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The International Palm Society

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The flowers of *Schippia concolor* as photographed by Kenneth Setzer.

FRONT COVER

Schippia concolor. See article by J.L. Dowe and H. Yoxall, p. 109. Photo by E.P. Mallory.

BACK COVER

This particular method combining palm wine extraction and fruit production may represent a sustainable and economically interesting way to manage oil palm populations (*Elaeis guineensis*) in Africa. This method is widely known by members of the Diola ethnic group (region of the Niayes, west-central Senegal). See article by M. Auger-Micou et al., p. 127. Photo by Fred Stauffer.

PALM NEWS

The previous issue of *PALMS* suffered from a printing error in parts of the journal. An unnoticed fluctuation in ink density on the press led to murky photo reproduction on several pages. Allen Press, which handles the printing of our journal, has taken responsibility for the error, so we can only apologize for the lapse in print quality.

A new paper by Dias et al. (*Scientia Horticulturae* 304: 111297. 2022. https://doi.org/10.1016/j.scienta.2022.111297) describes **the phenology and reproductive biology of *Butia capitata* under cultivation and evaluated the storage potential of its pollen**. Male flowers open first, followed by a gap of one to six days, then the female flowers open. The species is self-incompatible, meaning that flowers must be pollinated by pollen from a different individual palm. This species differs from *B. odorata*, which has overlap between the male and female flowering phases and is self-compatible. Pollen of *B. capitata* can be stored in the viable state for 180 days either refrigerated or frozen, but under natural conditions of temperature and humidity, viability lasts less than 30 days.


Scott Zona

A major new paper presents a much-needed solution to the taxonomy of the Madagascar palm subtribe Dypsidinae. The work, published by W.L. Eiserhardt and colleagues in *Taxon*, is entitled "Phylogenomics and generic limits of Dypsidinae (Arecaceae), the largest palm radiation in Madagascar" (https://doi.org/10.1002/tax.12797). In it, the authors lay out the necessity, underpinned by thorough DNA sequence data, for adjusting the taxonomic boundaries of the large genus *Dypsis*. The researchers conclude that Dypsidinae now comprise six genera – *Masoala*, *Marojejya*, *Lemurophoenix*, *Vonitra*, *Chrysalidocarpus* and *Dypsis*. New combinations are validated in the publication, making the new names immediately available for use. Field work for this project was supported in part by a grant from the International Palm Society.

The European Network of Palm Scientists (EUNOPS) is hosting its 21st biennial meeting in Switzerland on October 15 & 16, 2022 at the Conservatory and Botanical Garden of Geneva. EUNOPS meetings are the premier scientific conferences that focus exclusively on the palm family and attract palm researchers from all over the world.

A recent study of lightning effects on 30 tree species is Panama found that palms are least likely to survive a strike. The three palms included in the study were *Astrocaryum standleyanum*, *Oenocarpus mapora* and *Socratea exorrhiza*. They are particularly sensitive because these palms have just one apical meristem, damage to which results in the death of the palm. Researchers also noted that abundant understory palms, such as *Geonoma* species, were seldom damaged by lightning because they were protected by the canopy. With changes in climate come the expectation of increases in lightning deaths and demographic changes in forest composition. The study, by J.H. Richards et al., is published in *Nature Plants* (https://doi.org/10.1038/s41477-022-01230-x).

William August Schipp (1891–1967): Commemorated in *Schippia concolor* and *Chamaedorea schippii*

John Leslie Dowe[1] and Helen Yoxall[2]

Two palm species names in current use – *Schippia concolor* and *Chamaedorea schippii* – commemorate William August Schipp (1891–1967), an Australian-born botanical collector who was active in Belize 1929–1937. Here we provide a brief biography and a summary of his contribution to palm research and taxonomy.

Apart from the published research that contributes directly to our knowledge of botany and taxonomy, the life history details of botanists and botanical collectors are not always recorded or perhaps overlooked because they are not considered relevant to their overall contribution to science. In regard to the botanical collector William August Schipp, who was one of the most productive collectors to have worked on the flora of Belize, Central America, there are broad biographical sketches available in the literature and on the web (Lowden 1970, van Steenis-Kruseman 1974, Spellman et al. 1975, Steere 1979, Stafleu & Cowan 1985, Convey & Convey 2017, Marcic 2018, Wikipedia 2022). However, scrutiny of these sources has revealed periods of lost years in his life history and factual errors, which we investigate further, as well as an examination of the palms associated with Schipp.

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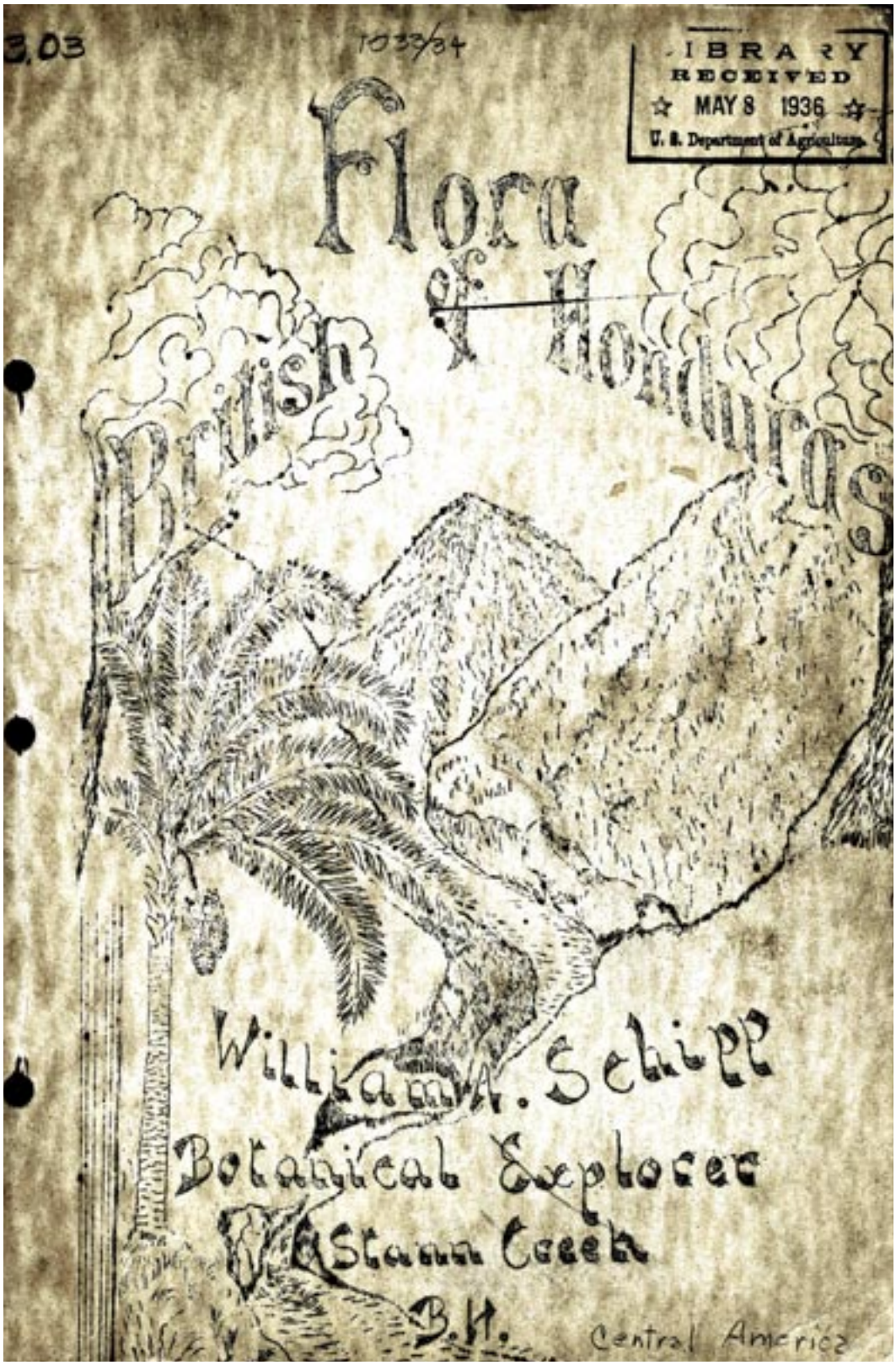
William August Schipp (1891–1967)

William August Schipp was born on 15 March 1891 at Silverton, a now largely abandoned mining town in western New South Wales, Australia, the son of Christian Schipp (1838–1897) and Barbara Schipp *née* McNair (1848–1915). Christian immigrated to Australia from Germany in 1855 and Barbara from Scotland in 1851 and they married at Menindee, NSW, in 1876. They had five children. William was the youngest sibling of Christian Kaspar (1877–1943), Louisa (1881–1964), Eva (1883–1897) and James Joseph (1888–1969) [1]. The family moved to Kalgoorlie, Western Australia, in the late 1890s [2], and in 1897 William was enrolled as an infant in the Kalgoorlie Public School [3]. Nothing more is known about his education or training. In his early twenties, from about 1911 to 1914 he was employed as a gardener by Kalgoorlie and Coolgardie municipal councils [4]. In July 1914 he travelled north on *S.S. West Australia* [5]. By 1916 he had settled in Darwin where he married Nellie Auter on 13 January 1916 [6]. The witnesses at their wedding were two members of the Larrakia First Nations group of Darwin, which



1. Cover of *Flora of British Honduras: price list of seeds & herbarium material*, illustrated by William August Schipp, 1933–34. Source: Biodiversity Heritage Library.

2. *Schippia concolor*. Cultivated, Montgomery Botanical Center, Miami, Florida. Photo by D.R. Hodel.

3. *Schippia concolor*. Leaf, lower surface. Montgomery Botanical Center, Miami, Florida. Photo by L.R. Noblick.

suggests that Nellie was possibly of indigenous heritage. Nellie died in 1919 [7], with no known children.

Schipp remained in Darwin, and in 1919 his occupation was given as "greaser" [8], a position associated with maintenance of engines on merchant ships. In 1922, he was employed as a dock worker and was prominent in a number of disputes involving the Northern Territory Workers Union of which he was an active member [9]. His first venture into botany was his employment from 1922 to 1925 in the Darwin Botanic Gardens as gardener and occasional acting curator and acting superintendent of agriculture. Indeed, Schipp had previously applied for the role of curator at Darwin in 1913, following the sudden death of Nicholas Holtz, but was unsuccessful. The position went to Charles E.F. Allen. Apart from a period when Allen was enlisted in the Australian Expeditionary Forces in WWI, 1915 to 1919, he remained as curator at Darwin until his retirement in 1936. Schipp, in Allen's short absences between 1922 and 1925, was appointed in the acting positions noted above. Allen (1925) wrote in his annual report for 1923–24 that "during my absence on these occasions Mr. W. A. Schipp, of the Gardens Staff, acted as Superintendent of Agriculture and Curator of the Botanic Gardens, and carried out those duties with skill."

Schipp's time at Darwin Botanic Gardens was marked by controversy. One newspaper report stated in January 1924 that "the acting curator of the Botanic Gardens at Darwin, Mr. William August Schipp has tendered his resignation because the amount of money essential to carry on operations is being denied him, and other obstacles are being placed in his way. The Administration was fortunate in being able to avail themselves of the services of Mr. Schipp, who is an expert botanist, and was an applicant for the position of curator when Mr. Allen secured the position" [10]. However, this threat did not immediately happen, and he remained employed at the gardens until December 1925.

Whilst at the botanic gardens, he befriended Florenz Bleeser (1871–1942) [11], a botanical collector then active in the Darwin area (McKee 1963, Willis 1966). It is pertinent to note that Bleeser's father had accompanied Robert Hermann Schomburgk during

4. *Schippia concolor*. Inflorescence. In habitat, lowland savanna at Belize Zoo's Tropical Education Center. Photo by E.P. Mallory. Source: Creative commons, https://www.flickr.com/photos/epmallory3/14938946296.

5. *Schippia concolor*. Fruit with a fissure developing in the epicarp, the first stage of dehiscence. Cultivated, Montgomery Botanical Center. Photo by L.R. Noblick.

explorations in British Guiana [now Guyana] during the 1840s, and his tales may well have influenced Schipp to consider similar adventures. Although it is reported in a number of accounts that Schipp collected botanical specimens in "Northern Australia," we could not locate any relevant specimens through herbarium database searches.

Schipp left Darwin on *S.S. Kinchela* in January 1926 with his destination as Sydney where [12], in November of that year, he had contact with Sydney Botanic Gardens [13]. In April 1927 he travelled to Java on *S.S. Houtman* [14], and then resided at Tjongdong, which was then the world's largest rubber plantation. A fellow passenger on the voyage was a "W. Froggart," possibly the recently retired entomologist Walter Wilson Froggatt, but whether he and Schipp were travelling together or it was coincidence is not known. Nothing is known of Schipp's employment or activities in Java and literature references that claim he made botanical collections in Java, Dutch East Indies and New Guinea have not been supported by any extant specimens. In early January 1929 he departed Tjongdong and travelled to San Francisco, where he met botanist E.D. Merrill. With Merrill's assistance, Schipp devised a plan to travel to Belize to undertake botanical work. He arrived in Belize (then known as British Honduras) in late January 1929. He travelled widely throughout Belize, collecting on a subscription basis for about 15 institutions. A detailed account of his collecting activities in Belize was provided by Lowden (1970).

In the introduction to Schipp's (1933–34) *Flora of British Honduras: price list of seeds & herbarium material* (Fig. 1), he acknowledged the support of many prominent botanists such as Paul Standley, Robert Pilger, Max Burret, Randolph Taylor, Albert Hitchcock, William Maxon, Rudolf Mansfeld and Eberhard Ulbrich. This may well indicate Schipp's limited taxonomic experience, although by all accounts he was a discerning collector and thorough preparer of specimens. In Belize, he collected at least 10,000 specimens during his nine years there (Lowden 1970). From these about 240 new species were described, about 60 of which were named to honor Schipp (JSTOR Global Plants 2022). Schipp also included a small number

6. *Schippia concolor*. Infructescence with dehiscing fruit. Cultivated. Fairchild Tropical Botanic Garden, Miami, Florida. Photo by S. Zona.

of his own illustrations in some sets of specimens. These exhibit a simple style and may be best described as flower paintings, not botanical illustrations in the strict sense. Two are figured in Lowden (1970). In 1938, Schipp wrote to director Alfred William Hill at the Royal Botanic Gardens Kew enquiring if Kew would be interested in purchasing his illustrations [15], but his request was declined [16].

In 1935, he contracted malaria [17], as well as experiencing the onset of a psychiatric illness for which he was "confined in the local asylum" as he suffered "periodic attacks of melancholia" [18]. After another period of confinement in the asylum in mid-1936, an effort was made by colonial officials to have him returned to Australia [19]. Subsequently, Schipp was repatriated to Australia in August 1938, and arrived on *S.S. Maunganui* in Sydney on 2 September 1938 [20]. A memo from the secretary, Department of Interior, Canberra to Collector of Customs, Sydney, stated: "In view of the fact that he is destitute and that he has also been an inmate of a mental hospital, it is desirable when he arrives to see that, if necessary, action is taken to place him in touch with the proper State authorities" [21].

At the end of September 1938, Schipp returned to Darwin Botanic Gardens where he was in charge of the plant house and seedling beds [22]. We have not been able to determine his whereabouts from December 1938, the last record of him being in Darwin, until November 1944, when he placed a newspaper advertisement offering his services in "gardening, propagation, landscaping, arts & crafts, signwriting and painting" with a contact address in Penrith, NSW [23]. By 1945, he was in the employ of artist Norman Lindsay and his wife Rose, at Springwood, in the Blue Mts, NSW. He lived in a cave on the property, dug the pond and built the pond wall for Lindsay's Seahorse Fountain, labelled plants with botanical names, planted kikuyu grass and attempted to eradicate calliopsis. His time there appears to have been difficult, as he was not allowed to share the servant's quarters because he "stank" and was seemingly antisocial and suffering from mental illness (Lindsay 1973, Stewart 1975). The duration of his employment at the Lindsays' garden is not known, but by 1952 he was living in a tent in Davies Avenue, Springwood [24]. During a storm in May 1952, a tree fell on his tent breaking his leg, and through being hospitalized for that he was subsequently

Table 1. Palms listed in William Schipp's Flora of British Honduras: price list of seeds & herbarium material of 1933–34, using his original spelling. Current names are in brackets. Collection numbers prefixed by S indicate that seeds as well as herbarium specimens were available for purchase.

Species	Collection Number
Acanthorrhiza warscewiczii [*Cryosophila stauracantha*]	S-442
Acoelorhaphe wrightii var. *hondurensis* [*Acoelorraphe wrightii*]	93
Acrocomia vinifera [*Acrocomia aculeata*]	662
Asterogyne martiana	392
Astrocaryum mexicanum	S-441
Bactris ovata [*Bactris major* var. *major*]	S-519
Bactris trichophylla [*Bactris mexicana* var. *trichophylla*]	S-368
Calyptrogyne donnell-smithii [*Calyptrogyne ghiesbreghtiana* subsp. *spicigera*]	S-512
Chamaedorea arenbergiana	S-515
Chamaedorea ernesti-augusti	92
Chamaedorea geonimiformis [*Chamaedorea geonomiformis*]	S-514
Chamaedorea neurochlamys	S-521
Chamaedorea oblongata	S-522
Geonoma binervia [*Geonoma pinnatifrons* subsp. *binervia*]	397
Geonoma longepetiolata [*Geonoma deversa* subsp. *deversa*]	94
Manicaria saccifera	S-513
Orbignya cohune [*Attalea cohune*]	S-439
Reinhardtia gracillior [*Reinhardtia gracilis* var. *gracilior*]	S-369
Reinhardtia latisecta	S-370
Sabal mauritiiformis	S-443
Schippia concolor	S-367
Synechanthus fibrosus	300
Thrinax wendlandiana [*Thrinax radiata*]	661

admitted to Parramatta Mental Hospital [25]. The diagnosis was paraphrenia [26]. In one hospital report it was recorded that he asserted that "his botanical collections, his paintings & his general interest in the Arts & Sciences is [sic] world famous." Another report described him as having "foolish and grandiose delusions" and that "he loathes it here because he wants to be back in his tent looking after his botanical collection." He was to spend the next eight years in Parramatta Mental Hospital as an inpatient.

During that time, Schipp had taken up painting "enthusiastically" [27], in the primitive or naïve style. He claimed he was working on plates for two proposed books that he titled "Beautiful leaved plants" and "Autumn Tints." He entered art competitions without success, but remained mentally ill, claiming that "I am a painter. They wouldn't let me exhibit at the Art Show. They persecute me" [28]. The art critic James Gleeson wrote of his paintings as "pleasant examples in a less sophisticated mode. Schipp … has assembled a veritable encyclopaedia of Australian flowers with patience and love, but with an unpractised hand. Its charm lies in its sincerity and lack of artifice" [29].

Schipp was discharged from Parramatta Mental Hospital in 1961 [30]. He then moved to

Table 2. Palms named after William August Schipp.

Publication details	Specimens and notes
Brahea schippii Burret, Notizbl. Bot. Gart. Berlin-Dahlem 12: 304 (1935). [= ***Brahea dulcis*** (Kunth) Mart., Hist. Nat. Palm. 3: 244 (1838)].	Alternative name of *Paurotis schippii* Burret, see there.
Chamaedorea schippii Burret, Notizbl. Bot. Gart. Berlin-Dahlem 11: 1038 (1934). [see Grayum 1998]	Holotype: Belize. Jacinto Hills, alt. 400 ft, 21 Aug 1933, *W.A. Schipp S-569*; B (destroyed); isotypes: BM, F, GH, MICH, MO, NY.
Desmoncus schippii Burret, Repert. Spec. Nov. Regni Veg. 36: 202 (1934). [= ***Desmoncus chinantlensis*** Liebm. ex Mart., Hist. Nat. Palm. 3: 321 (1853)]. [see Henderson 2011]	Holotype: Belize. Toledo: Rio Grande, 29 March 1933, *W.A. Schipp S-517* (B (destroyed).
Paurotis schippii Burret, Notizbl. Bot. Gart. Berlin-Dahlem 12: 303 (1935). *Acoelorraphe schippii* (Burret) Dahlgren, Publ. Field Mus. Nat. Hist., Bot. Ser. 14: 9 (1936). [= ***Acoelorraphe wrightii*** (Griseb. & H.Wendl.) H.Wendl. ex Becc., Webbia 2: 109 (1907)]. [see Moya López 2019]	Holotype. Guatemala. Petén Department, Pojktuun (Poptún) Trail, swamp forest, 780 m, 1 Jul. 1934, *W.A. Schipp S-893*: B (destroyed).
Schippia Burret, Notizbl. Bot. Gart. Berlin-Dahlem 11: 867 (1933).	
Schippia concolor Burret, Notizbl. Bot. Gart. Berlin-Dahlem 11: 868 (1933).	Holotype: Belize: Stann Creek, 19 Mile, Stann Creek Valley, alt. ca. 200 m, 5 Jul 1932, *W.A. Schipp S-367*; B (destroyed).

Bathurst, NSW. At this time, he again began to collect botanical specimens, all of which are held in the National Herbarium of New South Wales (AVH 2022). He continued to paint and exhibited in three joint exhibitions titled "Naïve painters in Australia" held in Melbourne, Sydney and Canberra in 1965–66 (Anonymous 1965). In the last few years of his life, he was described as living "modestly in one room on a veranda and was a familiar figure shuffling around town with his large Stetson hat, long overcoat and a sugar bag full of tools and specimens over his shoulder" (Tony Convey & Peter Dixon, pers. comm.). He died on 3 October 1967 at Bathurst District Hospital [31] and was cremated at Canobolas Crematorium, Orange [32]. Despite an exhaustive search, we have been unable to locate any photos or images of William Schipp.

Palms associated with William August Schipp

With regards to Schipp's work in Belize from 1929 to 1937 (then known as British Honduras), his intention was to "produce in time a fairly comprehensive catalogue of the flora of the whole of this colony" (Schipp 1933–34, p. 1). Schipp's activities in Belize were clearly an economic enterprise, as every entry in his catalogue was given a price reflecting rarity, seasonal availability or obtainability. About 1400 species, including algae, ferns and flowering plants, were listed in the catalogue. Included were 23 palm species of which seeds were available for 15 species (Table 1). The prices per 100 seeds ranged from US$1 to $8. For "classification of my palms," Schipp (1933–34, p. 1) acknowledged the assistance of Professor Max Burret, a leading expert on the family then based at the Berlin Herbarium. Indeed, all new palm names based on Schipp's collections were introduced by Burret. These amounted to one new genus and four new species, and all were named to honor Schipp (Table 2). Unfortunately, all the holotypes for the new names were held at Berlin Herbarium and were destroyed during World War 2, although duplicates of some species were distributed by Schipp to other herbaria and those specimens represent isotypes. There were also other palm collections not listed in the catalogue, including those of *Chamaedorea schippii* [S-569], *Desmoncus schippii* [S-517] and *Paurotis schippii* [S-893] (Table 2). Confusingly,

the collection numbers were duplicated on plants not related to the palm collections. Of the names introduced by Burret, only two are in current use, the others relegated to synonymy (Table 2). Only those names in current use, *S. concolor* and *C. schippii*, will be discussed here in detail.

Schippia concolor

The genus *Schippia* was established by Burret (1933) dedicating the name to "Mr. William A. Schipp, who has made a great contribution to researching the flora of British Honduras, especially the palms, through his insightful collections." The genus has been placed within the Cryosophileae: Coryphoideae and is most closely related to *Zombia* and *Thrinax* (Baker et al. 2009). Burret described a single species, *S. concolor*, with the type citation as: "Britisch-Honduras: 19 mile Stann Creek Valley, etwa 200 m Höhe, Bergflanke, in dichtem Schatten, etwa 10 m hohe Palme, 10 cm Durchmesser. Frucht gelb. Gelegentlich, bekannt als "Silver Pimento" oder "Mountain Pimento" (mit Früchten 5. Juli 1932 - William A. Schipp Nr. S. 367)." The holotype was destroyed during World War II, but unlike many of his collections of which duplicates were distributed, none has been located and typification of *S. concolor* requires further research. The epithet *concolor* (Latin: of the same color) refers to the color of the leaf surfaces. Burret wrote, "the leaves are almost the same color on each side, but with the underside scarcely paler."

Schippia concolor is a moderate-sized, solitary fan palm to 10 m tall (Fig. 2). The lower surface of the leaf is a slightly lighter color than the upper surface. Petioles are unarmed. Inflorescences are held within the leaf bases, well branched and with bisexual and male flowers. Fruits are globose, to 25 mm diameter, and mature from green through to light creamy white (Standley & Steyermark 1958, Henderson et al. 1995, Dransfield et al. 2008) (Figs. 3–7).

Schippia concolor is unusual among palms in that it is one of only a few species in which the fruits are dehiscent. At maturity, the epicarp splits full length, curls outward and exposes the endocarp (Figs. 5 & 6). Other examples of species with fully dehiscent fruits include *Astrocaryum gynacanthum*, *A. rodriguesii*, *Syagrus hoehnei*, *S. insigne* and *S. weddellianum*.

The known distribution of *S. concolor* is in southern Belize and adjacent Guatemala, in rainforest and pine forests at low elevation. Some populations are subject to fire (Henderson et al. 1995) (Fig. 7). The conservation status was investigated by Balick and Johnson (1994) and designated as vulnerable by Johnson (1998), a status that requires to be updated considering the extent of recent land clearance in Belize. Although not widely known in cultivation, it is easy to cultivate in tropical and subtropical areas.

Chamaedorea schippii

Chamaedorea schippii was described by Burret (1934) with the type citations as: "Britisch-Honduras: Jacinto Hills, 400Fuß, im Waldesschatten. Blüten cremefarben. Früchte schwarz. Fruchtrhachis rot (mit Früchten 21. August 1933 - William A. Schipp S. 569)." Burret described it as one of the most beautiful and elegant *Chamaedorea* species, and closely related to *C. graminifolia*. Like that of *S. concolor*, the holotype at Berlin Herbarium was destroyed during World War II, but many duplicates of *C. schippii* were distributed and represent isotypes.

Although Hodel (1992) and Henderson et al. (1995) placed *C. schippii* in synonymy under *C. graminifolia*, an exhaustive assessment by Grayum (1998), indicated that the two species were readily separated and that "the name *C. schippii* applies to a distinctive species with no other valid name, and should thus be liberated from the synonymy of *C. graminifolia*." Grayum's assessment was the result of the rediscovery in the early 1990s in Costa Rica of material identified as the "true" *C. graminifolia* and the need to resolve that species identity for the Manual de Plantas de Costa Rica (Grayum 2003). Grayum's (1998) descriptions compared the morphology of the two and concluded that *C. schippii* differed significantly from *C. graminifolia* in many characters, including "its unusual, open-caespitose growth habit, with long-spreading rhizomes, pinnately compound leaf-blades with rather numerous, narrow, plicate leaflets, and limestone habitat." Hodel (2013) concurred with Grayum's proposal and noted that all illustrations and most of the description and discussion in Hodel (1992) were indeed of *C. schippii* and not of *C. graminifolia* as captioned and noted. Hodel (2013) provided additional character differences.

7 (*facing*). *Schippia concolor*. Population in pine forest with the aftermath of fire, in lowland savanna at Belize Zoo's Tropical Education Center. Photo by E.P. Mallory. Source: Creative commons, https://www.flickr.com/photos/epmallory3/8035651836.

8. *Chamaedorea schippii* in habitat. South of Augustine, Cayo, Belize, on limestone, 600 m elevation (*Hodel 1132*). Photo by D.R. Hodel.

Chamaedorea schippii is a small palm with an open habit, forming colonies by rhizomatous growth, with stems to 4 m tall, 25 mm diameter. The stems have persistent leaf-sheaths and when shed expose a dense glaucous covering. The long leaves bear numerous narrow linear grayish or dull green pinnae. The inflorescences emerge through the

9. *Chamaedorea schippii*. Leaf detail. Cultivated, Montgomery Botanical Center, Miami, Florida. Accession no. 20040370, ex Belize, 16°48′24.1283 N, 088°4757.3763W (*Hodel 11288B*). Photo by L.R. Noblick.

persistent leaf bases. The flowers are bright yellow and aromatic. The fruits are globose, 6–10 mm diameter and black at maturity (Standley & Steyermark 1958, Hodel 1992, as *C. graminifolia*, Grayum 1998, Brewer 1999, *as C. graminifolia*) (Figs. 8–10). The known distribution is in Belize and Guatemala, where it is most often associated with the summits and slopes of limestone hills up to 700 m elevation in seasonally moist forests (Hodel 2013). It may also occur in the Tehuantepec region of southern Mexico, an area of similar habitat to that of Belize and adjacent Guatemala, as collections from there of a cultivated plant in Los Angeles identified as *C. schippii* noted that locality on the field collection label (*Bailey 9125*, BH) (D.R. Hodel, pers. comm.). Limestone habitats are the harshest environments where species of *Chamaedorea* occur, being rainless for 4–6 months of the year and accompanied by high temperatures and soils with high evaporation rates (Hodel 1999). The species has a proposed conservation status of vulnerable in Belize because of its restricted range, small population numbers and threats posed by agricultural expansion (Bridgewater et al. 2007). It is very rarely cultivated.

Conclusion

The contribution of William Schipp to the study of the flora of Belize is without comparison, as he was able to collect throughout the country as a resident for eight years from 1929 to 1937. However, his time there came to a seemingly abrupt end when his mental condition deteriorated, and he was repatriated to Australia in a destitute and unhealthy state in 1938. His mental health appears never to have improved and he remained unsettled and "delusional" for the remainder of his life. Schipp's work on palms is of particular interest as he made significant collections, some of which were described as new to science by Max Burret, one of the world's leading students of palms at that time. Reflecting on the genus *Schippia* and those species with the epithet *schippii*, we have presented here the unusual backstory of the man who is commemorated in those names.

Acknowledgments

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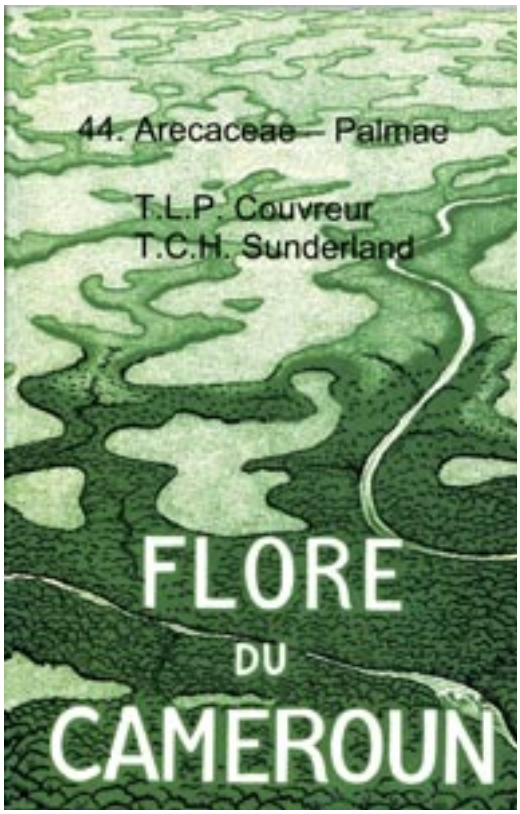
PALM LITERATURE

FLORE DU CAMEROUN 44: ARECACEAE – PALMAE – T.L.P. Couvreur and T.C.H. Sunderland. Ministère de la Recherche Scientifique et de l'Inovation (MINRESI), Yaoundé, Cameroun. 2022. Paperback. ISBN 0071-5875. Pp 138, line drawings and color photgraphs. Price £35. (available from mikeparkbooks.com)



The long-running series, *Flore du Cameroun*, is published by the Ministry of Scientific Research and Innovation in Yaoundé, Cameroon. Volume 44 has just appeared and is devoted to palms, authored by Thomas Couvreur and Terry Sunderland, both specialists in African palms. The resulting publication is a handsomely produced paperback encased in the standard *Flore du Cameroun* cover. The account covers 13 genera (including the introduced *Cocos* and *Nypa*) and a total of 37 species; for an African country this is great diversity. There are keys to species and each species receives a full nomenclatural citation with typification, technical description and notes on distribution, habitat, local names, uses, Cameroonian specimens examined and general discussion where appropriate. The illustrations consist of line drawings, many reproduced with permission from elsewhere, and color photographs. Presumably because of constraints over cost and size, the color illustrations are often reproduced at very small size; useful though these are, they are nevertheless rather tantalizing, particularly in the composite plate of *Raphia*.

This is an altogether valuable and very welcome addition to the *Flore du Cameroun* and marks substantial progress in our understanding of the palms of Africa. Congratulations to the authors.

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Palm Diversity and Ethnobotany in Senegal, West Africa

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This paper describes the diversity of palms in Senegal, West Africa and discusses their uses

Senegal is a tropical African country located in the extreme west part of the continent, between latitudes 12°20′ and 16°40′ in the north and longitudes 11°20′ and 17°30′ in the west. The country covers an area of 196,700 km^2 and is neighbored by Mauritania and Mali in the north and east, Guinea-Conakry and Guinea-Bissau in the south, and Gambia is located in the center. The central-north areas of the country are much drier, as they are influenced by the Sahel, a transitional biogeographic zone in Africa between the Sahara to the north and the Sudanian savannas to the south. The southern regions of the country, where the large area known as the Casamance is present, displays much more humid conditions as it is influenced by the Guinean climate, the latter allowing the presence of the few remains of wet forests still present in the country.

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As observed in other West African countries, the climate of Senegal is characterized by two main seasons (Sultan & Janicot 2004), a dry season starting in November and ending in June, characterized by major trade winds from the sea and the continent, and a rainy season, also called the monsoon season, starting in the middle of June and ending in October. If you plan to visit the country, take note that the peak of rain occurs around August and September (Bodian et al. 2011) and roads, especially in the countryside, might be impassable. The impressive high temperatures in the northern areas of the country, reaching up to 44°C (111°F), are caused by the *harmattan*, a dry and dusty wind blowing from the Sahara, and playing a major role in the distribution of biodiversity (Bodian et al. 2011).

Palm diversity in West Africa and in Senegal

The West African palm flora includes 13 genera and 39 species (Stauffer et al. 2014, 2017). The species grow in different types of environments, ranging from the dense and wet Guinean forests to the arid regions of the Sahelian belt. Nigeria, a country still little known from the point of view of its palm

1. Field mission undertaken in Senegal by researchers of the University of Dakar, the Botanical Garden of Geneva and the Montgomery Botanical Center. The "*rônier* palm" (*Borassus akeassii*) is one of the most popular and useful species in the country. Photo by Patrick Grifffith, MBC.

diversity in the region, hosts the largest number of species (32 spp.), followed by Ghana (18 spp.), Côte d'Ivoire (16 spp.), Benin and Liberia (with 15 spp. each) (Stauffer et al. 2021). According to our records, the best represented species are the widely naturalized coconut (*Cocos nucifera*, 16 countries), *Calamus deerratus* G. Mann & H. Wendl. (12 countries) and *Hyphaene thebaica* (L.) Mart. (12 countries). Regarding endemism, *Eremospatha dransfieldii* Sunderl. and *Oncocalamus wrightianus* Hutch. are the only species considered strictly unique to West Africa. Several field missions in Senegal carried out by the Conservatory and Botanical Garden of Geneva (CJBG), the team of the herbarium of the University of Dakar and the Montgomery Botanical Center (MBC) between 2018 and 2021, highlighted the presence of 8 genera and 12 palm species, two of them being cultivated and the coconut palm regarded as naturalized (Table 1). These palms are arranged in 3 subfamilies, 5 tribes, and 7 subtribes. This flora has a close taxonomic affinity with the floras of neighboring countries, such as Guinea (11 spp.) in the South, Mali (5 spp.) in the east and Mauritania (4 spp.) to Northeast. As for the palm flora of Gambia, a small country that is completely surrounded by Senegal, despite the rather incomplete knowledge we have on its palm flora, the current inventory documents about 7 species.

Although it is true that the palm diversity in Senegal is lower than other countries of tropical continental Africa, the reported uses given by local ethnic groups is strikingly diverse and worth preserving for future generations. Our research highlights this diversity of uses, but also raises concerns about the sustainability and transmission of this ancestral knowledge to the new generations of Senegalese.

Historical account of palm studies in Senegal

We can attribute to the celebrated French naturalist Michel Adanson (1727–1806) the first records on the palms of Senegal and their uses by local ethnic groups. Adanson explored the country between 1748 and 1754 and briefly described "palm trees," most likely referring to two of the most widely spread species, the so-called rônier (*Borassus akeassii*) and the African oil palm (*Elaeis guineensis*). In the beautiful map included in his famous publication on the natural history of Senegal (Adanson 1757), he presents the different regions where palm wine could be tapped. Interestingly, this remains nowadays as one of the more important economic activities associated with native palms in Senegal, often associated with major concerns for the conservation of palm populations.

2. Removing the sweet and fragrant mesocarps from the seeds of *Borassus akeassii* in the locality of Fandène, western Senegal. Photo by Matteo Auger-Micou.

Table 1. Native palm species in Senegal and their distribution.

Species	Distribution
Calamus deerratus G. Mann & H. Wendl.	Recorded in southern Senegal, particularly in the region of Casamance. The species was observed in the district of Oussouye, in open, sunny-exposed areas and forming dense thickets.
Laccosperma secundiflorum (P. Beauv.) Kuntze	Only small populations observed and collected in the Casamance region, growing in swampy areas along the banks of the Casamance river. Populations of this species seem extremely rare in the country. One remarkable population was spotted inside a "Sacred Forest" nearby the village of Oussouye, on the road from Ziginchor to the coastal locality of Cap Skirring.
Raphia aff. *farinifera* (Gaertn.) Hyl.	Populations of this species were only observed along the banks of the Casamance River, on the road Ziguinchor- Kolda, near the village of Birkama. The palm grows sympatrically with *C. deerratus* and *L. secundiflorum*.
Raphia palma-pinus (Gaertn.) Hutch.	Reported by Govaerts et al. (2022) as present in the country but not observed by us. Though, its presence in the wet forest of the Low Casamance National Park is highly probable, and villagers of the surrounding areas of the park suggested its presence inside the dense forest.
Raphia sudanica A. Chev.	We reported some populations of this palm in southern and south-western Senegal, the main populations were located along the road Kedougou- Dindefelo.
Phoenix reclinata Jacq.	This is a widely distributed palm in Senegal. It was observed in the coastal region of the Niayes, in the center-east of the country (Bassin Arachidier), as well as in the coastal savannas of the Casamance region.
Phoenix dactylifera L.	Occasionally cultivated for ornamental purposes or for its edible fruits.
Hyphaene thebaica (L.) Mart.	Several populations observed along the banks of the Senegal river, from Saint-Louis to Matam. Other populations spotted in the region of Fatick, Kaolack, and Tambacounda. The current distribution of this palm might be shaped by its highly important economic value (fruits, leaves). The palm is also appreciated as an ornamental plant and sometimes observed as cultivated.
Borassus akeassii Bayton, Ouédr. & Guinko	Observed through the entire territory, from the northern part, along the banks of the Senegal river (in the alluvial soils towards Matam), to the National Park of Niokolo-Koba. Also observed in the Casamance region. A dense population of semi-domesticated palms was observed in the region of Thiès (from Fandène to Tivaouane, Lalane, Ndiobène, Ndiassane). The current distribution of this palm might be shaped by its highly important economic value (trunks, leaves, fruits, wine tapping).

Borassus aethiopum Mart.	Observed as cultivated in several regions of the country but probably brought from Mali. In particular appreciated for its edible fruits.
Cocos nucifera L.	Widely naturalized throughout the coastal savannas of Senegal due to its edible fruits and raw material extensively used for construction and handicraft (trunks, leaves).
Elaeis guineensis Jacq.	Widely spread in the central and southern regions of the country, intensively exploited for edible fruits and cosmetic seed oils. Also largely appreciated for wine tapping and handicraft manufacture.

French colonial interests in potentially useful native palm species were relatively important in increasing our knowledge of the diversity of the family in Senegal. In particular the botanist Auguste Chevalier (1873–1956), affiliated to the colonial agronomy laboratory of the Natural History Museum of Paris, concentrated his efforts on the economic use of palms (Chevalier 1900) and gathered an important palm herbarium now stored in the

3. Floating ripe fruits of *Elaeis guineensis* ready for the preparation of the red oil palm sauce, a highly appreciated component in the West African cuisine. Photo by Matteo Auger-Micou.

4. The edible fruits of *Hyphaene thebaica* are commercialized in the market of Fatick, western Senegal. Photo by Matteo Auger-Micou.

Paris herbarium (P). His historical collections remain the only testimony of palm populations in Senegal that once occupied natural savannas that are nowadays severely destroyed by peanut plantations in central-north or rice plantations in the south. Additional contributions to our knowledge of the palm flora were added by Father Jean Berhaut (1902–1977) who carried out an in-depth study of the flora of Senegal, a census of more than 2000 species of angiosperms (Berhaut 1967).

The aim of this paper is to present a detailed account on the amazing diversity of uses of the native palms of Senegal. In particular we describe their consumption (drinks and food), construction, crafts (mats, furniture, baskets, sieves, baskets, brooms, ropes, etc.), medicinal uses, oils and cosmetics, decoration, as well as spiritual and ceremonial uses. Additional comments on the conservation of the species are also included.

Material and methods

Field missions: Two main field trips were carried out in the framework of our study (Fig. 1). The first field mission was undertaken between February and April 2019, covering the regions of Casamance, Dakar, Diourbel, Fatick, Kaolack, Kedougou, Sine Saloum and Tambacounda. To our deep regret we could not access the Low Casamance National Park, supposed to be the richest spot in the area for palm diversity, as local authorities strongly warned us about separatist rebel groups still active in the area. The second field mission was carried out by the end of the same year (November to December 2019) and focused on the region of Thiès and a region of "Niayes," an ecologically interesting dune-like zone mid-way between Dakar and Saint-Louis. Additional field missions to the country where undertaken by FS and DR in 2018 and 2021.Throughout these missions we collected herbarium and ethnobotanical samples, and recorded morphological, ecological and conservation data.

Study of herbarium specimens: In order to compare our samples with historical herbarium and ethnobotanical specimens we visited the herbarium and the collection of Economic Botany of the Royal Botanic

5. Palm wine tapping in the oil palm (*Elaeis guineensis*) is a dangerous activity exclusively undertaken by men. The oldest leaves have been removed in order to get easy access to the top of the palm. Photo by Didier Roguet.

Gardens of Kew (K) (London, England), the herbarium of the Botanical Garden of Geneva (G), the herbarium of the Natural History Museum of Paris (P), and the herbarium at the University Cheikh Anta Diop (DAKAR).

Ethnobotanical survey: The ethnobotanical approach consisted of a qualitative inventory of palm uses and common names in the villages where our research was conducted. The method was mainly driven by surveys based on semi-structured interviews. We elaborated an inquiry form (available upon request to the authors) that contained both general information and specific questions adapted to the farmer, manufacturer, seller, buyer, and user of handicrafts. We also carried out an ethnobotanical sampling of handcrafts made with palm organs traded in major street markets (Thiès, Ziguinchor, Yatang-Batang, the latter known to be a prominent trade market in the border between Senegal and Guinea-Bissau). Each object was referenced with the name of the craftsman or woman, date of purchase, the palm species, local names, the price and the ethnic group. These objects are now recorded in an ethnobotanical database and permanently stored in the ethnobotanical collection of the Conservatoire (G).

Results

Diversity of palm uses in Senegal: Here we present a qualitative inventory of the palm uses recorded in Senegal. It is organized in eight parts, accordingly with the main categories of uses identified in our field surveys:

a) Food and beverage (fruits and seeds, stem tapping, palm hearts);

b) Construction

c) Handicraft (stem, petiole, rachis and leaflets, entire leaf blade);

d) Medicinal uses;

e) Oil and cosmetics;

f) Art and decoration;

g) Spiritual and ceremonial uses (fertility, symbol of protection);

h) Forage and fuel.

We also include two miscellaneous notes addressing aspects that we believe could be interesting for the palm community. The first note deals with the imported palm-made objects coming from neighboring countries, and a second note describes the selection of several morphological traits on *Borassus akeassii* by local people in the area of Thiès (western Senegal), considered by us as a case of early efforts of palm domestication.

Food and beverage

Palm organs are largely used for food and beverage consumption in Senegal. Here we provide details on the most important observations gathered in our missions.

Fruits and seeds: The fruits (mesocarps and endosperms) of *Borassus akeassii* are edible and whole infructescences are frequently sold along main roads for the cost of approximatively 500–1000 F CFA (1.5 USD). In particular in the region of Thiès the Serer Non ethnic group appreciate the orange and fragrant mesocarps as they are supposed to have positive effects on the digestion (Fig. 2). More to the east, in surrounding areas of the Niokolo-Koba National Park (i.e., Wassadougou), we observed that the fruits (*koni* in Wolof) were collected and transformed in a paste often mixed with sugar and milk, and this is supposed to produce laxative effects. The water and the jelly and sweet endosperm are consumed before ripening and exported from several villages surrounding the city of Thiès to other regions of the country. The liquid endosperm of this palm is consumed against nervous weakness, cold, stomachache and as an intestinal vermifuge.

Palm oil extraction from Elaeis guineensis: The fruits extracted from the large infructescences of *E. guineensis* are transformed into red palm oil and kernel oil in the southern region of Casamance and in the Niayes (central Senegal). Our observations in the field showed that the extraction processes observed were relatively similar in both areas.

Red palm oil extraction: The harvest season of the fruits is relatively short (maximum of 1 week, usually between January and March), and they are commercialized in plastic rice bags of several prices, depending on the size of the bag. The highly appreciated red oil, often called "sauce rouge," is generally produced by women for the preparation of the traditional "fitafou" or "foufou" sauces, usually accompanying stews of beef or fish. The ripe fruits with a reddish mesocarp are manually extracted from the infructescence and boiled at a high temperature until they float on the surface of the sauce (Fig. 3). At this stage, the mesocarp can be easily removed from the seeds. The sauce will be then pressed at high temperature, filtered, bottled and commercialized on street markets. It is particularly appreciated in the Casamance but can equally be served in private houses and restaurants in other regions of Senegal.

6. *Volvariella volvacea* is a small mushroom highly appreciated in traditional West African cuisine. The decomposing stems of the fallen oil palm from which wine has been tapped represents an optimal substrate for its development. Photo by Fred Stauffer.

Kernel oil extraction: The kernel oil "*huile de palmiste*" is extracted from the solid endosperm and this activity is only undertaken by farmers who own mechanical presses; these are particularly expensive and therefore only used by wealthy members of the village. The final oil is colourless and clear and is mostly used for cosmetics (usually for hair and skin care); however, it can be also added to traditional dishes in small quantities.

Other uses and consumption reported for palm fruits: In the region of Tambacounda the endocarps of the fruits of the doum palm (*Hyphaene thebaica*) are soaked and boiled in water and given to babies for their digestive properties (Fig. 4). The dry and empty endocarps of *Borassus akeassii* are used to craft spoons for palm wine consumption; this traditional use seems to originate from the Diola ethnic group and transferred to the central region of the Niayes a few decades ago. These spoons are frequently decorated with colors as well as a carved wooden handle. The fruits (mesocarp) of *Phoenix reclinata* are consumed by the local inhabitants of the Casamance (Diola ethnic group) but

7 (top). Traditional roofing constructed by the Serer ethnic group using leaves and planks made of stems of *Borassus akeassii* (City of Thiès, western Senegal). Photo by Matteo Auger-Micou. 8 (bottom). House fence made with the large entire leaf blades of *Borassus akeassii* in the village of Diatock (Casamance). Photo by Fred Stauffer.

9 (top). Furniture made of petioles of *Borassus akeassii* and commercialized along the road Ziguinchor-Kolda (Casamance). Photo by Didier Roguet. 10 (bottom). Street seller of palm basketry made of leaves of *Borassus akeassii* (street market of the City of Thiès, western Senegal). Photo by Didier Roguet.

unfortunately this tradition is disappearing. The fruits of this palm were reported as not particularly tasty, and this was advanced as the main argument for the loss of popularity of its consumption.

Stem tapping and palm hearts: Palm wine tapping represents an important cultural and economic tradition for Senegal local populations; here, we describe our observations on the different methods of extraction associated to the two species intensively exploited in the country:

Palm wine tapping from Elaeis guineensis *(palmier à huile)*: The extraction of the wine of

E. guineensis is very popular in Casamance and in the Niayes (Fig. 5). The technique has been part of a long tradition for the Diola ethnic group and therefore considered as an important way to produce extra income at the family level. This method is considered as non-destructive and the wine can be tapped the whole year. The harvester climbs the palm with a special belt (*kadamp*) made with rachis fibers of *Elaeis guineensis*. As the life of the climber relies completely on this tool, the belt needs to be regularly humidified and replaced every month in order to preserve strength and flexibility. The palm wine harvester taps the base of the peduncle of the infructescence and fixes a bottle with a freshly braided funnel made of leaflets while waiting for the sap to flow. The harvest is undertaken two times per day, the first one from 2 to 6 a.m. and the second one from 6 to 9 p.m. The harvesters can extract between 5 and 25 liters of wine per day, depending on the season and the number of palms tapped, each liter being sold from 500 to 1000 FCFA in Dakar (0.5–1 USD/l).

The sap can be drunk right away, or it is fermented for two days in large plastic barrels to obtain the final product. Its transport to other villages representing major centers of consumption (i.e., Thiès, Dakar) needs to be done quickly as its quality decreases with time. The palm wine can also be distilled in order to obtain a spirit with a high degree of alcohol. The palm wine harvester generally works in open air workshops where several objects representing mystical protectors and fetishes were observed. It is interesting to highlight the close relation between the palm wine activity and the Diola animist traditions, although Christianity was established by the Portuguese missionaries in Casamance. Although harvesters believe that palm wine extraction is significant from an economic perspective, they do not rely completely on this activity and combine it with farming.

Palm wine tapping from Borassus akeassii *(rônier)*: The extraction of wine from this palm (koop) is a process carried out exclusively by men, who produce a sharp cut on the apical-most region of the stem during a long period of time (the harvest lasts for generally 2 or 3 months but can continue up to 6 or 7 months). Palm wine tapping from this palm is deeply rooted in the tradition of the Serer Non ethnic group from the region of Thiès, and the knowledge associated is transferred from one generation to the next one.

The selection of the palm to be tapped is a well-kept secret, probably associated with animist beliefs. We learned that the harvesters

11. The mesocarp extracted from the seeds of *Raphia sudanica* are locally used due to its different medicinal properties (village of Dindefelo, southeastern Senegal). Photo by Matteo Auger-Micou.

12. The King of Essaout, a traditional authority highly respected by local ethnic groups, sits in front of his palace. Note the massive fence made of entire leaf blades of *Borassus akeassii* (Essaout, region of Casamance). Photo by Didier Roguet.

tend to choose the male palms because they do not produce fruits, and this arguably would let the palm produce more sap. The harvester climbs the palm, not necessarily with a special belt, as described for the sap extraction in *Elaeis guineensis*, but simply using naked feet and hands. The leaves and leaf sheaths are removed, and the apical meristem is perforated. The apical incision on the palm is then stimulated every day with an abrasive powder (*pou* in Serer Non and *genge dek* in Wolof), which is apparently extracted from a root, whose name was kept secret, of a plant in the region of Casamance. The sap is afterwards collected in a bottle, later stored in large plastic containers, and stored in open glass bottles to avoid high pressure and explosion due to the active fermentation of the sap. Due to rapid fermentation the koop does not keep well and needs to be sold relatively quickly. The harvester collects the wine generally three times a day on six to seven palm trees simultaneously during the dry season. The final product is consumed in a calabash by local inhabitants. The economic benefits are shared between the harvester and the landowner, if he is not the owner of the palm. The koop is sold between 450 and 500 FCFA/l (0.7–1 USD) and it represents an economically significant business according to the harvester interviewed.

The edible and tender palm hearts of *Elaeis guineensis*, also known as *chou palmiste*, are appreciated in the region of Casamance, particularly in the village of Diatock in the department of Bignona. The dead fallen trunks of this palm were reported to be used as a substrate to grow the edible mushroom (*Volvariella volvacea*, Agaricales, Pluteaceae), which is part of different traditional sauces (Fig. 6).

Construction

The entire leaf blades of the *rônier* palm (*Borassus akeassii*) are assembled in circles on girders to build traditional roofing in the villages close to Thiès (Fig. 7) and house fences in several villages in western Senegal (Fig. 8). Although these structures are supposed to be waterproof, they are regularly replaced by the villager. The use of these leaves is now becoming rare as our observations showed that they are now replaced by modern metal structures in the region of Thiès and the next villages near to Niokolo Koba national park. Several types and shapes of fences made of entire leaf blades, as well as petioles and stems of *Borassus akeassii*, and much less of *Elaeis guineensis*, were reported in the Casamance region, the city of Thiès, and in southeastern Senegal.

The trunks of *Borassus akeassii* and *Elaeis guineensis* are split, cut, and transformed into boards or beams in several region in Senegal (Thiès, Casamance and southeastern Senegal). The inhabitants argue that the wood of these palms is very resistant, of high quality, termite-proof and resist well to the damage caused by molds. Concerning the quality, there are no apparent differences between the trunks of the two species and regarding the case of male and

13 (left). Traditional costume made with leaflets of *Borassus akeassii* for the kumpo dance, a ritual ceremony practiced by the Diola ethnic group in Casamance. Photo by Anton Ivanov. 14 (right). These colored hats, typical of the Fulani craftsmanship in Mali, are manufactured with leaflets of the doum palm (*Hyphaene thebaica*) and they are imported to Senegal (market of Yatang-Batang border between southern Senegal and Guinea Bissau). Photo by Didier Roguet.

female individuals (*Borassus*) no major differences were highlighted. In the Mlomp museum of the Diola tradition (Oussouye, Casamance) we observed an impressive beehive made of a stem of *Elaeis guineensis*. Nowadays, these traditional beehives have been replaced by plastic material.

Handicrafts

A high diversity of handicrafts was reported from literally every organ of the palms studied. The handicrafters choose the palm species and the organ based on the type and the size of the object to be produced. Here we provide information on the different organs used and the main objects manufactured. Some of them are only produced for private use (i.e., furniture, kitchen tools), whereas others will be crafted exclusively for the tourist market.

The stem: In the Casamance region we observed that the canes of the rattan palm *Calamus deerratus* are used to manufacture tables, stools, chairs and frames for beds. Craft work is generally carried out during the hunger season, as an extra income source for the family. Unfortunately, this activity tends to disappear due to the reduction of the palm populations attributed to overharvesting and destruction of natural habitats. During our visit to the headquarters of the Department of Water and Forests of the city of Kedougou we could appreciate an important quantity of rattan furniture seized by the authorities as it was illegally imported from Guinea-Bissau and Guinea-Conakry and supposed to be commercialized in the Senegal markets.

The petiole: Petioles of several palm species are commercially exploited in Senegal. The use of the petiole of *Borassus akeassii* is widespread in the country and this is especially the case in several villages (i.e. Fandène, Ndiobène and Lalane) surrounding the city of Thiès. The entire petioles are used to construct bed frames, tables, chairs, loungers, stools, brooms and other types of furniture, particularly appreciated for its strength and shiny

15. Population of *Borassus akeassii* in the region of Fandène. These plants have been selected according to criteria that may correspond to an early process of domestication. They are managed in a relatively sustainable way (village of Fandène, western Senegal). Photo by Fred Stauffer.

appearance (Fig. 9). The objects are often varnished to make them waterproof and more resistant to insect attack. The activity seems to be extremely lucrative as most manufacturers interviewed received permanent requests for furniture, especially for the markets in the cities of Thiès and Dakar. The crafts made from leaves of *Borassus akeassii* (i.e. baskets, hats and mats) are often displayed in the outskirts of the city of Thiès, in particular on the road in the direction of Tivaouane and Saint-Louis (*route des artisans*, "road of manufacturers"). Interestingly, the majority of the manufacturers belong to the Wolof ethnic group; however, they purchase the leaves from members of the Serer Non ethnic group, who are traditional owners of the lands and the palms that grow there.

We identified a large diversity of craftwork made with petioles and the main veins of the pinnae of *Raphia sudanica* in south-eastern Senegal, in particular in the village of Habibou near Dindefélo, close to the border of the Guinea-Bissau, where almost all the inhabitants of the village rely strongly on this activity. The petioles of this palm are much appreciated as they are very strong and light at the same time. As the activity seems to be economically significant, knowledge of craft techniques remains alive and it is transferred to new generations.

The rachis and leaflet veins: The main veins, after being removed from the leaves, are also widely used for handicrafts as they display qualities such as strength and flexibility. The main veins of *Borassus akeassii* are used in the region of Thiès, near to the National Park of Niokolo-Koba (Wassadougou) and in the Casamance region, to produce baskets, brooms, chairs, stools, lamps and several other decorative objects (Fig. 10). A large quantity of small baskets is manufactured in Fandène and is offered between the families to celebrate the end of the Ramadan. The leaf segments of *Borassus akeassii* are also used to pack bunches of leaves of *sekhew* or *kenkeliba* (in Wolof) (*Combretum micranthum*), the latter being highly appreciated as a substitute of coffee and for its effects on hypertension. The main veins removed from the leaflets of Elaeis guineensis are woven to produce hand brushes and are generally sold in the street markets of the cities of Saint-Louis, Fatick, Tambacounda and Ziguinchor.

Entire leaf blades: The young leaves of *Borassus akeassii*, just before the segmentation of the leaflets, are used to manufacture traditional

water containers. These are still used in the Casamance region in order to extract water from sinks and they represent a heritage of the Diola tradition. The leaf segments of this palm are also used to manufacture firelighters, especially in Casamance. Between five and six workshops present in the city of Thies produce large quantities of big baskets that are made with the entire leaf segments of *B. akeassii*. These baskets are widely used by local inhabitants to transport fish, fruits, vegetables and other products that are commercialized as far as the northern city of Saint-Louis.

Medicinal uses

The yellowish mesocarp of *Raphia sudanica* fruits is used to treat venous insufficiency, bilharziasis and hemorrhoids in the village of Habibou, region of Kedougou, southeastern part of Senegal (Fig. 11). The mesocarp is dried, cooked, and sometimes mixed with sugar and milk powder to sweeten its bitter taste. A powder extracted from the mesocarp of the doum palm (*Hyphaene thebaica*) is used to produce compact sticks in the city of Tambacounda, the latter burnt to keep mosquitoes away. A powder produced from the stem of *Elaeis guineensis* has the properties to relieve toothache and is used as a gargle in Diatock (region of Casamance).

Borassus akeassii is believed to display properties against infertility, and this medicinal use was mentioned in t several interviews in different regions of Senegal (i.e., Sédhiou, Bignona and Thiès). The latter may most probably be associated with the morphology of the male inflorescences and the fruits, somehow relating to the human reproductive organs. From the same palm, drinking the palm wine (*koop*) may have beneficial effects against weakness, digestion troubles and constipation.

Oils and cosmetics

Only a few applications from palm organs for cosmetics and oils were reported during our field missions. The oil extracted from the endosperm of *Elaeis guineensis* (“*huile de palmiste*”) is used for the elaboration of cosmetic products associated with body care. Indeed, an artisanal production of palm soap from this palm was observed in local markets in the department of Ziguinchor (southern Senegal).

Art and decoration

The seeds of *Raphia sudanica* are pierced and used as beads in the traditional culture of the Bedik region (southeastern Senegal); however, according to our local informant in the village of Habibou this traditional use tends to disappear due to cultural erosion. We observed that the shiny and solid epicarps of *Hyphaene thebaica* are a main component for the manufacture of castanets, the latter being traditionally used for rhythmic Wolof music. Decorative buttons are manufactured with the same material. This palm has also been observed planted as a decorative ornamental tree in villages of central Senegal, from Sine Saloum to Tambacounda.

Spiritual and ceremonial uses

Fertility: The palms symbolize male and female fecundity in ceremonies associated with traditional life in Senegal. We found several fetish objects made with the stems and seeds of *Borassus akeassii* in the Sine Saloum region, in the surroundings of the “sacred baobab” in the village of Palmarin. The seeds of an unknown species of *Raphia* are used during the ceremony of circumcision of the Diola ethnic group, regarded as a rare ceremony given that it only takes place every 30 years. The seeds are attached to a belt around the waist and petioles are also used during the ceremony. The materials are harvested by the traditional practitioners in the “Sacred Forest,” whose access is completely forbidden for all those non-initiated in the traditional rituals.

Symbol of protection: The palms are also an icon of protection, especially against curses. Fetish objects of the Diola ethnic group made with leaflets of *Borassus akeassii* were reported in Oussouye and would have the power to protect the inhabitants of the village. The scepter held by the king of Essaout is made by the wise men of several villages with the veins of *E. guineensis* (Fig. 12) and it is said to have the power to protect the villagers from the bride of the evil spirits. In the region of Casamance, the costume of the traditional ceremony called *kumpo* is made with leaflets of *B. akeassii* (Fig. 13). The spiritual “genie” is fully covered with the leaflets and symbolizes the power of nature and the protection against crop shortages. The genie turns around and the people dance close to him.

Forage and fuel

We observed that the waste of mature fruits of *Borassus akeassii* were frequently used to feed animals (poultry, cows and goats) in the rural community of Fandène (central Senegal) and in the village of Diatock (southern Senegal).

The remaining parts of the leaves of *Borassus akeassii* and *Elaeis guineensis* that were not used for handicraft manufacture were often used to feed animals. The young and tender leaves of *Hyphaene thebaica* are appreciated by goats, donkeys and cattle in central Senegal (Fatick Tambacounda, Kaffrine, Niahène, Kougheul, Koussanar), as well as in the region of Matam in eastern Senegal. In the same way, palm organs such as stems and petioles from *Borassus akeassii*, *Elaeis guineensis* and *Raphia sudanica*, are widely used in the country for domestic fires. We recorded that palm waste from the handicraft manufacture was often used as fuel material.

Miscellaneous notes

Palm handicrafts imported from neighboring countries: We observed several handicrafts imported from other West African countries such as Mali, Burkina Faso and Guinea. Among these objects we could cite sponges made from the fruit fibers of the doum palm (*Hyphaene thebaica*), imported from Burkina and the beautifully decorated pointed hats made with leaf segments of the same palm. These hats are typical of Fulani craftsmanship and are manufactured in Mali (Fig. 14). According to our informants they are imported in large quantities by pilgrims during the Mawlid (traditional celebration commemorating the birth of Muhammad) before they reach the city of Touba, holy city of Mouridism. We purchased a sieve made from petiole ribbons of *Borassus akeassii* imported from Guinea at the market of Yatang-Batang (region of Casamance). This was covered with a reddish resin from the tree *Khaya senegalensis* in order to make it waterproof.

On the early domestication efforts observed on Borassus akeassii *in the area of Thiès*: A dense population of *Borassus akeassii* is present in the city of Thiès and surrounding villages (i.e., Fandène, Lalane, Ndiobène and Ndiassane), and this may explain the high diversity of crafts reported in these villages, by far much higher than observed in other parts of Senegal (Fig. 15). The city represents an important crossroads of products heading to the capital and most of the products are manufactured there. Moreover, fruits are highly appreciated

16. Donkeys and goats represent a major threat for the rare *Hyphaene thebaica* in northeastern Senegal. The fruits and the tender seedlings are intensively consumed by these animals, which freely roam in the region of Matam. Photo by Didier Roguet.

for their sweet mesocarp or the yellowish endosperm.

Given the relatively high and diverse use that palm populations present in the area, and based on preliminary information of villagers, we investigated the potential signs of early domestication of the palm for fruit consumption or leaf exploitation. During our survey we recorded that the palms were planted by older generations of the village. The traditional owners of the lands in the area belong to the Serer Non ethnic group, and they used to keep the seeds after consumption of the mesocarps and plant them in what we could describe as a sort of "nursery area" in the fields. After a period of germination lasting from 6 months to 2 years, the seedlings will emerge, and farmers will plant them in rows in their own parcels of land.

Our observations showed that only specific seeds were planted in the village of Fandène. The selection of the fruits and the seeds was based on at least three different criteria associated to the mother palm: 1) the general aspect of the palm, 2) the length and the shape of the leaves, and 3) the size of the fruits. Farmers argued that keeping the seeds fulfilling these criteria will guarantee more robust and productive palms for the next generation. Not all the farmers clearly explained in such an explicit way these criteria, but they pointed out that selecting the "better-shaped" individuals would be important. The type of plantation of *Borassus akeassii* observed in the rural community of Fandène is not practiced elsewhere in Senegal, and it is almost unique in tropical Africa.

Discussion

High diversity of palm uses observed in Senegal: Most of the palm uses recorded in Senegal have already been reported in other countries of West Africa (Stauffer et al. 2021), and this may be explained by the shared palm flora and the fact that local populations frequently migrate from one country to another, taking with them palms that are regarded as economically or culturally important. From all regions of Senegal visited it is in the region of Thiès (villages of Fandène, Ndiobène, Lalane, Ndiassane) that we observed the most remarkable examples of palm uses, in particular for the manufacture of handicrafts made from *Borassus akeassii*. According to our interviews, handicrafts made of this palm originated during the early 1960s, and this was confirmed by Giffard (1967).

Palm wine tapping represents an important economic and cultural activity in Senegal, often contributing to extra income for families in rural areas and playing a major role in culltural ceremonies. Although the sap is extracted from two palms (*Borassus akeassii*, *Elaeis guineensis*), the latter seems to be preferred and this corresponds to our surveys in countries such as Côte d'Ivoire and Ghana.

17. "Sacred Forests," as the one developing behind the oil palm trees in front line of the picture, are becoming major refuges of biodiversity in tropical Africa. Many rattan palm species requiring dense understory conditions (i.e. *Eremospatha*, *Laccosperma*) or *Raphia* palms, are present in these areas. Photo by Elif Tekkoyun.

It would be interesting to further explore the reasons behind this statement, probably carrying out thorough chemical and nutritional analyses.

The use of rattan palms (*Calamus deerratus*, *Laccosperma secundiflorum*) to manufacture furniture and handicrafts appears to be significantly much less important in Senegal than in other West African countries. In Ivory Coast and Ghana, it is an important sector of the economy of the inhabitants (Da Giau 2012, Ouattara 2015). Sunderland (1997) reported that a large number of objects made with rattan in Senegal came from Guinea; however, during our field missions in the region of Casamance we identified only few objects coming from Guinea-Bissau. Our surveys revealed that leaves and fibers of the doum palm (*Hyphaene thebaica*) were no longer used at all, demonstrating that this type of use did not pass to younger generations and will soon disappear. There is a concerning loss of knowledge on the uses of this palm, in comparison with observations from Ghana, Benin and Togo, where the species is still widely used (Ouattara 2015, Michon 2016). The wide range of handicrafts made with the petioles of *Raphia sudanica* (loungers, chairs, stools) in south-eastern Senegal (region of Kedougou) seems unique and has not been reported in other countries. Da Giau (2012) and Michon (2016) reported several objects made with the leaves of *R. sudanica*, but certainly in much less diversity than the ones reported in our surveys.

The manufacture of cosmetic products from palm trees is much less important than has been observed in Ghana and Ivory Coast (Da Giau 2012, Ouattara 2015). We reported a moderate use of coconut oil but the market in Senegal is mainly dominated by *Vitellaria paradoxa* (Sapotaceae) (Masters 2004). The symbolism of protection of the palms has also been reported in sub-saharan countries (Gruca et al. 2014, 2015) and in the case of Senegal, the symbol of the fecundity of the palms is very widespread. Diop et al. (2018) reported several fetish objects for the Diola, Bassaro and Bedik ethnical groups. The seeds of *Raphia* spp. are used for the ceremony of circumcision for the Avikam of Ivory Coast, in Congo and for the Bakota ethnical group in Gabon (Joseph 1919, Perrois 1968, Rombi 1994) as we recorded it in Essaout (Casamance). In general terms we believe that knowledge of the medicinal and traditional uses of the palms could be further explored as the subject seems clearly under-represented in the literature.

Early efforts of domestication in the area of Thiès: Borassus akeassii In the framework of our study, we identified empirical evidence suggesting an early process of domestication, through the selection of desirable characters, for the multi-purpose palm *Borassus akeassii*. In the area of Thiès (villages of Fandène and Ndiobène), we reported that the seeds of the palms were selected on the base of criteria such as the general aspect of the palm, the length of the petiole and the shape of the leaves, and the size of the fruits, According to the definitions of palm domestication proposed by Harlan (1976) and Clement (1992), the populations of *B. akeassii* in the region of Thiès could represent a case of early domestication, an idea that was already suggested by Sambou et al. (1992). Further research, including the population genetics, would be important to reveal any significant differences between wild population of the species and the ones cultivated in the region.

Palm use diversity and conservation in Senegal: Cosiaux et al. (2017) reported that African palms are negatively affected by threats impacting their survival due to the loss of the natural habitats and their degradation. This results mainly from land conversion to farmlands in addition to other human activities such as mining, logging and urbanization (Fig. 16). In Senegal, destruction of natural habitats clearly makes palm resources rare and consequently unavailable for their use, whereas overexploitation severely reduces their populations. Our observations in the field highlighted that the forest landscape in the southern territory is increasingly subject to deforestation. The forests are converted for agriculture and this in turn causes a strong tendency to "savanization" the latter. The same author also reported that the department of Vélingara in Casamance lost 17% of its rainforest area between 1987 and 2003. This is affecting the habitat of palm species thriving in dense and humid forests such as rattans (*Laccosperma secundiflorum*) and *Raphia* spp. that grow in swamp lands in the south of the country. In central-north Senegal, drought has already been present for several years and could further affect the populations of *Borassus aethiopum*, *Hyphaene thebaica* and *Phoenix reclinata*. Intensive grazing (i.e., sheep, zebu, camels and goats) also causes significant damage to the palms, especially for young seedlings, which cannot properly develop, and this is particularly the case for the populations of doum (*Hyphaene thebaica*) in the Sahelian

region (Giffard 1967). In Senegal, many sheep are raised and eaten for religious festivals (especially during the celebration of the Tabaski) (Ninot 2010).

We noticed that an important degree of plant diversity, including palms, can be preserved in the so-called "Sacred Forests," which are usually protected by the villagers and closely associated to animistic beliefs (i.e., spiritual beings concerned with human affairs and capable of helping or harming human interests) (Fig. 17). Protection of these forested areas may be guaranteed by the fact that only initiated members of the village have access to the areas. Not far from the city of Oussoye in the region of Casamance, we could appreciate one fine example of these "Sacred Forests," hosting at least two different rattan species (i.e., *Eremospatha* sp. and *Laccosperma* sp.). Although more studies should quantify the specific role of these forests for the conservation of plant biodiversity, we believe that this represents an important alternative to more formal government figures of nature conservation (i.e., Natural Reserves, National Parks), often subject to uncontrolled deforestation and logging.

The overexploitation of natural resources remains very critical in the country (Lericollais 1994). We noticed that the leaves of *Borassus akeassii* were often overexploited in areas such as Fandène and Casamance. Local inhabitants usually leave only a few leaves on the palms, and this reduces considerably the surface available for photosynthesis and can affect the general growth of the palm (Sambou et al. 2002). In the framework of our field work we observed several dead adult palms, no longer bearing leaves.

Finally, it is notable that two completely different methods of palm wine tapping are carried out in Senegal. In the case of the rônier (*Borassus akeassii*) the incision to the apical most region of the stem generates severe damage, and this method is certainly not sustainable through time. Our field work in central Senegal gave evidence of several populations in which only dead stems were observed. This was clearly the consequence of palm wine tapping overexploitation, producing severe damage to the apical meristem. In contrast, the palm wine tapping method observed in the populations of *Elaeis guineensis* in the region Niayes is, to our knowledge, the only case of truly sustainable palm wine extraction in Africa. The incision at the base of the peduncle not only allows the continuous extraction of the sap, but also guarantees the development of the infructescence. This double-purpose economic activity undertaken on the palm avoids severe damage to the meristem and could be cited as an example of good practice that should be transferred and encouraged in other countries of the region.

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Addressing the Monoculture System: Challenges in Oil Palm-Based Agroforestry

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TRAILS stands for "climaTe Resilient lAndscapes for wIldLife conservation." It is a multidisciplinary research project aimed at assessing innovative solutions for wildlife and people in oil palm-dominated landscapes in Sabah, Malaysia, on the island of Borneo (https://www.trails-project.org/).

Mixed-tree forests can provide habitat in a context of industrial agriculture; pioneer native tree species are efficient in restoring healthy riparian forests and providing shelter for wildlife. Biodiversity corridors also contribute to climatic resilience as agroforestry complex systems can mitigate climate change through the sequestration of atmospheric carbon dioxide in plants and soil. Mixed plantations also improve livelihoods: it is key to understand ecosystems services and wellbeing values attributed by local communities to the reforestation of riparian areas and changes induced by the transition from monoculture plantations towards mixed-planted systems.

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TRAILS objective is to install oil-palm-based agroforestry systems, using selected oil palm seedlings and native forest tree species grown in locally run village nurseries. The project also aims at monitoring the dynamics of recolonization by wildlife (abundance, diversity and mobility) in areas covered with mixed-planting, riparian corridors, and oil palm plantations. The project monitors the agronomic performance of oil palms planted under agroforestry designs. TRAILS also aims at understanding key characters of climate resilience through the monitoring of bioclimatic conditions of the parcels and their ability to provide environmental services. TRAILS builds on a complementary partnership, linking academic, NGOs, private and public stakeholders, thus enabling integrated approaches arising from various science fields, from agronomy and forestry to veterinary sciences, including a detailed socioeconomic approach of changes.

Background

Southeast Asia is home to 20% of the remaining tropical forests. The region also has one of the highest rates of deforestation in the world because of urbanization, extractive activities and the expansion of commercial plantations. Malaysia harbors the largest forest

areas in the region and one of the "megadiverse" areas for their rich biodiversity. The expansion of tree-crop plantations (including oil palm, *Elaeis guineensis*) is one of the main causes of deforestation (Vijay et al 2016). Driven by growing world demand, palm oil production has expanded dramatically in recent years. Palm oil is the most consumed vegetable oil globally and the demand has accelerated with the emergence of new outlets in the agrofuel sector, adding to traditional food and oleo-chemical uses (Rival & Levang, 2014). This strong growth has undeniably contributed to the economic development of the main producing countries, mainly Indonesia and Malaysia, which now supply 87% of world production. The expansion of palm cultivation has also caused serious environmental damage: through tropical deforestation, it has a strong impact on the erosion of biodiversity, with the decline of emblematic species such as orangutans in Southeast Asia. Oil palm cultivation contributes to climate change through deforestation, but also through the conversion of peatlands that promote carbon sequestration in soils.

Back in 1997, the El Niño phenomenon, resulting in a dramatic drought in many parts of Southeast Asia, affected oil palm cultivation. Subsequently, uncontrolled development of fires in Indonesia led to the development of haze, which spread across neighboring countries. Caliman and Southworth (1998) estimated the impact of the drought on future yields together with changes in the performance of the palms due to the haze in terms of oil extraction rate. The replacement of forests with monoculture plantations of rubber and oil palm reduces biodiversity and carbon pools but also modifies canopy structure, which is an important determinant of microclimate (Meijide et al. 2018). More, the proportion of male flowers increases with drought stress, with a direct impact on fruit production that can last for several months (Rival 2017).

A need for change

Changes in agricultural practices rely on innovative planting designs aimed at mixing selected forest species with plantation crops. A detailed monitoring will help in characterizing both the performance and the resilience of mixed agroforestry systems compared to traditional monospecific planting designs. Changes in wildlife diversity and abundance must be monitored together with the impact of agroforest designs on yields and resistance to both biotic and climatic stress. It is also of paramount importance to avoid the total destruction of the whole biotope at replanting time, which jeopardizes 30 years of effort in integrating agro-environmental services into best agricultural practices.

Oil palm plantations managed as agroforestry systems (Bhagwat & Willis 2008) can further conservation efforts. When oil palm is cultivated in mixed-tree orchards rather than monoculture plantations, such complex systems can provide habitat for forest-dwelling species (Ancrenaz et al. 2021). Mixed plantations within the landscape act as buffer zones and biodiversity corridors, connecting distant forest reserves. More, forest and agricultural resources in mixed plantation landscapes provide livelihood to local people.

In the state of Sabah, Malaysia, several groups including members of the PONGO (Palm Oil NGOs) Alliance have restored and reforested riparian areas using native forest species including pioneer tree species that grow a canopy fast and fruit trees that provide food to wildlife. Most of river floodplains have been massively converted into oil palm plantations in the early 1980s and that destruction of natural forests is still a major threat to biodiversity.

The presence of orangutan in the mature oil palm landscape is correlated with proximity to natural forest patches. Ancrenaz et al. (2015) thus suggest that forest patches, even when small, fragmented and degraded, are required to sustain the species in human-transformed landscapes. Homogenous oil palm plantations are incompatible with viable populations of orangutans.

Pioneer tree species were most efficient in restoring sustainable riparian forest, as they were able to stabilize soil erosion and to provide shelter for wildlife. As soon as the canopy started to be formed, wildlife recolonized this habitat and species such as small mammals, primates or birds started to disseminate seeds from different trees species originating from nearby natural forests. This natural enrichment of the original planting creates a more diverse forest than what was originally planted, and it is able to support a wide array of wildlife species. Hunting remains the major threat to wildlife in tropical forests worldwide where this activity goes uncontrolled.

1. The Borneo pygmy elephant (*Elephas maximus borneensis*) is a cohabitant in oil palm plantations at the MOPP site, Sabah, Malaysia.

Agroforestry-based solutions

Agroforestry systems have an important role to play in mitigating climate change, having the ability to sequester atmospheric carbon dioxide (CO2) in plant parts and soil. Indeed, changes in soil organic carbon (SOC) stocks can be monitored after land conversion to agroforestry. Donfack et al. (2021) showed that oil palm agroforests can regulate extreme microclimate and that stand structural complexity and tree island size can control microclimate, although alleviating the harsh microclimate conditions in oil palm plantations might take longer to occur.

Agricultural practices in tree crop plantations are changing as a response to growing social and environmental concerns (Bessou et al. 2017). Indeed, plantation management increasingly relies on agro-environmental services, which means that basic agricultural functions such as soil preservation, pollination, or pest control can be performed by living organisms (plants, insects, microbes etc). Allen et al. (2017) assessed changes in soil-N cycling rates with conversion of forest to oil palm and rubber plantations. Findings suggest that the larger the initial soil fertility and N availability, the larger the reductions upon land-use conversion. Because soil N availability was dependent on microbial biomass, management practices in converted oil palm and rubber plantations should focus on enriching microbial biomass.

Agroforestry systems can provide multiple benefits including reduction of bank erosion and soil loss, maintenance of water quality and natural hydrology, carbon storage, together with the provision of habitat for a wide range of biodiversity.

Wildlife-friendly management practices can go hand in hand with Best Agricultural Practices and the subsequent enhancement of yields according to the concept of agro-ecology and ecological intensification. Foster et al. (2011) and Zemp et al. (2019) stressed the importance of conserving biodiversity and ecosystem processes within the oil palm habitat itself. However, little is known about the effect of local management practices and landscape design on biodiversity and its relation to ecosystem services or disservices, specifically in the oil palm agroecosystems (Foster et al. 2011, Savilaakso et al. 2014). Khasanah et al. (2020) showed that oil palm agroforestry can achieve economic and environmental gains, as some diversified systems use land more efficiently than monocultures and are thus "land sparing."

Location of the Project

The TRAILS Project is hosted by the Hutan NGO, on the banks of the Kinabatangan River in Sabah, Malaysia, where the Kinabatangan Orang Utan Conservation Program or KOCP has developed for more than 20 years. TRAILS is presently implementing agroforestry

experimental trials on sites selected by Melangking Oil Palm Plantations (MOPP) in the District of Sandakan and Kinabatangan, Sabah. There are five different sites allocated to the TRAILS project by MOPP, amounting a total acreage of 269.75 ha for agroforestry trials.

Mixed plantings provide wildlife habitat

TRAILS is assessing the effects of different riparian restoration treatments on a wide range of environmental variables, diversity of key taxa, ecosystem processes and economic factors relating to each restoration strategy. The Project builds on the previous planting of selected tree species in riparian areas along the rivers crossing the MOPP oil palm plantation. We are planting a first batch of 17,000 native forest trees originating from 17 different species. Pioneer tree species were preferably selected as experience showed that the plantation of fruit trees to attract wildlife is not necessary, as animals progressively bring seeds during the colonization of space. Monitoring of the reforestation processes (growth of newly planted seedlings) is implemented by measuring seedlings size in sample plots on a regular basis: survival (yearly percentage of plants still alive), and growth rates (monitoring of height of the seedlings).

Microclimate and soil baseline measurements

A key hypothesis supporting TRAILS is that agroforestry systems confer a stronger resistance to extreme climatic events (like El Nino) than monocrop plantations. The TRAILS project relies on the assumption that mixed forest species associated with oil palms will be able to generate a new type of more resilient plantation (da Silva Maia 2021). We monitor changes in microclimate using a series of capture systems located in selected areas (oil palm monoculture plots, agroforestry trials and young riparian forest). Soil, plant and water analyses are subcontracted to a specialized Laboratory. Soil analyses include measurements of pH, nitrogen, phosphorus, potassium, calcium, magnesium, carbon, electrical conductivity and cation-exchange capacity (CEC). Plants (oil palms and forest species) are analyzed for foliar elements, namely: nitrogen, phosphorus, potassium, calcium, magnesium, boron, copper and zinc (Zn).

Wildlife management and monitoring

Over the years, our HUTAN partner has developed simple, efficient, and practical ways

2. Long-tailed macaques (*Macaca fascicularis*) occasionally eat oil palm fruits.

to monitor populations of various species (Fig. 1 & 2). Taxa being monitored (Shia 2020) include small mammals (trapping and release); primates (direct and indirect sightings, calls); amphibians and reptiles (direct sightings); birds (calls); terrestrial animals (camera trapping). The Project also monitors invertebrate species via trapping (fall-traps and light trapping) or bioacoustics to assess micro fauna in agricultural landscapes. Standard Operating Procedures for wildlife monitoring are developed and they can be applied and replicated in an oil palm context.

The Rasig Corridor Project is located close to the Kinabatangan River, less than 10 km away from the Trails' Project. The HUTAN team recently completed the third year of Biodiversity Monitoring activities at the Rasig corridor. This project consists of 30 small plots located in three different treatment areas: 10 plots are in pure oil palm plantations; 10 in disturbed and protected forests; 10 in a reforestation plot (where seedlings are planted under mature and unharvested palm plants). Every year, the team uses a series of techniques to document this corridor's wildlife dynamic and recolonization (Shia, 2020). The results collected at Rasig are also processed and analyzed in order to test various statistical analyses that will then be applied to TRAILS' data (diversity indexes for biodiversity value and species richness; non-metric multi-dimensional scaling analysis and general linear modelling to test the influence of environmental variables on the community structure).

Mixed plantations can improve livelihood

The long-term viability of protected areas depends on the integrity of complex ecological

processes that stretch well beyond their geographical boundaries. Efficient conservation initiatives need to be undertaken at the landscape level, incorporating multiple-use habitats where people and wildlife co-habit (Ancrenaz et al. 2007). Since most traditional conservation efforts were typically designed to exclude human residents, they have often failed to actively involve groups of people living within or near protected areas. This failure to consider the interests of local communities has resulted in a general lack of support for conservation and subsequent degradation of protected areas. Since substantial biodiversity still occurs outside of protected areas, poverty eradication and biodiversity conservation are intimately interconnected.

The TRAILS Project also focuses on the identification of economic opportunities linked to the implementation of ecosystem services by local communities (Ancrenaz et al. 2007). For several years, HUTAN has been supporting initiatives from local communities through the creation and management of tree nurseries for reforestation, the implementation of reforestation activities and wildlife monitoring. More recently, these initiatives were complemented by the development of an ecotourism program involving family homestays in the Project's area. In addition, some villagers are combining various activities from artisanal fisheries to smallholding oil palm farming. We shall study changes in standards of living that accompany the transition from oil palm monoculture to mixed agroforestry plantings.

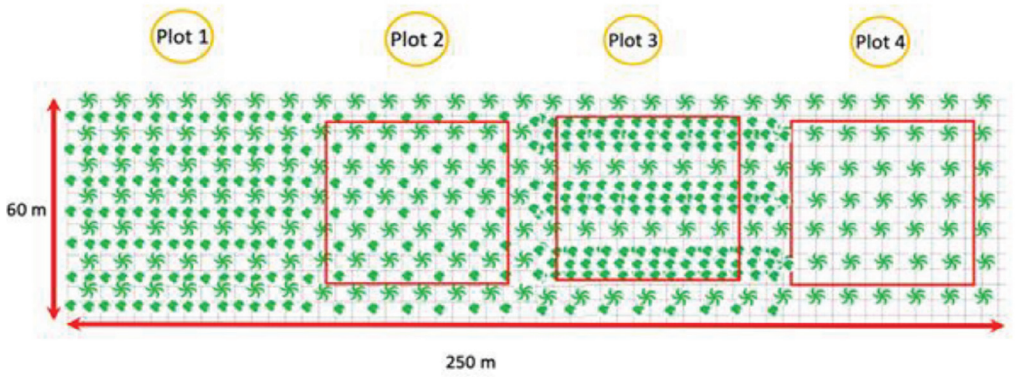
The socioeconomic focus of the TRAILS Project consists of identifying ecosystems services and wellbeing values attributed by local communities to the reforestation of riparian areas, as the Kinabatangan River water quality is vital for the health and livelihood of these communities. The local perception of ecosystem services is being studied through individual interviews and collective workshops with villagers in the project area. TRAILS also undertakes a quantitative survey based on villages' population sampling, to determine the system of activities and the income mobilized by stakeholders.

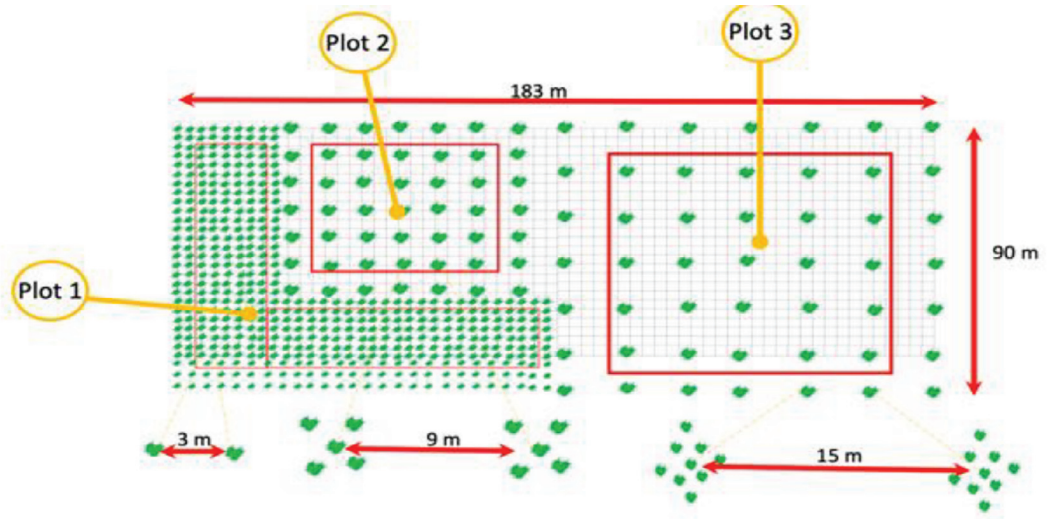
The role of communities in reforestation is key, not only through their active participation in wildlife monitoring, but also through the creation and management of nurseries and related activities. The Project builds on the economic opportunities provided through the diversity of landscapes and the maintenance of biodiversity, such as ecotourism, local development, and education. The very efficient system for community development that has been installed by HUTAN combines homestay accommodation for scientists and visitors (zoos, partnering NGOs, officials and others), conservation activities and oil palm smallholdings.

Innovative planting designs

Agroforestry trials using mixed species can take 10 years before giving definitive results. Before that, we will learn as we go along, which will make it possible to propose associations on the basis of increasingly consolidated knowledge. In the first years, the species that do not support the mixed plantation conditions will be eliminated quickly, of course; then, among the species that best adapt to the association with the oil palm, it will take much longer to determine those whose behavior are really adapted to the desired functions of the mixed plantation. Indeed,

3. Planting design mixing oil palm and native forest species at various different densities.





4. Planting design for the installation of forest trees islands inside oil palm plantations.

after several years, the trees can more or less overtake the palms and compete for light; thus, almost continuously, the mixed plantation characteristics will change, and it will be monitored.

The TRAILS Project relies on two types of plantation designs: one is "interplanted rows" and the other is "forest islands." There are five different sites allocated to the TRAILS project by the MOPP Plantation Company, amounting a total acreage of 269.75 ha available for agroforestry trials. Such trials aim at assessing the ability of a forest species (either as single-species or mixed planting) to be successfully associated with oil palm and create viable complex systems, able to support wildlife on a sustainable way.

Interplanted rows. Oil palms are usually planted in line with a spacing of 9 m between the palm trees on the line and about 9 meters between the lines, which makes about 143 palm trees/ha. Forest plantations for the production of timber wood are often planted at 3 × 3 m, which makes 1111 trees per hectare.

A planting design using randomized complete blocks was installed to identify the most proper layout allowing the mixture of trees and palms without excessively affecting the productivity of oil palms (Fig. 3).

This type of plantation design involves randomized plots with five repetitions (blocks). Each block consists of fouor plots with different treatments, plus a control which is a pure oil palm plot of same size. In Plot 1, forest trees are planted in a line every 4.5 m in the inter-row of oil palms, thus forming a rather dense plantation. In Plot 2, forest trees are planted in the inter-rows of palms every 9 m on the line, staggered in relation to the palms. In Plot 3, every other palms rows are removed (or not planted with palms), then planted with three rows of trees every 4.5 m. The trees rows are staggered and 1.5 m apart, which limits competition with palms. Plot 4 is the control treatment, consisting of oil palm plantation only, without any trees. This block or repetition is composed of four treatments, and it is repeated five times.

From such design, we implement dendrometric measurements, namely root collar diameter (RCD), diameter at breast height (DBH), total tree height, live crown length (LCL), crown radius and crown diameter (CD). We also estimate the production of Fresh Fruit Bunches from palms; and implement biodiversity measurements. Diversity and abundance of fauna and the level of natural regeneration within plots is monitored at soil level, and the quality and health of soil was assessed using the BioFunctool kit developed by Thoumazeau et al. (2019).

Forest islands. Inside the oil palm plantations, patches of forests are created in order to increase the connectivity between plantations and wild spaces. It is important to study the behavior of planted trees in mixed plantation of several native forest species and to understand which planting design is able to create the largest species diversity as quickly as possible (Fig. 4).

The experimental layout combines two approaches which combine planting all kinds

of species randomly and assessing which ones support this type of planting design, with a second design consisting of plots made of one single tree species, which are planted densely in small groups, sometimes called nuclides or Anderson plots. The gregarious species which do not support the proximity of other species might be eliminated. The latter design generates more "messy-looking" forested areas than a classic plantation, but it offers much greater biological diversity. As the canopy is not rapidly closed, such design can have an interest in biological diversity and wildlife circulation.

This block diagram describes three plots of different planting densities and two types of treatments. The species inside the plot 1 is one treatment, and the tree arrangement is another treatment.

Plot 1: the objective is twofold: first, we need to compare several different forest species, each species being considered as a statistical treatment. These species are randomly mixed and 25 trees per species are measured in the plot. The second objective consists in comparing the type of design (the design is then the analyzed treatment, here species in mixed plantation at 3 × 3 m), with nuclides in Plots 2 and 3. The planted density is 1111 trees/ha.

In Plot 2, the effect of the nuclide layout on restoration is assessed. The nuclides have a spacing of 9 × 9 m, which corresponds to the classic spacing of oil palms. This can further allow the use of results by integrating them into an oil palm plantation design. In this plot, there are five trees of the same species per nuclide, inside the plot there are five different species, the nuclides are randomly mixed. 25 nuclides are measured, i.e. 5 nuclides per species, or 25 trees per species. The planted density is 617 trees/ha.

In Plot 3, the nuclides have a spacing of 15 × 15 m, there are ten trees of the same species per nuclide, inside the plot there are five different species, the same species as in plot 2, the nuclides are randomly mixed. The planted density is 444 trees/ha.

Conclusions

It is now of paramount importance to challenge the monospecific plantation system in place in tropical landscapes for more than a century (Abram et al. 2014, Zemp et al. 2019). Oil palm-based agroforestry plantings are currently underway in Sabah, and a series of baseline studies are documenting the status of parcels at time zero of the Project.

At the end of the TRAILS Project, we hope to be able to decide on the ability of native tree species to grow in association with oil palms, and the capacity of oil palms to support this association. We will also better understand the function as service providers of the selected native forest species. The present study will provide a first assessment of risks linked to the change of plantation model, as the nature and pathogenicity to oil palm of the microflora colonizing the soil of mixed plantations are yet to be carefully monitored.

The TRAILS Project is of modest size when compared to the huge oil palm-cultivated area in the region; nevertheless, its comparative value resides in its role as a prototype and a catalyzer.

We hope that TRAILS will inspire and initiate the implementation of many other projects on oil palm-based agroforestry under different agroecological contexts. Given the uncertainties faced by the sector (climatic fragility, dependence on labor), the multisite assessment of the capacities of oil palm-based agroforestry system must be a priority for scientists, policy makers and the oil palm industry in all producing countries (Purwanto et al. 2020). Since the pioneering work initiated in 2007 by Miccolis et al. (2019) on a 18 ha plot in Brazil, such initiatives remain rather scarce and more often disconnected, thus a significant research effort is needed to gain and share knowledge. The TRAILS Project is expected to create a prototype for future planting designs based on oil palm-based agroforestry.

The Chinese proverb should say: *The best time to plant a palm-based agroforestry system was 20 years ago. The second best time is now.*

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