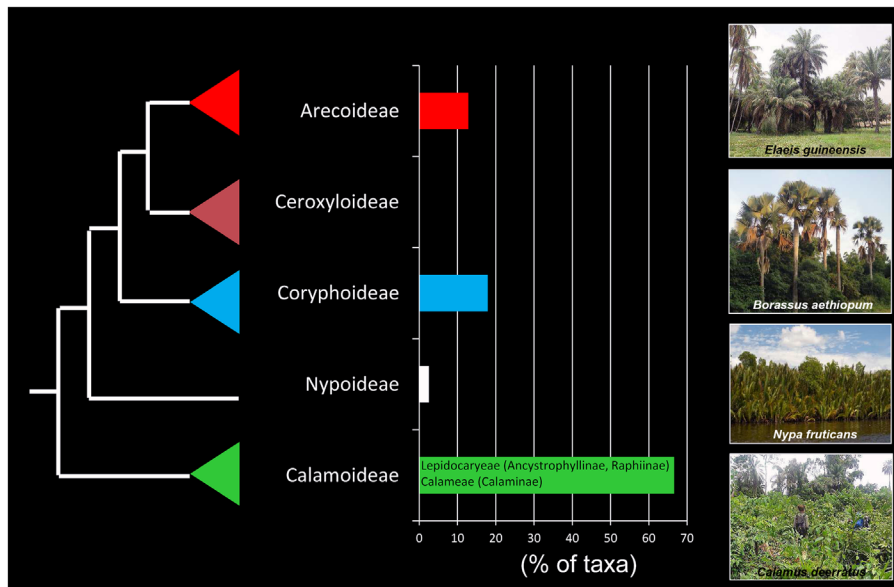
### 3. Results

#### 3.1. A general overview on Continental African palms

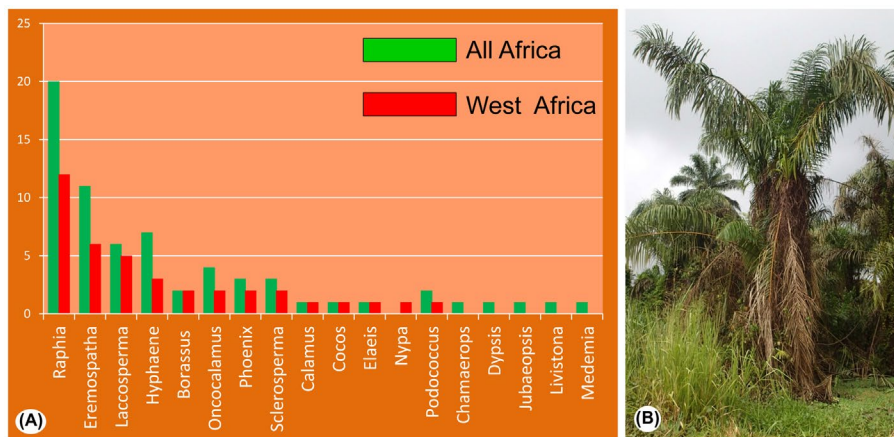
The Continental African palm flora is composed of 18 genera and 68 spp., about 60 of them are completely endemic to the region; the most recent species discovered and described is *Laccosperma cristalensis* Couvreur & Niangadouma (Couvreur and Niangadouma 2016). The subfamily Calamoideae, in particular with representatives in the tribes Lepidocaryeae (Ancistrophyllinae,

Raphiinae), and Calameae (Calaminae), is largely dominant with 62.68% of the taxa, whereas the subfamilies Coryphoideae and Arecoideae are only represented by 22.38% and 13.42% of the taxa recorded for the area; *Nypa fruticans* (Nypoideae) is in our analysis included in this flora given its rapid expansion as an invasive plant in Nigeria and Cameroon (Figure 5). The genera *Raphia* and *Hyphaene* should be regarded as the main contributions by Africa to the palm family diversity. This incompletely understood genus is largely dominant with 20 species and is followed in the second place by the rattan genus *Eremospatha*, represented by 11 species; the two genera contribute with 46% of all African palm species and are still common elements in well-preserved forests of the tropical region (Figure 6).

It is very striking to note that almost half of all genera are monotypic, a condition that is only represented to a very low degree in American or Asian palms. The



**Figure 5.** Palm sub-families and percentage of species per sub-family represented in the continental African palm flora. The sub-family Nypoideae is here included given its rapid invasion in the shores of Nigeria and Cameroon.



**Figure 6.** Diversity of palm genera and species in Africa. (A) Species reported in West Africa (red bars) in comparison with the species reported for the entire continent (green bars). (B) *Raphia hookeri* is a West African representative of the species-rich palm genus *Raphia*, the latter regarded as the most important African contribution to the palm family.

African palm genera also show interesting facts with respect to the way they are also represented in the palm flora of other regions of the world. With respect to endemism, seven palm genera are only present in continental Africa (*Eremospatha*, *Jubaeopsis*, *Laccosperma*, *Medemia*, *Oncocalamus*, *Podococcus* and *Sclerosperma*). On the other hand some African genera have been also reported in continents such as South America (*Elaeis*, *Raphia*), Europe (*Chamaerops*), Asia (*Borassus*, *Calamus*, *Hyphaene*, *Livistona*, *Phoenix*), Madagascar (*Borassus*, *Dypsis*, *Elaeis*, although its presence is still subject to controversy, *Hyphaene*, *Phoenix*, *Raphia*) and Oceania (*Livistona*).

### 3.2. Shared African–South American taxa: the interesting cases of *Elaeis* and *Raphia*

The genera *Elaeis* and *Raphia*, shared between Africa and South America, are worth discussing in detail. The taxonomic identity of the South American member of the genus *Elaeis* (*Elaeis oleifera* (Kunth) Cortés) is not under debate as there are important features (i.e. growth habit, infructescence architecture, fruit size and form) supporting its separation from the well-known African oil palm (*Elaeis guineensis* Jacq.). In the case of the genus *Raphia* several authors support that the continent share exactly the same species (*Raphia taedigera*); in Africa this palm has been reported in Nigeria and Cameroon, although according to Tuley (1995) it could also occur anywhere near the coast and the nearby off-shore island between the Niger and Congo deltas. The same author also pointed out that this palm, at least based on the study of African collections, may be probably better considered as a variety of the closely related *Raphia vinifera*. The presence and distribution of this species in eastern South America (coastal Brazil) and southern Central America have been documented by Henderson et al. (1995). This palm belongs to the large Section *Raphia* (as defined by Otedoh 1982), characterized by petioles and leaf rachis of high quality and very durable thatch and with the exception of *Raphia africana* generally not good for wine production. The fruits in this Section are usually thick and have an oil-rich edible mesocarp. All in all, it is clear that the accurate taxonomic identification of the South American and the African populations would be critical to solving whether the populations present in the two continents correspond to the same species or not. The new project launched by Mogue and co-workers on the genus *Raphia*, explained in detail later in this paper, will probably contribute to our understanding of this matter.

### 3.3. Palm richness and endemism in the different African sub-regions

Our analysis highlights that richness and endemism at a continental scale concentrate in the tropical belt, where forested areas are much better represented, and decrease

towards the northern or southern latitudes, in which the savanna areas are clearly dominant. Central Africa, with 12 genera and 52 species, corresponds to the area with the largest palm diversity; 24% the species present there are endemics (*Eremospatha barendii*, *Eremospatha cabrae*, *Eremospatha cuspidata*, *Eremospatha tessmanniana*, *Laccosperma korupensis*, *Laccosperma robustum*, *Oncocalamus macrospathus*, *Oncocalamus mannii*, *Podococcus acaulis*, *Raphia gentiliana*, *Raphia laurentii*, *Raphia matombe*, *Raphia rostrata*, *Raphia sese*, *Raphia textilis* and *Sclerosperma walkeri*). West Africa follows with 13 genera and 38 species, 9% of them being endemics (*Eremospatha dransfieldii*, *Hyphaene macrosperma* and *Oncocalamus wrightianus*). East Africa is represented by 10 genera and 18 species, 18% of them endemics (*Dypsis pembana*, *Hyphaene compressa* and *Livistona carinensis*). Northern Africa contributes to the African palm flora with eight genera and nine species, 18% of them endemics (*Chamaerops humilis* and *Medemia argun*). Palm richness is lower in southern Africa, which hosts six genera and seven species, only one them being completely endemic (*Jubaeopsis caffra*) (Figure 7).

### 3.4. Analysis of some biological traits

Our analysis of the three important biological patterns (growth form, reproductive strategy and leaf form) in the 68 species concerned in our area of study showed some interesting results. Continental African palms display four different and more or less clearly defined ways of growth form: erect and with an aerial stem is

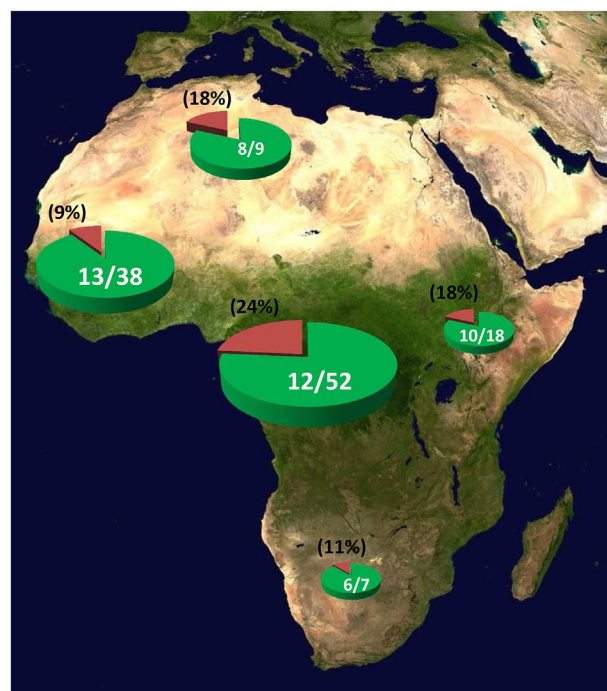


Figure 7. Palm richness present in the different sub-regions of Africa. The numbers in the pie charts refer to the number of genera / number of species, and the percentage of endemism at species level is indicated in brackets.

dominant (51%), climbing and lianescent habit (25%), acaulescent to almost acaulescent (12%) and erect, with a prostrate tendency (10%). For a few taxa (about 2%) the type of growth form remains. An interesting case to be mentioned is *Raphia matombe* De Wild, a palm that has been only reported for Angola and the Democratic Republic of Congo, for which the growth form has not yet been described; cases like this should be investigated in detail by means of further field work. The reproductive strategies observed in the African palm taxa are diverse and expressed in four different ways: monoecy is dominant (48%), whereas hermaphroditism (27%) and dioecy (24%) are much less represented. The complex polygamous–dioecious reproductive syndrome, which requires in-depth study, has only been reported in northern African – Southern European palm *Chamaerops humilis*. Leaf form is represented in four different ways: pinnate leaves are clearly dominant (80%), whereas costate-palmate (17%), entire-bifid (2%) and palmate (1%) are much less common.

We tried to perform an analysis of the dominant ecological conditions that prevail for each species; however, this proved to be challenging as some taxa (i.e. *Calamus*, *Elaeis*, *Phoenix*) may be adapted to relatively broad conditions. Although approximately 40% of all African palms prefer forested, warm and humid habitats, they can also be represented in lowland savannas (coast and inland savannas), mountain savannas, swamps and riverine areas, arid and semi-arid regions, rocky banks of the rivers and disturbed–anthropogenic areas, among others.

Incompletely understood and often under collected African palm taxa are not necessarily associated with the presence of massive stems (i.e. *Borassus*) or long leaves (i.e. *Raphia*). More than half of the palms lacking morphological or ecological information belong to the rattan groups, which combine climbing growth habit, they are always spiny and often ant-associated by modifications

of the leaf sheath or the ochrea; all these features may at least partially explain why access to informative vegetative or reproductive organs is strongly hindered. Poorly known taxa are dominant in the genus *Eremospatha*, for which comprehensive information on flowers and fruits is not available for five out of the 11 species known in the genus (Table 1). Indeed, as extensively explained in many publications by Terry Sunderland (i.e. Sunderland 2007, 2012) sampling of informative herbarium specimens in rattan species is not an easy task because these palms are strongly armed and flower far up in the canopy. The identification of reproductive organs in these palms requires special skills, most often developed by palm experts. Other factors that strongly hinder the collection of informative specimens are related to country instabilities (i.e. civil wars, terrorist groups) or health conditions (i.e. malaria, ebola outbreaks) predominant in the countries where the palms grow.

### 3.5. Current research in West Africa: floristics, systematics and structural botany, ethnobotany and conservation

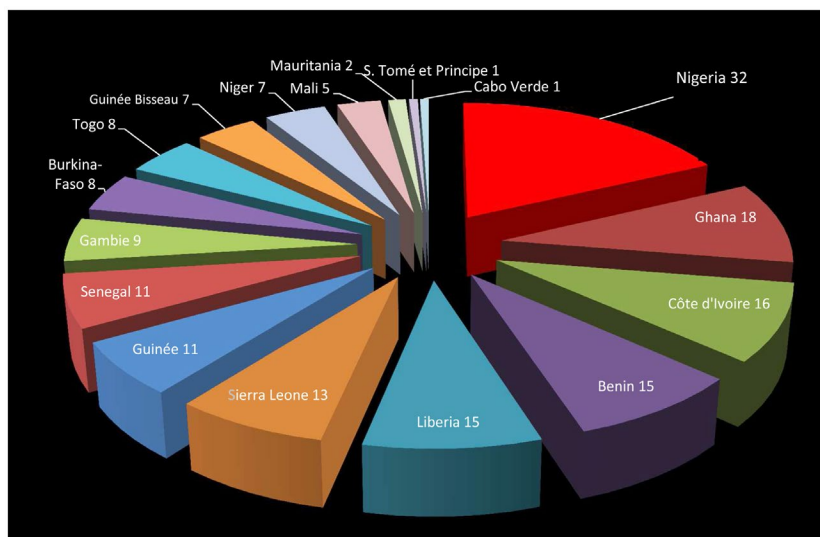
#### 3.5.1. Taxonomic and floristic diversity

West Africa, as defined for our analysis, is composed of 16 countries in which 13 genera and 39 palm species are present. Most of these palms are associated with the different vegetation types present in the broadly defined Upper Guinean Forest, a large vegetation unit of c. 109,000 km<sup>2</sup> hosting about 2800 vascular plants. An important interruption to this now extremely fragmented forest belt is represented by the Dahomey gap, extending from the Accra plains in Ghana to southern Nigeria. In this region, the savannas reach the coast and host species such as *Borassus aethiopum*, *Hyphaene guineensis*, *Phoenix reclinata* and *Raphia sudanica* grow. With respect to the palm flora, the richest country in West Africa corresponds to Nigeria (32 spp.), where

**Table 1.** African palm species lacking critical morphological data associated with vegetative and reproductive organs. Note that almost half of species in the rattan palm genus *Eremospatha* are poorly known and require further collecting efforts.

Species	Distribution	Lacking data
<i>Eremospatha barendii</i> Sunderl	Cameroon (Sunderland 2012)	Flowers
<i>Eremospatha dransfieldii</i> Sunderl	West Ghana and east Ivory Coast – outliers in Sierra Leone (Sunderland 2012)	Inflorescences, flowers and fruits
<i>Eremospatha hookeri</i> (G. Mann & H. Wendl.) H. Wendl	Northernmost part of the Congo Basin (Sunderland 2012); presence in Angola to be confirmed (Baker 2008)	Flowers
<i>Eremospatha quinquecostulata</i> Becc	From southeast Nigeria through Cameroon (Sunderland 2012)	Flowers and fruits
<i>Eremospatha tessmanniana</i> Becc	Cameroon–Nigeria border and cross border region of Cameroon and Equatorial Guinea (Sunderland 2012)	Flowers and fruits
<i>Hyphaene macroserma</i> H. Wendl	Northern Benin	Vegetative organs, inflorescence, flowers and ecology
<i>Hyphaene reptans</i> Becc	Restricted to Kenya (reports to be confirmed in Somalia and Arabia)	Almost only known from the original description (Beccari 1908).
<i>Laccosperma korupensis</i> Sunderl	Restricted to Cameroon (Sunderland 2012)	Inflorescences, flowers and fruits
<i>Oncocalamus wrightianus</i> Hutch	South Benin to southwest Nigeria (Sunderland 2012)	Flowers and fruits
<i>Raphia matombe</i> De Wild	From Angola (Cabinda) to the southern region of RDC (Otedoh 1982; Baker 2008)	Growth habit and most leaf features unknown





**Figure 8.** Floristic palm diversity, expressed in number of species, present in the different West African counties.

more field work, currently hindered by political instability, could highlight the presence of additional taxa. Other countries such as Ghana (18 spp.), Côte d'Ivoire (16 spp.), Benin and Liberia (15 spp.), rank among the most diverse countries with respect to the palm family in the continent (Figure 8). In West Africa the most frequently found species include the widely cultivated *Cocos nucifera* (16 countries), the sun-tolerant rattan palm *Calamus deerratus* (12 countries), the doum or gingerbread palm *Hyphaene thebaica* (12 countries), the raphia palm *Raphia sudanica* (11 countries), the African oil palm *Elaeis guineensis* (10 countries), the forest rattan palm *Laccosperma secundiflorum* (10 countries), the clustered date palm *Phoenix reclinata* (10 countries), and the raphia palm *Raphia farinifera* (10 countries).

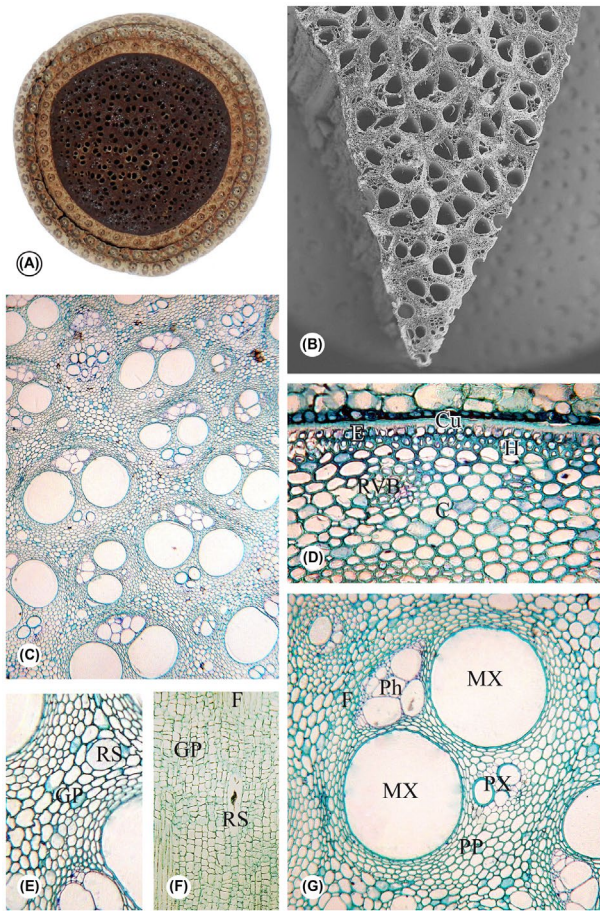
As indicated earlier in this paper, three species (*Eremospatha dransfieldii*, *Hyphaene macrosperma* and *Oncocalamus wrightianus*) are regarded as the only endemic taxa of the region. In particular one of them, *Hyphaene macrosperma*, requires further study as it remains extremely poorly known. This palm is currently taxonomically accepted and reported as endemic to Benin (Govaerts et al. 2017); its original description was proposed by Wendland (1881) based on a single fruit collected by Baikie. However in the publication *Flore analytique du Bénin* Aké-Assi et al. (2006) did not mention this species and cited *Hyphaene thebaica* as the only species of the genus *Hyphaene* present in that country. According to Furtado (1967), the fruit was described as ovate rather obtuse, very smooth at the top, slightly swollen on the ventral side, hardly ventricose, 7 cm long, 6 cm in diameter, resembling that of *Hyphaene thebaica* but rounder, more obtuse and of a duller colour. The seed was described as roundish ovoid, 45 mm long, 40 × 45 mm in diameter. Beccari (1908) indicated that he studied the type specimen proposed by Wendland and after comparison with its original

description he noticed that it corresponded well with the description of *Hyphaene dahomeensis* Becc. (together with *Hyphaene nodularia* Becc., one of the currently accepted synonyms for the species), a name that has in turn been proposed by several authors (i.e. Tuley 1995) as a synonym of *Hyphaene thebaica*. In the frame of a master project dealing with a floristic and systematic study of the native palms in Togo and Benin (Michon 2017), the presence of *Hyphaene macrosperma* could not be confirmed and only populations of *Hyphaene thebaica* were spotted in the northernmost regions of these countries. Current taxonomic efforts on the genus *Hyphaene* ([www.hyphaene.org](http://www.hyphaene.org)) will probably show that *Hyphaene macrosperma*, long regarded as an independent, yet poorly known taxonomic entity, can be rather interpreted as a morphological variant of the widely distributed *Hyphaene thebaica*.

Other taxa requiring further studies are *Borassus akeassi* and *Phoenix reclinata*. According to Bayton et al. (2006) *Borassus akeassi* is present in eight West African countries, for which accurate characters supporting its clear differentiation from the widespread *Borassus aethiopicum* are still lacking. The clustered date palm *Phoenix reclinata*, for which we have observed important growth form variability (inland, tall individuals versus coastal, almost acaulescent individuals) in countries such as Senegal, Côte d'Ivoire, Togo and Benin needs to be studied in more detail. The taxonomic implications of the high plasticity observed in this palm should be assessed with the support of molecular phylogenetic studies and with this aim we have been systematically collecting material for DNA studies.

### 3.5.2 Structural botany

In the frame of a master project (Da Giau 2014), the anatomy of Côte d'Ivoire rattan canes was studied in several native species (*Calamus deerratus*, *Eremospatha*



**Figure 9.** One example of the histological studies carried out on the rattan genera of Côte d'Ivoire (Da Giau 2014), in this case on the cane of *Eremospatha macrocarpa*. **(A)** General view of the stem with sheaths in cross-section, scale bar: 1 cm. **(B)** Scanning electron microscope image of a portion of the stem, cross-section, scale bar: 500 µm. **(C)** Stem in cross-section, central cylinder; black arrow: protoxylem replacing metaxylem, 500 µm. **(D)** Epidermis and cortex; cuticle (Cu); epidermis (E); hypodermis (H); reduced vascular bundles (RVB), scale bar: 50 µm. **(E)** B-type ground parenchyma (GP) in cross-section with the presence of a raphide sac (RS), scale bar 100 µm. **(F)** Parenchyma in longitudinal section (GP), raphide sac (RS) and fibres (F), scale bar: 200 µm. **(G)** two-vessel type with one phloem (Ph) field; MX, metaxylem; PX, protoxylem; PP, paratracheal parenchyma; F, fibres; scale bar: 500 µm.

*laurentii*, *Eremospatha macrocarpa*, *Laccosperma acutiflorum*, *Laccosperma laeve*, *Laccosperma secundiflorum*), although one species of *Oncocalamus* (*Oncocalamus mannii* (H. Wendl.) H. Wendl.), not reported for that country, was also included in the study to have a representative of all African palm taxa (Figure 9). The main aims of this study were to provide in-depth descriptions of the anatomical features of stems of useful species, to perform an identification key based on the anatomical stem aspects and also to detect correlations between the anatomical features and the quality of the Ivorian canes. Based on several studied characters it was possible to clearly differentiate from an anatomical perspective members of the two tribes of Lepidocarpaceae (Calaminae and Ancistrophyllinae); the genus *Calamus*

shows an arrangement of phloem fields that is clearly different from that of all members of Ancistrophyllinae and this anatomical character could be useful to distinguish Calaminae to Ancistrophyllinae present in Africa. Exploring affinities within Ancistrophyllinae demonstrated that the one-vessel structure of vascular bundles observed in *Oncocalamus* and *Laccosperma* suggests a close affinity between these two genera. *Eremospatha* remains isolated with a two-vessel structure of vascular bundles; these results support some of the affinities proposed by Faye et al. (2014) based on molecular phylogenetic studies. *Calamus deerratus* displays the best histological characters associated with stem quality, namely the presence of sections with even distribution of the vascular bundles across the stem, moderate to high values with respect to area covered by vascular bundles and fibres, fibre walls showing high values of thickness and stigmata lacking in peripheral vascular bundles. Despite the optimal anatomical features displayed by *Calamus deerratus*, in particular Côte d'Ivoire handcraft makers prefer other rattans such as *Eremospatha macrocarpa* and *Laccosperma secundiflorum*. This may be at least partially explained by the fact that the latter species present better mechanical features that allow easier work when bending the canes. All in all, other biomechanical studies, such as the one proposed by Isnard and Rowe (2008) and Isnard et al. (2005), should be performed on African taxa to better understand the features taken into account by handcraft makers when choosing canes of a specific rattan, this information being critical for any domestication programmes launched on these useful species.

### 3.5.3 Palm uses and conservation

In West Africa palm resources rank among the most appreciated Non-Timber Forest Products and contribute significantly to household incomes of people, particularly those living in rural areas. As observed in several native populations of Senegal, Côte d'Ivoire, Ghana, Togo and Benin, palm organs can be classified under use categories that include: edible, used for construction or crafts, or even exploited for their medicinal or cosmetic properties. On a more specific scale, those organs are associated with several sub-categories including food, beverage, oil, building/house construction, thatch, basketry, furniture, art craft, clothes, jewellery, medicinal and cosmetic additives. The Relative Importance Index (RI) was calculated for the native palms from Côte d'Ivoire and highlighted the species that were better represented in categories and sub-categories: the oil palm *Elaeis guineensis* is at the top of the list (RI 2), meaning that this species is by far the most economically important palm in that country (Figure 10). This species is followed by *Raphia hookeri* (RI 1.8), *Cocos nucifera* (RI 1.6), *Raphia sudanica* (RI index 1.5) and *Borassus aethiopicum* (RI 1.4). In the case of the latter, locals apparently do not make any distinction with *Borassus akeassi* and



**Figure 10.** Useful palms from West Africa. In Côte d'Ivoire, the oil extracted from the fruits and the seeds of the oil palm (*Elaeis guineensis*) ranks among the most important palm products commercialized in the country. (A) Sun-dried fruits. (B) Women smashing fruits. (C) Cooking of the smashed paste. (D) Paste pressing. (E) Extracted red oil, still boiling. (Didokro, Central Côte d'Ivoire)

therefore, the uses reported may include the two species. For the rattans reported to be used (i.e. *Calamus deeratus*, *Eremospatha laurentii*, *Eremospatha macrocarpa*, *Laccosperma laeve* and *Laccosperma secundiflorum*) the RI values are lower because those species do not present edible organs.

The uses of West African palms are extremely diverse and the demand for palm products is steadily increasing in several countries. To meet the high market demand, harvesting is done from wild populations and this raises questions about their survival and sustainability. Today, the majority of native palms in the region are exposed to multi-factorial threats and about 90% of them are not cultivated; only some examples of cultivated populations of *Borassus aethiopum* in the region of Thiès

(Senegal) highlight that the promotion and domestication of West African palms have a future. Although some species can be found in agro-ecosystems (i.e. *Hyphaene guineensis*), their management in these farmlands is not convincingly sustainable. Many taxonomically interesting palms are not represented in protected areas, or if they are, then they are present in only a few of them (i.e. *Sclerosperma profiziana* in Ghana). Other species are rare and economically important ones are intensively harvested from natural populations. Agriculture and urban development has undergone unprecedented expansion, drastically reducing forested areas and natural savannas. The conservation of African palms is a real concern and the information associated with this in the frame of our project aims to support local initiatives



**Figure 11.** Centre of environmental education and promotion of palm traditions in the City of Divo (Côte d'Ivoire). The Dida ethnic group makes important use of raffia fibres extracted from the leaves of *Raphia hookeri*. These traditional clothes are entirely woven from raffia fibres and dyed with plants and mineral products. The City of Geneva Solidarity Fund supports this centre and the associated palm botanical garden, which is now under construction.

addressing conservation issues. An important effort is currently being undertaken in the city of Divo (South-Central Côte d'Ivoire) where the Conservatory and Botanic Gardens in Geneva are developing an environmental centre focusing on the conservation of native palms (rattans, *Borassus aethiopum*, *Elaeis guineensis*, *Raphia hookeri*) and the promotion of palm-based products (Figure 11). Although mainly focused on the traditional and cultural practices associated with the Dida ethnic group, this environmental centre aims to join efforts at a country level, with palm representatives of other regions in the country. An interesting conservation issue is related to the South-East Asian palm *Nypa fruticans*, which has spread from Lagos to the Woury Estuary near Douala (Cameroon). The palm was originally introduced from Singapore in 1906 and 1912 and again 1946 (Sunderland and Morakinyo 2002; Beentje and Bandeira 2007; Dransfield et al. 2008). According to Tuley (1995) there are now reservations with regard to its colonizing power as it could possibly be achieving the status of a serious weed, to the exclusion of the native mangrove species.

#### 4. Future perspectives

We would like to finish this contribution by describing current research efforts that focus on several interesting aspects of African palms. Our project continues, providing new data on floristic and taxonomic aspects of African palms and our permanent field missions to several countries of the continent offer new perspectives to local and foreign researchers. The sampling efforts steadily increase our current knowledge of African palms, and this is in particular true in the herbarium of Geneva (G),

which has now become the most important repository of modern West African palm collections (about 150 new herbarium specimens). Here we present four interesting projects for which we provide direct or indirect scientific collaboration. For all of them the Conservatory and Botanic Gardens of Geneva (CJB) provide support either by sampling efforts or offering direct advantages for laboratory work; here below we briefly describe some of these collaborations.

*Raphia* project (University of Yaoundé, IRD, CJB): In the frame of a wide project including floristics, taxonomy and economic botany of the genus *Raphia*, the PhD candidate Suzanne Mogue is undertaking a modern taxonomic revision of this interesting palm group (Figure 12). This work is supervised by Dr Thomas Couvreur (IRD, France), Prof. Bonaventure Sonké (University of Yaoundé), Dr Anders Barfod (University of Aarhus) and Fred Stauffer (CJB). In the frame of the monographic study, Suzanne Mogue has also undertaken an in-depth analysis of the morphology and anatomy of leaves and flowers in *Raphia* (with emphasis in androecium structure), in search of taxonomically informative characters.

African palm phytoliths project (Universidad Nacional de Colombia, CJB): Phytoliths are silica bodies that accumulate in the tissues of leaves and other organs and remain in the soil for thousands or even millions of years. As already shown for Neotropical palms (Morcote-Rios et al. 2016) they are widely used as proxies in the reconstruction of palaeo-environments and ancient plant–animal and plant–human interactions. In Africa, this is particularly interesting for hominid palaeontology, archaeology and palaeoecology, including reconstruction of ancient landscapes. A collaboration has been started with Gaspar Morcote and Lauren Raz



**Figure 12.** The 'Raphia Project'. The PhD candidate Suzanne Mogue (University of Yaoundé – IRD) undertakes floristic and taxonomic research on the species-rich palm genus *Raphia*. **(A)** *Raphia* collecting in Cameroon. **(B)** The massive leaves of *Raphia* palms rank among the longest in the Plant Kingdom; a comprehensive collection of these palms requires several hours of field work. **(C)** The access to the 'Raphiales' is not easy as these environments are often inundated during the rainy season. **(D)** Suzanne Mogue has carried out detailed morphological and anatomic studies on the leaves and the flowers of several species of *Raphia*. (Laboratory of Anatomy of the Conservatory and Botanic Gardens of Geneva)



**Figure 13.** A multi-disciplinary study of the palm genus *Hyphaene*. A monographic study of these palms is currently undertaken in the Conservatory and Botanic Gardens of Geneva. This image shows our collection of *Hyphaene compressa* in the region of Lushoto. (Tanga Region, Tanzania) during 2016 (photo Didier Roguet).

(Universidad Nacional de Colombia) to produce an illustrated catalogue for all African genera, which includes at least 45 species, with special emphasis on economically important palms. In the frame of this collaboration the phytolith morphotypes will be described and illustrated, and their taxonomic distribution will be discussed along with their potential for use in applied studies throughout the continent.

A multidisciplinary study of the palm genus *Hyphaene* (CJB): This is a project started in 2015 by the palm

research team of the Conservatory and Botanic Gardens of Geneva. It aims to undertake a multidisciplinary study on the palm genus *Hyphaene* (Coryphoideae: Borasseae), which is apparently composed of eight species and ranks among the most economically important, yet extremely poorly known African palm genera. This palm group was monographed about 90 years ago, and our project aims to undertake modern taxonomic, morpho-anatomical, phylogenetic (collaboration with M. Perret and Y. Naciri from CJB), ecological and conservation

studies of the group. Extensive sampling of informative herbarium specimens and material for DNA studies has been carried out in Ghana (2014), Djibouti (2015) and Tanzania (2016, Figure 13), and new populations will be sampled in South Africa during 2017. Extensive sampling was also carried out in cultivated individuals of the Montgomery Botanical Center and the Fairchild Tropical Botanical Garden (Florida, USA).

Conservation status assessment of African palms (IRD, Kew Gardens, CJB): Conservation issues associated with African palms have been discussed in the frame of the floristic inventories carried out in Côte d'Ivoire (Da Giau 2014), Ghana (Ouattara 2012; Ouattara et al. 2014, 2015) and Togo and Benin (Michon 2017). This relatively updated information is being used for a more formal assessment of the conservation status of African palms carried out by Oriane Cosiaux, Thomas Couvreur and William Baker, in collaboration with our team of CJB. The recent conservation status assessment undertaken on the threatened rattan palm *Eremospatha dransfieldii* (Cosiaux et al. 2017), is a good example of the efforts that will be carried out for other African species.

Floristic, ecological and ethnobotanic studies of the palms in the Democratic Republic of Congo (Faculty of Sciences, University of Kinshasa): The Democratic Republic of Congo shows, with 36 species, the second most diverse palm flora in the continent; however, many regions of the country remain under-collected and incompletely understood taxa, in particular in the genus *Raphia* and most rattan groups, require further study. The PhD candidate Pelagie Mbandu Luzolawo, supervised by Dr Constantin Lubini Ayingweu and Fred Stauffer (CJB) is currently undertaking extensive palm sampling to increase our taxonomic and floristic knowledge of this group.

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