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ABSTRACT

Although the palm flora of continental Africa totals just 66 species, they are amongst the most useful plants across the continent, providing many important resources for human populations. Studies have shown that African palms will likely be negatively affected by global change, leading to increased threats to their survival. Here we conduct the first full global conservation assessment for 61 continental African palm species following IUCN Red List Categories and Criteria. Our study revealed that fewer than 10% of the evaluated species were assessed as Threatened. Within the Threatened category, one species was assessed as Critically Endangered, three as Endangered and two as Vulnerable. These results underline an overall low extinction risk for African palms in the immediate future, which is substantially lower than the global estimate of 21% for all plants. These results could be linked to the generally large distribution patterns of African palm species, the broad ecological amplitudes of most species and their good representation inside the African protected areas network. However, a non-negligible number of species (~15%) lack sufficient data to be properly assessed. This highlights the importance of further studies to improve our basic understanding of their distribution and threats. Our study provides a rather optimistic view of this highly important African plant resource yet, some widespread species are becoming locally rare due to over-harvesting for human use. At a local level, palm resources are generally non-sustainably exploited, which, coupled with climate change, could lead to a rapid increase in threat status over time.

1. Introduction

The palm family (Arecaceae/Palmae) comprises 181 genera and ca. 2600 species (Baker and Dransfield, 2016; Dransfield et al., 2008) mainly distributed in tropical regions of the world. Palms are considered to be keystone species of tropical ecosystems, especially within tropical rain forests (Couvreur and Baker, 2013; Henderson, 2002). Palm species richness is highest in Asia (with c. 1200 species) and South America (with c. 730 species). This contrasts sharply with mainland Africa where only 66 species, in 17 genera, are currently recognized (Couvreur and Niangadouma, 2016; Dransfield et al., 2008; Stauffer et al., 2014, 2017). Seven genera are endemic to the continental landmass.

Palms are one of the most important components of various vegetation types across Africa (Dransfield, 1988). The majority of the species occur in tropical rain forests while a few species inhabit dry and open habitats (inland and coastal savannas, deserts and sub-desert steppes). In addition, an important component of the African palm flora is associated with riparian forests or waterlogged soils such as swamps or marshes (Dransfield, 1988; Tuley, 1995). Across Africa, palms are among the most economically important plant resources (Sunderland et al., 2008), especially for rural households. In addition, several species have a multi-purpose utility as sources of food, construction materials, medicine, and crafts (Burkill, 1997; Dransfield, 1988; Gruca et al., 2015). This is a rare attribute for African species providing non timber forest products (Ingram, 2014).

African palms are negatively affected by threats impacting their survival linked to habitat loss and habitat degradation (Cosiaux et al.,

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2017), mainly resulting from land conversion to agriculture coupled with other human activities (logging, mining, urbanization). Future climate change is thought to exacerbate and add to these threats. A recent study underlined that African palm species will experience a decline in climatic suitability in > 70% of their current ranges by 2080 (Blach-Overgaard et al., 2015). However, to date, the overall extinction risk of most continental African palm species remains unknown and no consistent approach has yet assessed their overall conservation status.

A major step in biodiversity conservation relies on better understanding the threats and the extinction risks species may face. Assigning these threat levels allow the identification of conservation priorities, improve the effectiveness of protected areas and guide conservation actions (Rodrigues et al., 2006). The IUCN Red List of Threatened Species, developed by the International Union for Conservation of Nature (IUCN), is recognized as the most comprehensive, authoritative and objective global mechanism for evaluating the conservation status of species. The Red List uses a standardized set of criteria (IUCN, 2012; IUCN Standards and Petitions Subcommittee, 2016) to classify taxa into a category according to its extinction risk. The IUCN Red List of Threatened Species plays a prominent role in guiding conservation actions of governments, industry, NGOs, and scientific institutions. For the world palm flora, currently just 558 species have been officially assessed following IUCN criteria, including a complete assessment of the conservation status of all Madagascan palm species (Rakotoarinivo et al., 2014). Prior to this study, a total of 3877 plant species from the continental African flora had been formally 'Red Listed', including just 19 palm species.

Here, we present the first extinction risk assessment of any continental African plant group to date. Specifically, we 1) assess the current extinction risk of continental African palms; 2) identify major and minor threats to these African palms based on an extensive literature review and field work and 3) compare our results with other regional or global assessments for palms and plants in general.

2. Material and methods

2.1. Study area

Continental Africa is defined here as the mainland and the continental islands of the Gulf of Guinea. The island of Pemba (Tanzania) and Zanzibar were not included in our study as their floras are considered as part of the Indian Ocean flora (Dransfield et al., 2008). Thus, *Dypsis pembana* (H.E.Moore) Beentje & J.Dransf. endemic to the island of Pemba was not taken into account here. In the same way, Cape Verde islands were excluded from our study as their floras are regarded as part of the Macaronesia flora (excluding the Cape Verde endemic *Phoenix atlantica* A.Chev. form our study (Barrow, 1998)).

The geographic range of six species is not restricted to continental Africa: *Hyphaene coriacea*, *Phoenix reclinata* and *Raphia farinifera* also occur in Madagascar, *Phoenix caespitosa, Hyphaene reptans* and *Livistona carinensis* also occur in the Arabian Peninsula. In order to produce global IUCN Red List Assessments, the study area was extended to these regions for these species.

2.2. Data acquisition

Distribution data for all studied species were extracted from the high quality expert-derived RAINBIO database (Dauby et al., 2016; Sosef et al., 2017). Distribution information for palms is particularly well documented as RAINBIO contains all data from Blach-Overgaard et al. (2010), a comprehensive dataset of all African palm occurrences derived from herbarium records and identified via expert knowledge (Bayton, 2007; Sunderland, 2012; van Valkenburg et al., 2008; van Valkenburg and Sunderland, 2008). For one specimen, the RAINBIO identification was incorrect, and we thus re-identified it. Other georeferenced occurrence records were collected from literature (Couvreur and Niangadouma, 2016; Ford and Baily, 2004; Hall et al., 2008; Kilian et al., 2004), fieldwork observations (Fred Stauffer, Thomas Couvreur, pers. comm.), and the most comprehensive database of Madagascar palms available (Mijoro Rakotoarinivo pers. comm.).

2.3. IUCN Red List conservation status assessments

Complete global conservation status assessments were carried out following the IUCN Red List Categories and Criteria, version 3.1 (IUCN, 2012; IUCN Standards and Petitions Subcommittee, 2016). Each species was assigned one of the IUCN categories according to its extinction risk: Extinct (EX), Extinct in the Wild (EW), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC) or Data Deficient (DD). Most species in this study were assessed using Criterion B which uses geographic range size and evidence of declining or fragmenting populations (Gaston and Fuller, 2009). Criterion B is suitable for estimating conservation status even when data is limited and the distribution of a taxon is only known from a few georeferenced herbarium collections (Schatz, 2002). For a few species, however, where appropriate data were available, criteria A or D were also applied in the assessment.

Full global conservation assessments were conducted species by species. The R package *ConR* (Dauby et al., 2017) was used to quantify the distribution range of each species (corresponding to the sub-criteria B1 and B2 via the Extent of Occurrence (EOO) and Area of Occupancy (AOO)) using occurrence records extracted from the RAINBIO database. All of the species were assessed for their entire global range. *ConR* calculates the EOO by constructing the minimum convex polygon around all known occurrences. AOO was calculated as the sum of occupied cells after superimposing a grid with cells of 2 km × 2 km. When the species was known from less than three unique occurrences only the AOO was calculated. For ten species (see Table 1), however, the EOO and AOO were finally calculated using the web service GeoCAT (Bachman et al., 2011). The occurrence records of these 10 species were extracted from the RAINBIO database, to which additional records were added. *ConR* was also used to calculate the number of collections within protected areas (PA) based on a shapefile of known protected areas downloaded from the World Database on Protected Areas (WDPA, https://www.protectedplanet.net/). When a species occurred in five or fewer PAs, detailed information about the effectiveness of each PA was obtained from literature, expert field observations and reports, in order to assess if the species could be facing potential threats within each PA. Then, for each species, we manually determined the number of threat-defined locations, inferred population trends, and estimated potential major and minor threats. A threat-defined location is considered by the IUCN to be a geographically or ecologically distinct area within which a single threatening event can rapidly affect all individuals of the taxon present (IUCN Standards and Petitions Subcommittee, 2016). Population trends, such as a continuing decline in the number of sub-populations, continuing decline in the number of mature individuals, and the fragmentation of the population, were identified for each species. In each case we scrutinized literature sources, expert field observations, herbarium specimen labels and reports, in order to obtain all available data on each species. To estimate or infer the continuing decline of the area, extent and/or quality of habitat, we proceeded as above, and satellite imagery from Google Earth was used to identify areas where species may be affected by habitat loss or habitat degradation.

2.4. Uses

Data about the known uses of each species were gathered from a wide range of different literature sources (Adu-Anning, 2004; Amwatta, 2004; Arbonnier, 2009; Barrow, 1998; Burkill, 1997; Cunningham and Milton, 1987; Defo, 2004; Dijkman, 1999; Dransfield, 1986; Dransfield and Beentje, 1995; el-Mashjary et al., 2001; Kahindo et al., 2011; Kahn and Luxereau, 2008; Kgathi et al., 2005; Konstant et al., 1995; Latham

Table 1
The conservation status and associated parameters of the 61 continental African palm species assessed in this study.

Species	Assigned Red List Category	EOO km^2	AOO km^2	Major threats	Number of occupied protected areas	Number of occurrence records	Tool for calculating EOO/AOO
Borassus aethiopum Mart.	LC	14,762,390	536	Palm wine extraction; over-harvesting of the leaves and the stems	25	184	ConR
Borassus akeassii Bayton, Ouédr. & Guinko	LC	1,609,176	60		0	20	ConR
Calamus deerratus G. Mann & H. Wendl.	LC	8,427,007	600		38	270	ConR
Elaeis guineensis Jacq.	LC	7,494,186	528		26	137	ConR
Eremospatha barendii Sunderl.	CR	8	8	Habitat loss (logging, agriculture)	0	4	ConR
Eremospatha cabrae (T. Durand & Schinz) De Wild.	LC	1,646,687	176		2	92	ConR
Eremospatha cuspidata (G. Mann & H. Wendl.) G. Mann & H. Wendl.	LC	3,208,475	100		2	47	ConR
Eremospatha dransfieldii Sunderl.	EN	251,334	40	Habitat loss (agriculture)/over harvesting of the stems	1	20	GeoCAT
Eremospatha haullevilleana De Wild.	LC	3,394,456	480		13	277	ConR
Eremospatha hookeri (G. Mann & H. Wendl.) H. Wendl.	LC	1,564,667	180		15	74	ConR
Eremospatha laurentii De Wild	LC	3,553,966	246		8	125	ConR
Eremospatha macrocarpa (G. Mann & H. Wendl.) H. Wendl.	LC	4,751,542	552	Over-harvesting of the stems	27	274	ConR
Eremospatha quinquecostulata Becc.	LC	166,826	36		3	17	GeoCAT
Eremospatha tessmanniana Becc.	LC	226,283	20		2	11	ConR
Eremospatha wendlandiana Dammer ex Becc.	LC	624,645	196		7	92	GeoCAT
Hyphaene compressa H. Wendl.	LC	1,203,516	208		6	75	ConR
Hyphaene coriacea Gaertn.	LC	4,259,267	384	Over-harvesting of the leaves; palm wine tapping	6	110	GeoCAT
Hyphaene guineensis Schumach. & Thonn.	LC	664,793	86	Habitat loss (agriculture)	1	47	ConR
Hyphaene macrosperma H. Wendl.	DD	–	–	–	–	–	–
Hyphaene petersiana Klotzsch ex Mart.	LC	3,800,682	392		17	127	ConR
Hyphaene reptans Becc.	DD	–	–	–	–	–	–
Hyphaene thebaica (L.) Mart.	LC	22,928,432	220	Habitat loss (agriculture); palm wine tapping	0	66	ConR
Laccosperma acutiflorum (Becc.) J. Dransf.	LC	1,799,083	116		4	49	ConR
Laccosperma cristalensis Couvreur & Niang.	DD	–	–	–	1	1	–
Laccosperma korupensis Sunderl.	LC	93,000	44		1	19	ConR
Laccosperma laeve (G. Mann & H. Wendl.) H. Wendl.	LC	1,733,564	192		11	83	ConR
Laccosperma opacum (G. Mann & H. Wendl.) Drude	LC	2,727,084	392		17	185	ConR
Laccosperma robustum (Burret) J. Dransf.	LC	1,849,286	232	Over-harvesting of the stems	9	128	ConR
Laccosperma secundiflorum (P. Beauv.) Kuntze	LC	3,820,809	536	Over-harvesting of the stems	26	228	ConR
Livistona carinensis (Chiov.) J. Dransf. & N.W. Uhl	EN	19,748	84	Habitat loss and habitat degradation (agriculture and diversion of surface water), flash-floods, livestock grazing and climate change (drought)	0	67	GeoCAT
Medemia argun (Mart.) Württemb. ex H. Wendl.	VU	> 20,000	880	Habitat loss and degradation (gold mining activities) and climate change (rainfall decline)	0	22	GeoCAT
Oncocalamus macrospathus Burret	LC	803,776	72		0	36	ConR
Oncocalamus mannii (H. Wendl.) H. Wendl.	LC	681,868	164		3	98	ConR
Oncocalamus tuleyi Sunderl.	LC	20,407	64		2	70	ConR
Oncocalamus wrightianus Hutch. & H. Wendl.	EN	3897	24	Habitat loss (urbanization, agriculture)	0	12	ConR
Phoenix caespitosa Chiov.	LC	306,917	68		0	22	GeoCAT
Phoenix reclinata Jacq.	LC	24,741,605	1080	Palm wine tapping	86	447	GeoCAT
Podococcus acaulis Hua	LC	132,333	180		4	44	ConR
Podococcus barteri G. Mann & H. Wendl.	LC	1,398,800	416		9	157	ConR
Raphia africana Otedoh	DD	–	–	–	–	–	–
Raphia farinifera (Gaertn.) Hyl.	LC	7,312,566	188		15	50	ConR
Raphia gentiliana De Wild.	LC	722,754	36		0	9	ConR
Raphia hookeri G. Mann & H. Wendl.	LC	2,706,844	304		11	92	ConR

(*continued on next page*)

Table 1 (*continued*)

Species	Assigned Red List Category	EOO km²	AOO km²	Major threats	Number of occupied protected areas	Number of occurrence records	Tool for calculating EOO/AOO
Raphia laurentii De Wild.	LC	867,984	40		1	14	ConR
Raphia longiflora G. Mann & H. Wendl.	DD	–	–	–	–	–	–
Raphia mambillensis Otedoh	LC	133,505	60	Habitat loss (agriculture)	2	22	ConR
Raphia mannii Becc.	DD	–	–	–	–	–	–
Raphia matombe De Wild.	DD	–	–	–	–	–	–
Raphia monbuttorum Drude	LC	1,515,539	36		1	10	ConR
Raphia palma-pinus (Gaertn.) Hutch.	NT	643,848	132	Over-harvesting of the leaves and fibres	6	56	GeoCAT
Raphia regalis Becc.	LC	736,709	132		4	31	ConR
Raphia rostrata Burret	DD	–	–	–	–	–	–
Raphia ruwenzorica Otedoh	DD	–	–	Oil exploration activities	1	–	–
Raphia sese De Wild.	LC	306,322	44		1	11	ConR
Raphia sudanica A. Chev.	NT	1,054,613	124	Over-harvesting of the leaves	3	34	ConR
Raphia textilis Welw.	LC	861,344	20		0	6	GeoCAT
Raphia vinifera P. Beauv.	LC	577,147	84		1	28	ConR
Sclerosperma mannii H. Wendl.	LC	3,019,029	244	Over-harvesting of the leaves	6	89	ConR
Sclerosperma profizianum Valk.	LC	1,883,087	44		1	27	ConR
Sclerosperma walkeri A. Chev.	LC	474,133	48		2	22	ConR
Raphia australis Oberm. & Strey	VU	–	64	Habitat loss and habitat degradation (agriculture, urbanization) (Matimele et al., 2016)	1	–	–

and Konda ku Mbuta, 2014; Nzuki Bakwaye et al., 2013; Otedoh, 1976; Ouattara et al., 2015; Peltier et al., 2008; Sola et al., 2006; Stave et al., 2007; Sunderland, 2001, 2007, 2012; Sunderland et al., 2001, 2004; Sunderland and Obama, 1999; van Valkenburg et al., 2008; van Valkenburg and Dransfield, 2004; van Valkenburg and Sunderland, 2008; Welch and Welch, 1999; Yembi, 1999; Zoro Bi and Kouakou, 2004) and the internet database PROTA4U (https://www.prota4u.org/). These data were used to assess the implication of plant resource harvesting and exploitation potentially impacting on each species.

3. Results

3.1. Number of species assessed

Our results (Table 1) are based on a total of 61 species assessed (out of the 66 species known for continental Africa). New full global IUCN conservation assessments for 60 species were completed, peer-reviewed via the international IUCN SSC Palm Specialist Group, and submitted for publication with the IUCN Red List Unit in Cambridge, UK. These assessments will all be published on the IUCN Red List webpage. *Raphia australis* had recently been assessed (Matimele et al., 2016) and thus was included in our overall analysis, as the 61st species. Five species were excluded from our analysis either because they were introduced or naturalized in Africa (*Cocos nucifera* L. and *Nypa fruticans* Wurmb), are under assessment by other research teams (*Jubaeopsis cafra* Becc. and *Chamaerops humilis* L.) or have an uncertain taxonomic status or doubtful presence in Africa (*Raphia taedigera*, Stauffer et al., 2014). A total of 4238 georeferenced occurrence records were used: 4096 of which were extracted from RAINBIO (Dauby et al., 2016) and the others from literature, field work observations and the database of Madagascan palms (Mijoro Rakotoarinivo pers. comm..). The dates of these occurrences records range from the years 1837 to 2016. The occurrence records dataset is provided in an excel file (Online Appendix A).

3.2. IUCN Red List conservation assessments

Of the 61 evaluated species, 52 species were found to be data sufficient and could be fully assessed (85.2%, see Tables 1, 2). Our analyses suggested that a total of eight species (13.1%) are of conservation concern. A total of six species (9.6%) are assessed as Threatened (see Fig. 1): one species is listed as Critically Endangered (1.6%), three species as Endangered (4.9%) and two species as Vulnerable (3.3%), with another two species being Near Threatened (3.3%). In contrast, 44 species were classified as Least Concern (72.1%). Finally, nine species (14.8%) were listed as Data Deficient (DD). Data on the current status of these taxa were insufficient or missing entirely as most of these species are currently known only from a single or very few herbarium collections and have not been recently collected. Access to these little known species is hindered by political instability or health problems in some

Table 2
Summary of the conservation status of the 61 African palm species assessed.

Red List Category	Number	Percentage
Extinct (EX)	0	0
Extinct in the Wild (EW)	0	0
Critically Endangered (CR)	1	1.6
Endangered (EN)	3	4.9
Vulnerable (VU)	2	3.3
Near Threatened (NT)	2	3.3
Least Concern (LC)	44	72.1
Data Deficient (DD)	9	14.8
Total Evaluated	61	100
Total Data Sufficient (CR + EN + VU + NT + LC)	52	85.2
Total Species of Elevated Conservation Concern (CR + EN + VU + NT)	8	13.1

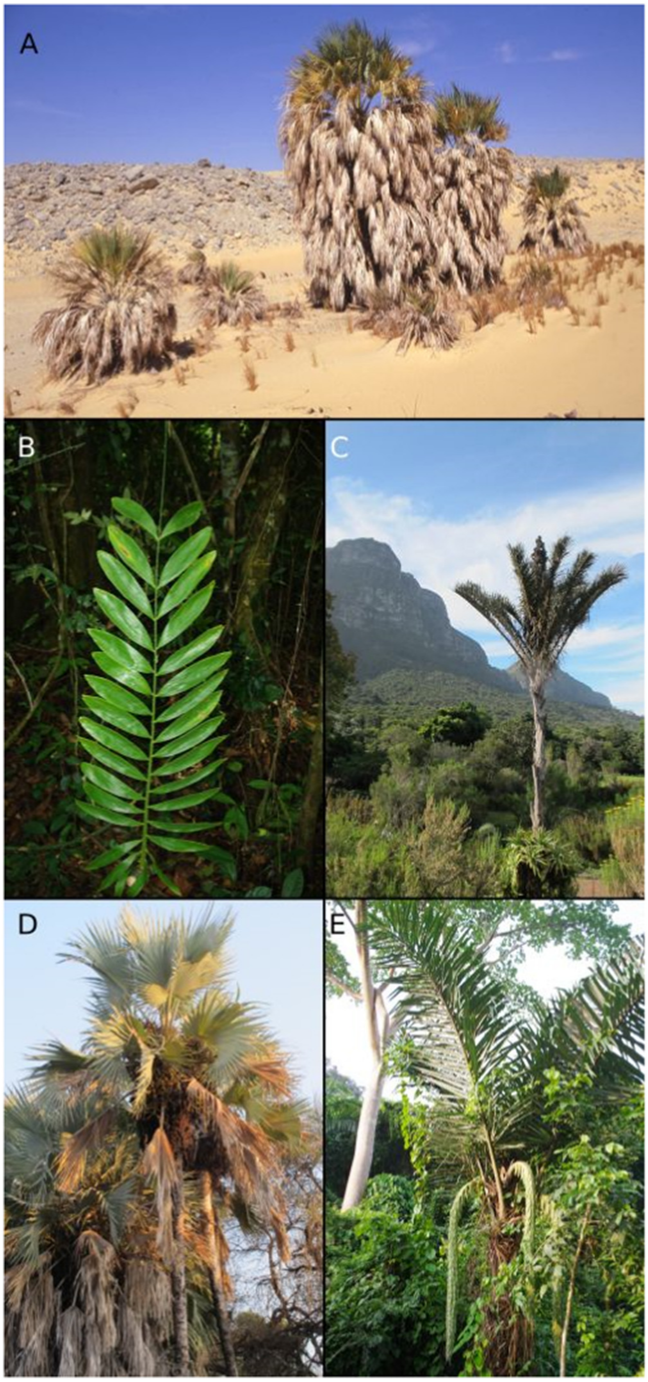

Fig. 1. Illustration of some threatened and non-threatened African palm species. A) *Medemia argun* (VU) in Egypt; B) *Eremospatha barendii* (CR) near Lolodorf, Cameroon; C) *Raphia australis* (VU), cultivated in the Kirstenbosch Botanical Garden, Cape Town, South Africa; D) *Hyphaene coriacea* (LC), Kruger National Park, South Africa; E) *Raphia textilis* (LC), Gabon.
Photos: A: Bill Baker, palmweb.org; B–E: Thomas Couvreur.

areas (for example, the recent Ebola outbreak in Western Africa).

3.3. Protected areas network

Most continental African palms are represented inside protected areas with 42 species (out of a total of 52 data sufficient species) reported to occur in at least one protected area (abbreviated here as PAs) (see Table 1, Figs. 2 and 3). Among the 52 data sufficient species, 33 palm species are known to occur in at least two protected areas, with 12, 8 and 13 species found in 2–5 PAs, 6–9 PAs, and > 10 PAs, respectively. Most of these species are assessed as Least Concern species (85%), while none are considered to be Threatened.

The remaining 19 species are not well represented inside African PAs: nine species are only present in one PA and 10 species are absent from any PAs. In this group, the proportion of LC species remains high, mostly due to species having overall large distribution ranges, but the proportion of Threatened species is significant: 40% of the species which do not occur in any PA are Threatened and ca. 20% of the species which occur in only one PA are listed in a Threatened category.

4. Discussion

4.1. Low extinction risk of African palm species

Our conservation assessment of the palm flora of continental Africa suggests that ca. 10% (6 species out of the 61 assessed) are considered as Threatened (CR, EN, VU) according to the IUCN Red List Category and Criteria (IUCN, 2012; IUCN Standards and Petitions Subcommittee, 2016). This is less than half the proportion (22%) estimated for plants in tropical Africa, calculated using the Sampled Red List Index for Plants approach (Brummitt et al., 2015). Globally, few regions or countries have comprehensive or up-to-date Red List for palm species, making comparisons difficult. Our results, however, contrast strongly with the very high extinction risk of the highly diverse Madagascar palm flora, where 83% of the 192 endemic Madagascan palms known at the time being listed as threatened (Rakotoarinivo et al., 2014). Moreover, this latter study revealed that almost a third of Madagascar palms are Critically Endangered (61 species, 32%) whereas only one palm species is in this category for the whole of continental Africa (Table 1). To date, a total of 558 palm species (out of ca. 2600 species, Dransfield et al., 2008) have been assessed globally, and are available on the IUCN Red List website (http://www.iucnredlist.org). Of these, 258 were assessed under the now outdated version 2.3 of the IUCN criteria (1998-2000) and do not follow the current criteria. They are thus not fully comparable with more recent assessments. Of the remaining 300 species assessed under the current criteria, version 3.1 (from 2003 onwards), a total of 67 species are listed as Critically Endangered, the large majority of these being endemic to Madagascar (Rakotoarinivo et al., 2014).

The observed low extinction risk of the continental African palm flora could be explained by several factors. First, this result could be representative of the African flora in general, suggesting that continental African plants are less threatened than plants in other regions. Brummitt et al. (2015), focusing on green plants, however, estimated a similar proportion of species to be threatened across the three main tropical regions, tropical Africa (22% of species threatened), the Neotropics (22%) and tropical Asia (21%). Even though this study relied on a small fraction of species being evaluated (~4000 out of the estimated 380,000 green plant species), the sampled approach nevertheless suggested similar levels of threat between tropical floras.

Second, the lower levels of threat to African palms could be linked to the distribution patterns of the constituent species. Most African palm species have wide geographic distributions across the continent (Fig. 4). Many African palm species are also gregarious, forming large stands (Otedoh, 1976; Tuley, 1995) that dominate the vegetation landscape (e.g. *R. hookeri* or *R. laurentii* (Dargie et al., 2017); *Sclerosperma* or *Podococcus* (van Valkenburg et al., 2008; van Valkenburg and Sunderland, 2008)). This contrasts to the numerous narrowly range restricted species in Madagascar (Rakotoarinivo et al., 2014), only known from single sites. This is also evident in the calculated EOO (Fig. 4a) for each species. When compared to Madagascar only 6% of continental African palms have an EOO $< 20{,}000\ km^2$ whereas 74% of the Madagascan palms have an EOO lower than $20{,}000\ km^2$. In contrast, the EOO of 79% of continental African palms is $\geq 20{,}000\ km^2$ versus only 20% of Madagascan species. The AOO class of 10-500 km^2

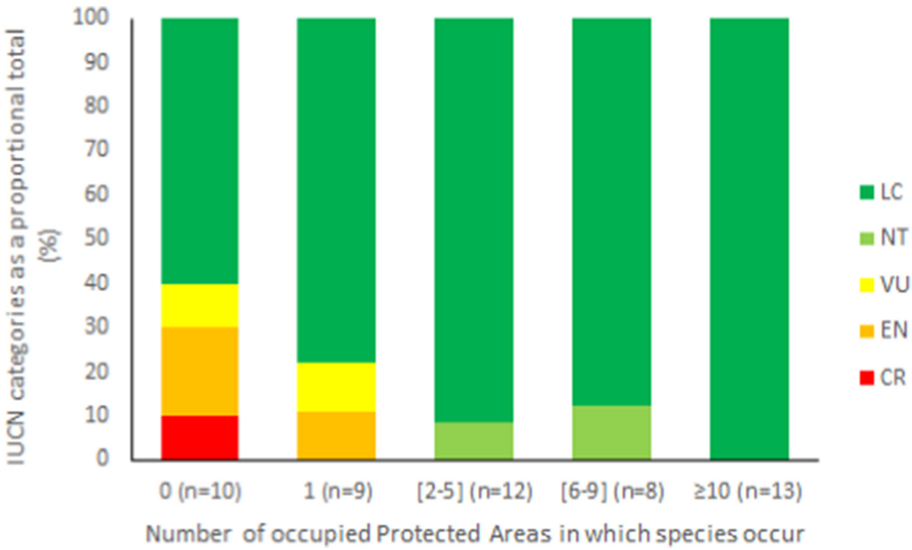

Fig. 2. IUCN conservation status of continental African palm species summarized by occurrence in protected areas. This figure follows the same design as Fig. 4 from Rakotoarinivo et al. (2014). It takes into account the data sufficient species (52 species). Of the 52 data sufficient assessed species, 10 are not recorded from any protected area (coded as 0 in the figure), nine species are recorded only from one protected area (coded as 1), 12 species occur from two to five protected areas (coded as [2–5]), eight species are recorded from six to fixe protected areas (coded as [6–9]) and 12 species occur in 10 or more protected areas (coded as ≥10).

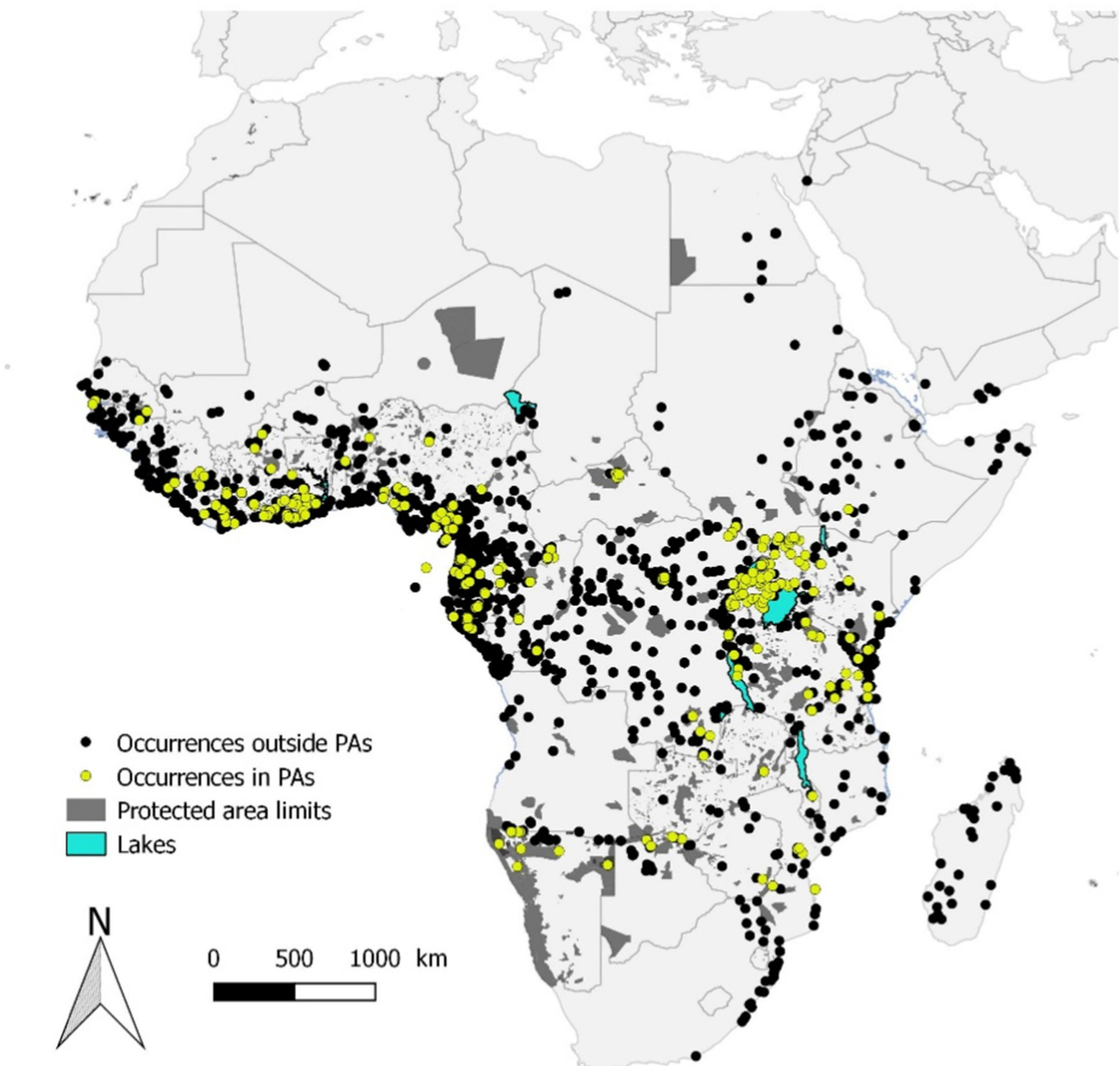

Fig. 3. Distribution of herbarium records used in this study to assess the IUCN conservation status of continental African palm species. Protected areas are indicated in dark grey. Occurrences in yellow are those found within protected areas (PA).

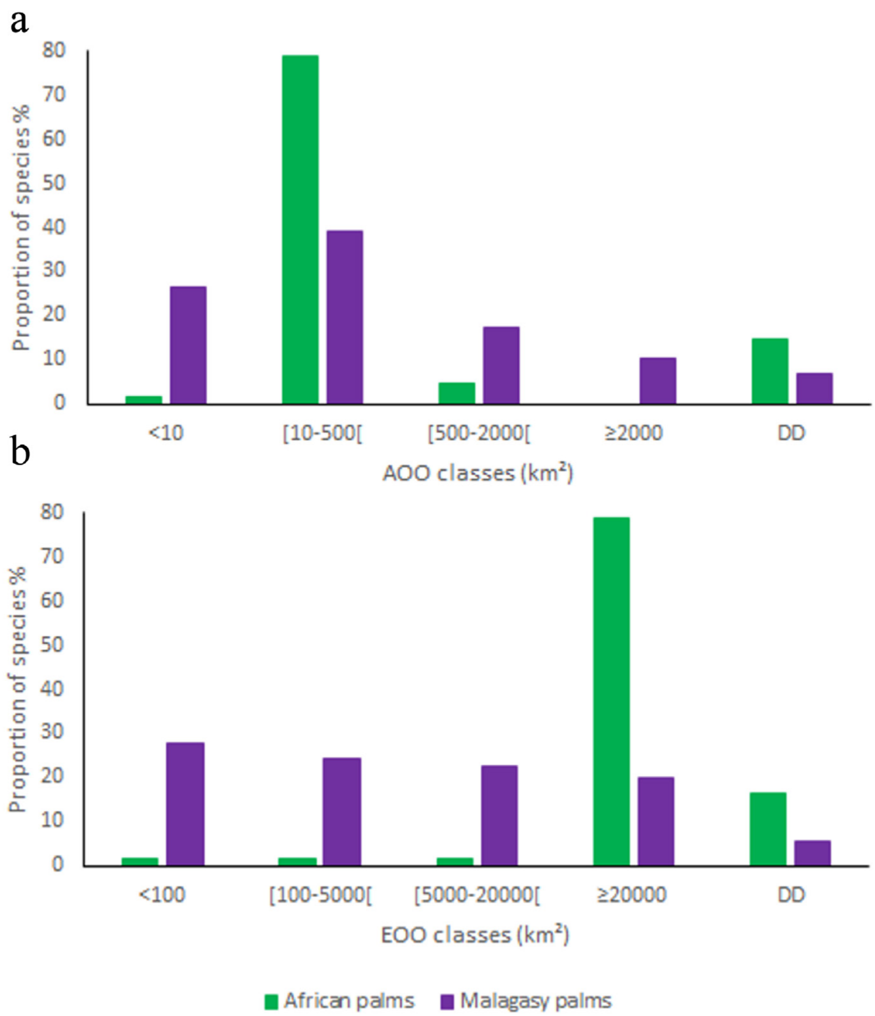

Fig. 4. Comparison of the proportion in % of species by Extent of Occurrence EOO (a) and AOO (b) classes, between continental African palms and Malagasy palms.

(see Fig. 4b), contains the highest number of both continental African (79%) and Madagascan (39%) species suggesting that a majority of species meet the AOO threshold (under Criterion B2) for the Endangered Category. However, for a large number of continental African palm species, the AOO is thought likely to be underestimated, being based on few herbarium records. Indeed, palms are generally under-collected by botanists due to their size and the difficulty of making good specimens in the field, especially by non-palm specialists. In addition, a fair number of species have very broad ecological niches. For example, the rattan species *Calamus deerratus*, *Eremospatha hookeri* and *Laccosperma laeve* are shade-tolerant, but are also encountered in secondary, sun-exposed vegetation (Sunderland, 2012; Tuley, 1995). Some species, such as *Calamus deerratus, Elaeis guineensis* or *Raphia hookeri* are found in waterlogged soils such as swamps, or riparian forests but are also encountered on *tierra firme* non-inundated soils (Dransfield, 1986; Otedoh, 1976; Stauffer et al., 2014; Sunderland, 2012; Tuley, 1995). These wide geographic and environmental distribution patterns for many continental African palm species could be the result of elevated extinction rates known to have affected plant diversity across Africa (Couvreur, 2015; Morley, 2000; Plana, 2004) since the Miocene (last 23 million years), especially for palms (Baker and Couvreur, 2013; Dransfield, 1988; Kissling et al., 2012; Moore, 1973; Pan et al., 2005). High extinction rates might have favored the survival of species with broad ecological amplitudes, coupled with larger distributions.

Third, these results could be linked to taxonomy and the possible existence of cryptic species, i.e. when one species actually represents two or more species (Bickford et al., 2006), across continental Africa. The taxonomy of African palms has been improving over the last two decades (e.g. Bayton, 2007; Sunderland, 2012). New species are still being described (Couvreur and Niangadouma, 2016), but the rate of these discoveries in continental Africa is very low compared to other regions such as South East Asia (Baker and Dransfield, 2017; Heatubun et al., 2014) and Madagascar. Thus, it is not obvious that taxonomy is a likely explanation for this pattern. However, detailed data are missing about the distribution and morphology of many species, which is well-illustrated by the high proportion of Data Deficient species (15%) found in our study.

The presence of cryptic species, could be a potential partial explanation for the low extinction risk. Among recently described species, some were previously considered as conspecific with other species. For example, *Podoccocus acaulis* was previously considered to be part of the widespread *P. barteri* (Faye et al., 2016a; van Valkenburg and Sunderland, 2008). A recent molecular phylogeny of African rattans suggested that several species are polyphyletic (Faye et al., 2016b) although no clear morphological differences were identified with the study of available herbarium samples. Cryptic speciation in continental African palms has yet to be verified on a larger scale, but non-recognized cryptic species would result in more species with smaller AOOs, thus potentially leading to an overall increase of their extinction risk (Angulo and Icochea, 2010).

One species not included in our assessments was *Dypsis pembana* (H.E.Moore) Beentje & J.Dransf. endemic palm to the island of Pemba (off the coast of Tanzania). This species was previously assessed as VU in 2006 (Eastern Arc Mountains & Coastal Forests CEPF Plant

Assessment Project 2009). Although up-to-date data about this species remains insufficient to conduct a final assessment, *Dypsis pembana* could be listed as threatened due to its very restricted distribution coupled with the expansion of touristic infrastructures on the island. Although we choose to not include this species in our assessment following Dransfield et al. (2008), *D. pembana* should be included in a future global assessment of the 23 palm species of the western Indian Ocean islands.

4.2. Major threats to African palms

The most important threats affecting continental African palms are habitat loss and over-harvesting (Table 1). Habitat loss is mainly due to land conversion to small holder agriculture, logging activities and urbanization, but will also be exacerbated in the future by climate change (Blach-Overgaard et al., 2015). Here we also differentiate species that are globally threatened (range-restricted species) versus species with large distributions but which are locally threatened.

4.2.1. Global major threats

The six threatened species (Table 1) mainly face habitat loss and degradation due to land conversion to agriculture, logging activities, expansion of urban areas and mining activities which affect their survival at a global scale. These six species are all range-restricted species and have been recorded from just one or no protected areas (Table 1). For example, the Cameroon endemic rattan palm *Eremospatha barendii* is facing habitat loss due to slash and burn agriculture and logging activities around its already reduced distribution (Couvreur et al., 2013; Sunderland, 2002). Another rattan palm, *Oncocalamus wrightianus*, is affected by habitat loss due to urbanization, especially around Porto-Novo (Benin) and Lagos (Nigeria) where the species is known to occur. *Medemia argun* is highly threatened by habitat destruction and degradation due to gold mining activities in northern Sudan. Finally, *Raphia ruwenzorica* appears to be threatened by oil exploration activities in the Virunga National Park (WWF 2016, https://savevirunga.com/), but insufficient data about its distribution has led us to assess the species as DD.

4.2.2. Local major threats

The species assessed as NT, *Raphia palma-pinus* and *Raphia sudanica*, are both affected by over-exploitation of their leaves and petioles which are used for house construction (Ouattara et al., 2014, 2015). The overcutting of leaves results in the palms death leading to the decline of population numbers. Even though the distribution ranges of these species are large and they are present in several protected areas (Table 1), the absence of local conservation measures could easily increase their extinction risk in the near future.

Although facing some important local threats, especially over-harvesting, six species are assessed as Least Concern. *Hyphaene thebaica* (the Doum palm) is locally affected by severe population declines in Niger (Kahn and Luxereau, 2008; Raison, 1988) due to increasing drought events and clearing for agriculture. In addition, it is threatened in other areas of its range such as in northern Côte d'Ivoire or Ghana (Ouattara et al., 2015; Fred Stauffer pers. comm.) where Doum palms are felled and replaced by crops or eradicated as a weed. In Djibouti, large populations of this palm, including juvenile individuals, are severely affected due to palm wine tapping. *Borassus aethiopum* (African fan palm) is locally threatened by palm wine extraction in West Africa (Mollet et al., 2000; Sambou et al., 2002). For example, in Benin, this species is considered to be threatened (assessed as vulnerable by Adomou et al., 2011) because of extensive agriculture and over-harvesting (Salako et al., 2015). This local threat does not appear to affect its survival across its wide distribution range in addition to occurring in 25 PAs, but an accurate quantitative assessment is required to confirm this statement. *Raphia hookeri* is threatened by habitat loss due to swampland conversion into field crops, especially to rice fields (Ouattara et al., 2015, Fred Stauffer, pers. comm.).

African rattans such as *Eremospatha macrocarpa* (Defo, 2004; Ouattara et al., 2015; Sunderland et al., 2001; Sunderland and Obama, 1999) or *Laccosperma secundiflorum* (Defo, 2004; Sunderland et al., 2001; Sunderland and Obama, 1999; Yembi, 1999) are also affected by local threats. Although not assessed as threatened, these species are unsustainably harvested for their canes, which are used for basketry. With an estimated 10 million US dollars trade per year in Central Africa (Sunderland et al., 2008), the harvesting, consumption and trade of rattan species provides an important part of livelihood strategies for rural communities and an important entry point to the cash economy across equatorial Africa (Sunderland et al., 2008). Unfortunately, high demand for rattan cane coupled with its unsustainable exploitation has led to a decrease in species' natural populations. Unlike in South East Asia, rattan cultivation in Africa has had limited success (Sunderland et al., 2008). Thus, even though rattan species are widely distributed and are not globally threatened, unsustainable management and destruction of the main forested areas could lead to a rapid decline of certain species in the near future.

4.3. Protected areas and threatened species

Protected areas (PAs) are core tools for global and local biodiversity conservation strategies. Well managed PAs have been shown to effectively reduce rates of habitat loss, although not in every case (Geldmann et al., 2013; Houehanou et al., 2013; Watson et al., 2014). PAs therefore play an important part in buffering negative anthropogenic effects on biodiversity. A third of African palms (21 species) occur in six or more PA's (Table 1, Fig. 2) and are thus well represented within the African PAs network. Nevertheless, another third (19 species), including all six threatened species, are absent or only found in a single PA (Table 1, Fig. 2). The remaining 13 species found in no or only one PA are listed as LC as they each have very wide geographic distributions. Although these LC species may be affected by local threats and are not well represented inside PAs, their wide geographic distributions buffer them globally against extinction at least the short term, and in the absence of major threats across their ranges. The African protected area network plays, and will increasingly play, an important role in protecting African palms in the future, especially in the face of increased threats from changing climate, habitat loss, and over-harvesting, as long as national and regional authorities commit to guarantee the investment of necessary funding towards their management.

4.4. Comparison with previous assessments

Only ten African palm species out of the 61 included in this study were previously assessed (Table 3) using the IUCN Red List Categories and Criteria. Three species, *Livistona carinensis* (VU), *Medemia argun* (CR) and *Raphia australis* (DD), were assessed in 1998 (Hilton-Taylor, 1998; Johnson, 1998a,b) using the IUCN Red List Categories and Criteria version 2.3. The seven other previously assessed species, namely *Eremospatha hookeri* (Loftus, 2013a), *Hyphaene macrosperma* (Loftus and Bachman, 2013), *Raphia longiflora* (Loftus, 2013b), *Raphia mambillensis* (Loftus, 2013a,b), *Raphia palma-pinus* (Ouedraogo, 2010a), *Raphia regalis* (Darbyshire, 2004) and *Raphia sudanica* (Ouedraogo, 2010b) were evaluated more recently, between 2004 and 2009 using the IUCN Red List Categories and Criteria version 3.1. Due to the change in the Red List criteria from the earlier version 2.3 to the version 3.1., it is difficult to compare the current assessments with the previous ones, but we can compare the earlier version 3.1 assessments with the reassessments completed during this current study.

For four species, no change in conservation status is reported (Table 3). Both *Hyphaene macrosperma* and *Raphia longiflora* remain as DD while *Eremospatha hookeri* and *Raphia mambillensis* remain as LC. For the six other species, conservation status has changed compared to

Table 3
Comparison between previously published continental African palm assessments and the new reassessments.

Species	Current category (2016/2017)	Previous category	Year of previous assessment	Change
Medemia argun	VU	CR	1998	Down-listed
Livistona carinensis	EN	VU	1998	Up-listed
Raphia australis	VU	DD	1998	N/A
Raphia palma pinus	NT	DD	2008	N/A
Raphia sudanica	NT	DD	2008	N/A
Eremosphata hookeri	LC	LC	2009	No change
Raphia mambillensis	LC	LC	2009	No change
Raphia regalis	LC	VU	2004	Down-listed
Hyphaene macrosperma	DD	DD	2009	No change
Raphia longiflora	DD	DD	2009	No change

the previous assessment. *Livistona carinensis* is up-listed from VU to EN (Table 3), a genuine decline in its conservation status. The change is linked to an absence of conservation measures since the previous assessment in 1998, which led to an increase of the extinction risk of the species (Ford et al., 2008; Ford and Baily, 2004) coupled with a better knowledge about the species, especially the populations occurring in Yemen. For the following five remaining species, the change of conservation status appears non-genuine, and is due to a better knowledge of these palms in the wild and the threats they are facing. *Raphia australis* was only recently reassessed as DD, and is now, with more information, classified under the category VU (Matimele et al., 2016). *Medemia argun* has been down-listed from CR to VU (Table 3). At the end of the 1980s it was thought that this species was possibly extinct (Ibrahim and Baker, 2007; Uhl and Dransfield, 1987). After the rediscovery of the species in Sudan during the 1990s, the palm was assessed as CR due to the low number of small and fragmented populations (Johnson, 1998a). Recently, important populations in Sudan have been identified via satellite imagery dating from 2005/2006, leading to a global population estimate of ca. 7400 individuals (Ibrahim pers. comm.). Two species, *Raphia palma-pinus* and *Raphia sudanica*, previously listed as DD are now assessed as NT due to an improved knowledge of the current threats and the species distributions. The estimation of the EOO and AOO which were previously unknown are now possible due to a better access to occurrence data records of African plants (Dauby et al., 2016; Sosef et al., 2017) and palms in particular (Blach-Overgaard et al., 2010; Stauffer et al., 2017). Finally, a single species, *Raphia regalis*, is down-listed from VU to LC, also linked to a better knowledge of the species distribution and its threats.

5. Conclusion

The presented global assessment of this important plant resource, the first of its kind for Africa, now opens the way for more fine-scale and local efforts at both the regional and country levels. Future studies should be undertaken to fine-tune the assessment of some species. Studies on population structure both at demographic and genetic levels can highlight different levels of threat compared with those estimated from distribution data alone. Demographically, apparently large, healthy populations of certain species can be found to be skewed towards adult cohorts with limited juvenile cohorts, and low recruitment linked to human or animal mediated disturbances, for example in *B. aethiopum* in Benin (Salako, 2016; Salako et al., 2017). In addition, genetic studies provide information about the genetic diversity and structure of different populations, also important for future conservation planning (Faye et al., 2016a). Future research should also focus on estimating and better measuring the impact of uses and trade activities affecting palm species (e.g. leaf harvesting, palm wine tapping). This can be achieved, for example, through value chain analyses of palm products (Brokamp et al., 2011; Donou Hounsode et al., 2016). Moreover, ethnobotanical and anthropological studies should be conducted to better understand the interaction between human societies and palms. A deeper understanding of how palms are perceived, managed and exploited by humans, would be helpful to lead relevant conservation actions, especially when palms are culturally and socially important. These data will be central for better implementation of sustainable management and conservation strategies of this important African resource in the near future. The effectiveness of these strategies would be enhanced by leading environmental awareness actions, supporting research about the cultivation of some species and improving local and national natural resource governance policies.

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Appendix A. Supplementary data

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