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REVIEW

Current knowledge and future directions on West African wild palms: an analytical review for its conservation and domestication in the context of climate change and human pressures

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Abstract Palms constitute vital species for local people's well-being, especially in West Africa. This analytic review aims at providing an overview of West African palms flora diversity, uses, ecology, and conservation. Scientific papers related to palms in West Africa were searched on electronic databases *Google Scholar, Web of Science,* and general web search on *Google* using the names of palms occurring in West Africa. From 108 scientific articles, we extracted relevant information after a critical reading. Papers were published between 1930 and 2019 and most of the studies focused on biochemistry, ethnobotany, and population structure. We identify in the literature 25 species belonging to 12 genera, 32% of them growing in dry areas. Five growth forms were identified among West African palms species. Erect and solitary stem forms were the most representative. Concerning leaf forms, most west African palms (84%) have pinnate leaves. Sexual systems of palms were represented by monoecy, dioecy, and hermaphrody, with the predominance of monoecy (44%). The pleonanthic species are the most represented reproductive feature (76%) and only *Raphia* palms are hapaxanthic. As far as uses are concerned, there is a link between used parts and uses categories. According to the relative importance index, the four first palm species in West Africa, namely *Borassus aethiopum* Mart., *Elaeis guineensis* Jacq., *Borassus akeassii* Bayton, Ouedr. & Guinko, and *Hyphaene thebaica* Mart. grow in dry areas. Rattans have a low relative index value due to their non-consumed organs. Critical analysis was presented in the focus of population structure, distribution, and propagation aspects. The review highlights a research gap in carbon sequestration, phenology, and called for more research effort in semi-arid and arid areas. Such investigations would help in planning better sustainable management and conservation of palm in West Africa.

Keywords Diversity · Ethnobotany · Population structure · Distribution · Arecaceae · Arid areas

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Introduction

The palms (*Arecaceae*) comprise 181 genera and approximatively 2600 species belonging to five sub-families namely *Calamoideae*, *Nypoideae*, *Coryphoideae*, *Ceroxyloideae* and *Arecoideae* (Baker and Dransfield 2016) occurring in tropical and subtropical regions of the world (Eiserhardt et al. 2011). In Africa, palms are less diversified compared to other large regions (Stauffer et al. 2017; Baker and Couvreur 2013; Couvreur 2015) and its risks of extinction are low at a continental scale (Cosiaux et al. 2018). In the contrary, at a local scale, they are threatened by overexploitation of their products (Mollet et al. 2000; Ahissou et al. 2017) and climate variability (Blach-Overgaard et al. 2015). For instance, West African palm species are exposed to multifactorial threats including climate change and 90% are not cultivated (Stauffer et al. 2017).

In West Africa, palm resources rank among the most appreciated Non-Timber Forest Products and contribute significantly to household incomes, particularly in the rural areas (Stauffer et al. 2017). Indeed, palms are important multipurpose trees in rural communities (Camara et al. 2017; Guinko and Ouédraogo 2005; Yaméogo et al. 2008), with all the parts being used for several purposes including food, traditional medicine, construction and trade (Ouattara et al. 2015). Besides, palms populations produce high amount of biomass in the frond and the stem which could allow them to contribute to climate change mitigation through carbon sequestration (Aholoukpè et al. 2013, 2018). Although the importance of palms for west African populations is undisputed, we still lack fundamental baseline information for the development of more responsible management practices. This includes a basic understanding of biology, taxonomy, genetic diversity, ecology, ethnobotany, applied harvesting practices and management techniques of palms**.** Regarding the substantial body of knowledge published on palms in West Africa, there is a need for capitalizing the available information to identify knowledge gaps and direct further research. Previous reviews of west African palms focused on the genus *Raphia* (Obahiagbon 2009; Russell 1965). Recently, Mogue Kamga et al. (2020) reviewed the uses and cultural importance of the Raphia's species in their distributional range. Stauffer et al. (2017) presented a floristic update of African palms and concluded to the presence of 39 species belonging to 14 genera in West Africa (Stauffer et al. 2017).

Here we carried out an analytical review to present an up-to-date overview of studies on diversity, uses, ecology and conservation of palms in West Africa. Specifically, this review aimed at (1) exploring the diversity and importance of palms species studied in West Africa; (2) summarizing the scope of the available literature; and (3) presenting key findings, knowledge gaps and prospects. We expect to provide synthesized information that would guide palms' domestication and conservation actions in West Africa.

Material and methods

Literature survey

We gathered scientific papers on electronic databases *Google Scholar, Web Of Science,* and general search web on *Google* by using a combination of generic and scientific names of palm trees occurring in West Africa (Stauffer et al. 2017). The checklist of palm species occurring in West Africa (following Stauffer et al. 2017) has been used to search literature on the different databases with a species-specific approach. Any article published in a peer-reviewed journal and having its title or keywords list, the name of a palm is included in this review.The articles that do not clearly specify the palm's name or the detailed description of the species are excluded from this study (e.g. Bi and Kouakou 2004; Idohou et al. 2015a). We extracted information from 108 articles, which carried out a study on palms published since 1930 and focused on many research fields to make a database. Besides, the reviews of literature and the studies on a global scale on palms (ex. Whole Africa) were considered to complete the information presented here (n = 8). All included articles were critically read.

Data extraction and analysis

Each species' scientific name, the publication date, the country, the study category of each article, and the different reported uses are extracted in each selected article. Some important biological traits of each palm species (leaf form, reproductive strategy, growth form) and their presence in dry areas are reported based on literature (Arbonnier 2009; Stauffer et al. 2014) and our fieldwork experience. The biological diversity of the palm species is estimated by the number of species, the number of genera, and the proportion of species belonging to every subfamily or having a particular biological trait.

The uses' information is extracted only from articles focusing on an ethnobotanical survey to report palms' uses in different communities. The data extracted concerned the palm part used and the uses category for each reported palm. The frequencies of the plant parts according to the used categories are calculated. Besides, the relative importance index (RI) of each palm species is calculated according to the formula of Tardio and Pardo-De-Santayan (2008) adapted by Zizka et al. (2015):

$$RI = \frac{[\max(FRC) + \max(RNU)]}{2}$$

With: RFC = relative frequency of citation (Frequency of citation/Number of References), RNU = Relative number of use-categories (Number of uses/Maximum number of uses of a species). The relative index of importance (RI) is calculated to rank the palm species according to their importance.

Correspondence analysis was computed to appreciate the link between plant parts and use categories of palms through the package '*FactorMiner*' in R program 3.6.1 (R Core Team 2019).

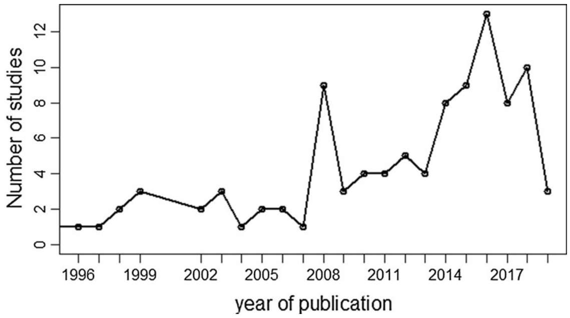

Fig. 1 Temporal trends of publication on palms in West Africa from 1996 to 2019

Results

Temporal and spatial trends and focus of the studies

The number of papers on palms in West Africa increased generally, but with some fluctuations (Fig. 1). About 73.83% of the papers included in our review were published from 2008 to 2019. The highest number of papers (n = 13) was recorded in 2016 while the lowest (n = 1) in many years before 2007.

In west Africa, the articles on palms come mostly from coastal countries as Nigeria, Benin, Ghana, and Cote d'Ivoire (Fig. 2a). The Sahel is relatively less investigated, with Burkina Faso holding the high number of publications in that region with 16 papers. In contrast, no publication has been reported in Mali and Mauritania, and only four publications from Niger (Fig. 2a). Moreover, the number of species reported is few in the Sahel than in the coastal countries (Fig. 2b). For instance, only two species are studied in Burkina Faso and Niger, while Stauffer et al. (2017) reported 8 and 7 species in these countries, respectively.

Most publications focused on ethnobotany, and to some extent, on biochemistry and population structure (Fig. 3). As compared to ethnobotany, there were fewer studies on distribution, and other fields as Biomass estimation, phenology and genetics (Fig. 3).

Biological diversity of palms in West Africa

From this literature survey, 25 species belonging to 12 genera and four subfamilies of palms were reported in West Africa (Table 1). Amongst the identified palm species, 32% grow in dry areas (Table 1), and 76% are pleonanthic (Fig. 4d). The hapaxanthic are made up of *Raphia*. Five growth forms and three leaf forms were identified with the dominance of erect and solitary stem (Fig. 4c) and pinnate leaves (Fig. 4a). The sexual pattern is dominated by monoecy (Fig. 4b).

Relative Importance of palms

Our findings highlighted the importance of 20 palm species over 25 identified in this review (Table 2). The relative importance index (RI) of each palm species, comprising between 0.09 and 0.80, was used to rank the species according to their usefulness in West Africa (Table 2). We do not report the RI of *R. regalis*

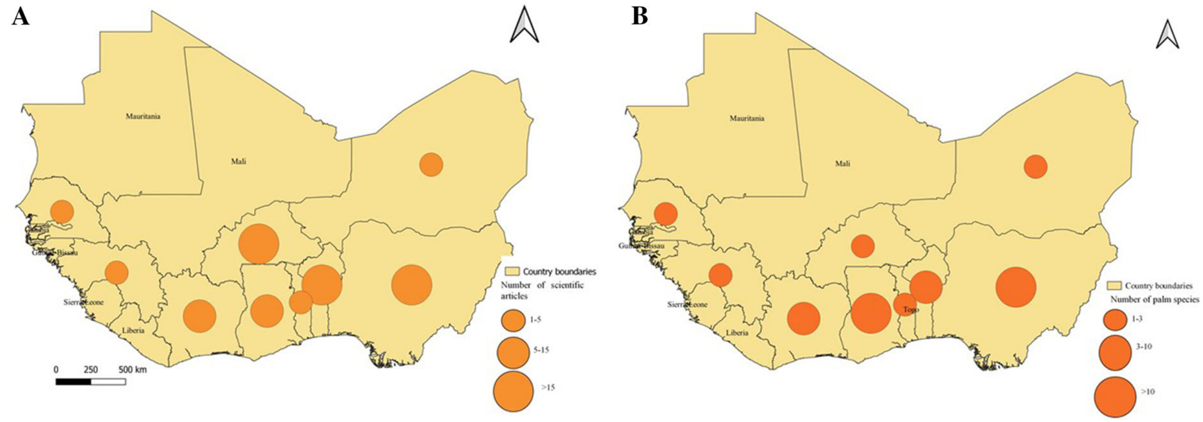

Fig. 2 **a** Spatial distribution of number of publications per country, **b** Spatial distribution of species recorded

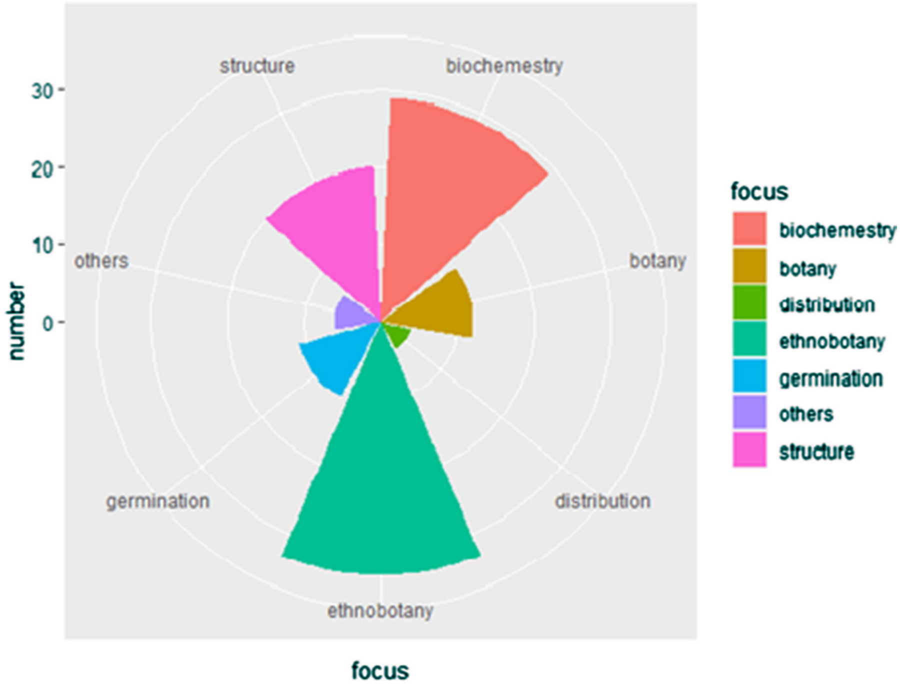

Fig. 3 Number of studies on palms following focus in West Africa

Becc., *Raphia farinifera* (Gaertn.) Hyl., *Raphia vinifera* P. Beauv. and *Phoenix dactilyfera* L. because few articles reported their uses in the west African palms' literature. Hence, *R. vinifera* was confused for a long time to *Raphia mannii* (Mogue Kamga et al. 2019). *Borassus aethiopum* Mart., *Elaeis guineensis* Jacq., *Hyphaene thebaica* Mart. and *Calamus deeratus* G. Mann & H. Wendl. were the most important palms in West Africa. At the same time, the rattans (*Eremospatha dransfieldii* Sunderl., *Eremospatha hookerii* (G. Mann & H. Wendl.) H. Wendl. and *Laccosperma opacum* Drude), *Phoenix reclinata* Jacq. and *Sclerosperma profizianum* Valk. & Sunderl. possessed low RI (Table 2).

Usefulness of palm parts in different categories

The cumulative percentage of variances derived from the correspondence analysis (CA) revealed that the first two dimensions explain 57.41% and 30.48% of

Table 1 Diversity of palms and their occurrence in dry areas in West Africa based on literature review

Species	Tribes	Subfamily	Occurrence in dry regions
Borassus aethiopum Mart	Borasseae	Coryphoideae	Yes
Borassus akeassii Bayton, Ouedr. & Guinko	Borasseae	Coryphoideae	Yes
Calamus deerratus G. Mann & H. Wendl	Calameae	Calamoideae	
Cocos nucifera L	Cocoseae	Arecoideae	Yes
Elaeis guineensis Jacq	Cocoseae	Arecoideae	Yes
Eremospatha dransfieldii Sunderl	Lepidocaryeae	Calamoideae	
Eremospatha hookeri (G. Mann & H. Wendl.) H. Wendl	Lepidocaryeae	Calamoideae	
Eremospatha macrocarpa H. Wendl	Lepidocaryeae	Calamoideae	
Hyphaene guineensis Schumach. & Thonn	Borasseae	Coryphoideae	
Hyphaene thebaica (L.) Mart	Borasseae	Coryphoideae	Yes
Laccosperma acutiflorum (Becc.) J. Dransf	Lepidocaryeae	Calamoideae	
Laccosperma leave (G. Mann & H. Wendl.) Kuntze	Lepidocaryeae	Calamoideae	
Laccosperma opacum Drude	Lepidocaryeae	Calamoideae	
Laccosperma secundiflorum (P. Beauv.) Kuntze	Lepidocaryeae	Calamoideae	
Nypa fructicans Wurmb		Nypoideae	
Oncocalamus mannii (H. Wendl.) H. wendl	Lepidocaryeae	Calamoideae	
Phoenix dactylifera L	Phoeniceae	Coryphoideae	Yes
Phoenix reclinata Jacq	Phoeniceae	Coryphoideae	Yes
Raphia hookeri G. Mann. & H. Wendl	Lepidocaryeae	Calamoideae	
Raphia palma-pinus (Gaertn.) Hutch	Lepidocaryeae	Calamoideae	
Raphia sudanica A. Chev	Lepidocaryeae	Calamoideae	Yes
Raphia vinifera P. Beauv	Lepidocaryeae	Calamoideae	
Raphia farinifera (Gaertn.) Hyl	Lepidocaryeae	Calamoideae	
Raphia regalis Becc	Lepidocaryeae	Calamoideae	
Sclerosperma profizianum Valk. & Sunderl	Sclerospermeae	Arecoideae	

the total variation (Fig. 5). Therefore, these axes explaining 87.89% of the total variation were used to describe the link between palms' parts and the uses categories. The correspondence analysis sustains that flowers, resin, and roots are mainly used in traditional medicine. In contrast, fruit, sap and hypocotyl are used in food and rites categories, and leaves and stipe are used as materials for building and handicrafts (Fig. 4).

Discussion

Biological diversity of palms

The number of species reported in this review is lower than that reported in previous studies (Stauffer et al. 2017). According to Stauffer et al. (2017), 39 species belonging to 13 genera of palms are present in West Africa, confirming that palms are under-investigated in this region. However, *E. dransfieldii*, *Hyphaene macrosperma* and *Oncocalamus wrightianus* were reported as endemic palm species in West Africa (Stauffer et al. 2017). No study was interested in the two last cited palm species. *H. macrosperma* is one of the eight recognised species of *Hyphaene*, extremely poorly known and for which type material is either very scant or completely lacking (Stauffer et al. 2018). *E. dransfieldii* grows only in the tropical rain forest in Ghana, Ivory Coast, and Sierra Leonne (Cosiaux et al. 2018; Ouattara et al. 2015). It is an endangered rattan palm because of habitat loss and over-exploitation of stems (Cosiaux et al. 2018). It is crucial to assess the conservation state of these species due to their endemism in West Africa. Also, the genus *Podococcus*

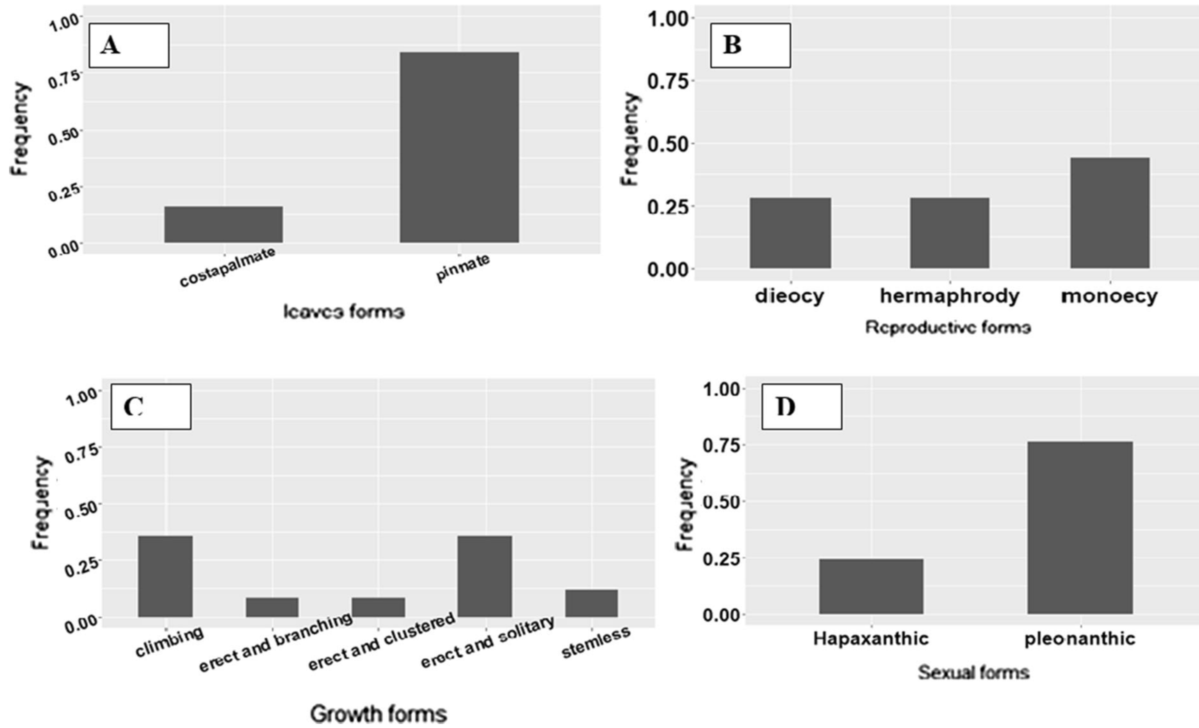

Fig. 4 Biological diversity of palms in West Africa: **a** Leaves forms, **b** Reproductive types, **c** Growth forms and **d** Sexual patterns

Table 2 Palm species in West Africa ranked using the Relative importance index

Species	RNU	RFC	RI	Rank
Borassus aethiopum Mart	6	0.375	0.80357143	1
Elaeis guineensis Jacq	7	0.05	0.55	2
Borassus akeassii Bayton, Ouedr. & Guinko	5	0.05	0.40714286	3
Hyphaene thebaica Mart	5	0.05	0.40714286	4
Calamus deeratus G. Mann & H. Wendl	4	0.05	0.26428571	5
Eremospatha macrocarpa H. Wendl	3	0.05	0.26428571	6
Laccosperma secundiflorum (P. Beauv.) Kuntze	3	0.05	0.26428571	7
Nypa fruticans Wurmb	3	0.05	0.23928571	8
Laccosperma acutiflorum (Becc.) J. Dransf	3	0.025	0.23928571	9
Raphia hookeri G. Mann. & H. Wendl	3	0.025	0.23928571	10
Raphia sudanica A. chev	2	0.05	0.19285714	11
Cocos nucifera L	2	0.025	0.16785714	12
Hyphaene guineensis Schumach. & Thonn.	2	0.025	0.16785714	13
Oncocalamus manni (H. Wendl.) H. wendl	2	0.025	0.16785714	14
Raphia palma-pinus (Gaertn.) Hutch	2	0.025	0.16785714	15
Eremospatha dransfieldii Sunderl	1	0.025	0.09642857	16
Eremospatha hookerii (G. Mann & H. Wendl.) H. Wendl	1	0.025	0.09642857	17
Laccosperma opacum Drude	1	0.025	0.09642857	18
Phoenix reclinata Jacq	1	0.025	0.09642857	19
Sclerosperma profizianum Valk. & Sunderl	1	0.025	0.09642857	20

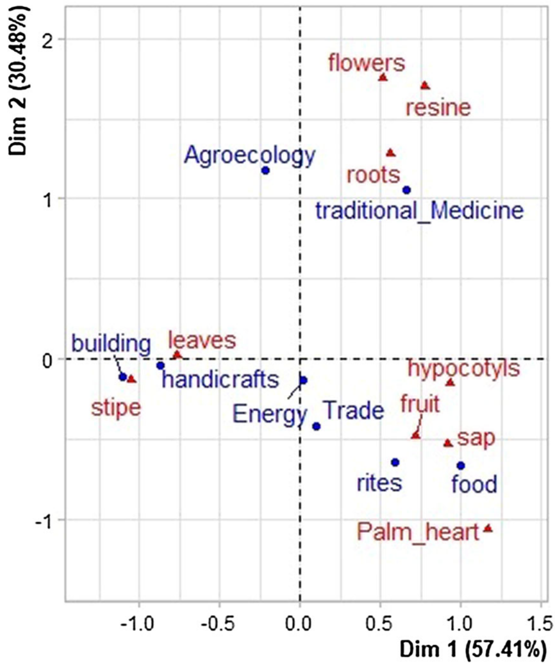

Fig. 5 Relationship between used parts and uses categories of west African palm species

was not reported from our literature survey, even if *Podococcus barteri* barely reach West Africa.

The palm family presents one of the most important growth form varieties in the plant kingdom. We identified five growth forms in West African palms in which erect, and solitary stem are the most frequent (Fig. 4). All species occurring in dry areas (32%) have an erect stem that makes this growth form the most adapted growth form in a dry area. One species, namely *H. thebaica* represented the erect and branching stem. The other growth forms constitute palms that grow exclusively in wet areas. Regarding leaves forms, only the genera *Borassus* and *Hyphaene* representing 16% of species, have costa-palmate leaves. The reproduction strategies are dominated by monoecy, while hermaphroditism and dioecy are less represented. These results corroborate the findings of Stauffer et al. (2017), who demonstrated the dominance of pinnate leaves and monoecy in African palm flora. The morphological diversity of palm was assessed for *B. athiopum* in Benin (Salako et al. 2019a) and *H. thebaica* in Benin (Idohou et al. 2015b). Salako et al. (2019a) identified five morphotypes of *B. aethiopum* based on fruits. They concluded that environmental factors are not the major drivers of morphological diversity while Idohou et al. (2015b) found three morphotypes for *H. thebaica* in Benin based on fruit characteristics.

Relative importance of palm species

The four first palm species ranked by RI in West Africa, namely *B. aethiopum*, *E. guineensis*, *B. akeassii,* and *H. thebaica,* naturally grow in a dry area. The socio-economic importance of these species has already been shown by many ethnobotanical surveys in West African countries (Camara et al. 2017; Salako et al. 2018a; Yaméogo et al. 2008). Before its description in 2006 (Bayton et al. 2006), *B. akeassii* has been confused to *B. aethiopium or Borassus flabellifer* (Ake Assi and Guinko 1996; Ouédraogo et al. 2002). However, these two species have been almost used in the same way by local people in West Africa, and their RI should be treated with caution.

No RI was reported for *P. dactylifera, R. vinifera, R. farinifera* and *R. regalis* suggesting lower importance of these species in West African palm literature. The RI calculated is dependent to the number of studies and the number of uses reported. While a high number of studies mentioning use of a species and a large number of different use categories can be interpreted as indicator of species importance, a low number of uses or references does not necessarily mean that a species is not of high value for specific purposes or on a local scale (Zizka et al. 2015). The date palm *P. dactylifera* is a cultivated palm in west Africa, and its uses are not documented in West Africa (Ouattara et al. 2015). The date palm is believed to have been domesticated in the Mesopotamian region more than 6,000 years ago, and is among the oldest cultivated tree crops. In desert oases of small-scale agriculture, where woody material is scarce, the date palm provides leaves for shading, thatching and weaving into baskets, mats, rope, hats etc. (Johnson 1998). Midribs and petioles have utility in construction and fencing. The entire date palm and date palm leaves have symbolic and ritual significance in major religions.

The non-report of the uses of *R. vinifera* in the literature could be explained by its long misidentification (Mogue Kamga et al. 2019). It has been recently reported that *R. hookeri* and *R. vinifera* are among the most exploited *Raphia* in Africa (Mogue Kamga et al.

2020). The leaves of *R. vinifera* and *R. regalis* are used in construction, and their fruits are eaten (Mogue Kamga et al. 2020). The epidermis of young leaflets yields raffia fibre, which is locally used for making baskets, mats, hats, bags, ropes, hammocks and ceremonial costumes. The Kuba people in DR Congo are well known for weaving beautiful raffia cloth used, such as ceremonial dance skirts and embroidered cloth panels for court rituals. In Europe, raffia fibre is used as tying material for horticulture and handicrafts. The leaves are highly valued for thatching. The petiole and rachis of the leaves of *Raphia vinifera* are often used as poles and rafters and for making furniture items such as stools, bedsteads and benches. Split midribs are woven into floor-mats.

In addition, rattans have low relative index value due to the absence of consumed organs. Almost half of species in the rattan palm genus *Eremospatha* are poorly known and require further collecting efforts (Stauffer et al. 2017), which could also justify their low RI reported in our study. Rattan provides canes for flogging, ropes for tying hides to drum frames, fish traps, and loop for climbing palm trees (Babajide and Bamidele 2004; Ouattara et al. 2015).

The usefulness of palm parts

Hypocotyls

Hypocotyls are a palm part mostly used in human food, in traditional medicine, and trade. Indeed, hypocotyls of *B. aethiopum* are boiled and consumed in many parts of West African regions (Guinko and Ouédraogo 2005; Salako et al. 2018a; Zongo et al. 2018). In traditional medicine, they are used to treat sexual weakness (Gbesso et al. 2016). In the east of Burkina Faso, the boiled hypocotyls are sold for 25FCFA (0.04USD) each (Kansole 2016). In contrast, it ranges between 50–150 FCFA (0.07–0.25 €) in Benin (Michon et al. 2018), contributing enormously to local people's income.

Fruit

The fruit is used in six categories: food, handicraft, traditional medicine, energy, trade and rites & ceremonies. The pulp of many palms as *B. aethiopum*, *B. akeassii*, *H. thebaica*, *E. guineensis* and *R. sudanica* are consumed raw or cooked (Camara et al. 2017; Salako et al. 2018a; Yaméogo et al. 2008). The flours of *B. aethiopum* had a high amount of crude fibre, carbohydrates, energy, relatively high water absorption capacity, swelling power, oil absorption capacity, and good flowability (Abe-Inge et al. 2018). In craft, the fruit hull was used as a substitute for the corrozo and employed to manufacture the buttons (Bellouard 1950). In Energy, *E. guineensis* pulp was used to produce fire (Camara et al. 2017). *Elaeis guineensis* seeds were used as sacred objects in rituals involved in oracles, which helped to discover the cause of disease or other calamities, for example, the Afan oracle of the Ewe in Togo, or the Ifa oracle of the Yorubas and Fa oracle of the Fon in Benin (Gruca et al. 2014).

Sap

The sap is one of the most important products from palms (Mogue Kamga et al. 2020; Obahiagbon 2009). In general, the sap is extracted from several palm species in West Africa as *Borassus aethiopum, B. akeassii, E. guineensis, Phoenix reclinata*, *Raphia sudanica*, *R. hookeri* and *R. vinifera* (Chevalier 1930; Mollet et al. 2000; Ouattara et al. 2015; Mogue Kamga et al. 2020). For Bellouard (1950), *Borassus'* sap is the best one, and this palm produces on average 100 L of sap per year. The sap was used for beverages, medicine, ritual, and trading. The sap/palm wine is useful in curing jaundice, measles, and flow of mammalian glands in nursing mothers (Obahiagbon 2009). The fresh sap of *B. aethiopum* contains less alcohol and some sugar (e.g. Sucrose, glucose and fructose), vitamin C, and minerals such as calcium, potassium, magnesium, and ammonium (Zongo et al. 2019). Thus, this sap presents a good nutritional value, and its consumption can improve the daily food intake of the rural population. The drinking of palm wine signals the start and end of all social activities undertaken by 50 million southern Nigeria people (Obahiagbon 2009). Sap can be use as vehicle for other medicines. In the trading, even if sap price varies according to the season, sap extraction seems to be the most remunerative activity compared to crafts (Yaméogo et al. 2008).

Leaves and stem

Palm leaves are widely used in handicrafts and construction (Guinko and Ouédraogo 2005; Michon et al. 2018; Salako et al. 2018a; Yaméogo et al. 2008; Zongo et al. 2018). For example, in Ghana, the petioles of *Raphia* are used to establish the dwelling's wall as well as the framework to the roof (Ouattara et al. 2015). In Cote d'Ivoire, the petioles of *B. aethiopum* are employed to build fences of fields (Portères 1964). In Agroforestry, leaves of *E. guineensis* are burnt and used as fertilizer (Camara et al. 2017). In medicine, young leaves of *B. akeassii* are used to treat earaches beginning of deafness (Yaméogo et al. 2008).

Palm stem are mostly used as material for construction and crafts. In construction. erect stems of males *Borassus* were mostly used to build house (Salako et al. 2018a; Yaméogo et al. 2008). Male individuals' preference was justified by the fullness and resistance of trunk non-attacked by pests (Chevalier 1930).

Flowers, resin, roots and palm heart

Palms flowers, resin and roots are used specifically in traditional medicine. The flower-bearing branches or rachillae of the staminate inflorescences of *B. aethiopum* are used to treat venereal diseases (Sambou et al. 1992). In Ghana, the Akan burn inflorescences from *Elaeis guineensis,* so the smoke drives away evil spirits (Gruca et al. 2014). Uses of resin are reported by few studies (Gschladt 1972; Yaméogo et al. 2008). The resin of *B. aethiopum* is used to delay children's dental thrust (Gschladt 1972; Yaméogo et al. 2008). *B. aethiopum* roots uses in medicine to treat malaria are reported by several ethnobotany survey (Salako et al. 2018a; Zongo et al. 2018) and confirmed by a pharmacological approach (Gruca et al. 2015). They are also used to treat sexual weakness (Gbesso et al. 2016).

Palm heart is used only in food. Indeed, palm heart of *B. aethiopum* and *H. thebaica* were rarely consumed by local people (Giffard 1966; Gschladt 1972).

Population structure of palm in West Africa

Palms stand structure is driven by natural and anthropogenic pressures which contribute to threaten palm populations in West Africa. It is evident that the extraction of non-timber forest products affects the palms' conservation. Indeed, the exploitation of palm heart, stem, roots, and hypocotyls can effectively lead to the palm's death. However, the overexploitation of organs that can immediately lead to palm death can affect the palm population's conservation. Indeed, it is proved that the fruit exploitation influences the stand structure and regeneration potential of *B. aethiopum* (Ahissou et al. 2017). Sap extraction harms the structure of *E. guinneensis, B. aethiopum* and *R. sudanica* in Cote d'Ivoire (Mollet et al. 2000). Nevertheless, sap extraction of *B. akeassii* in Burkina Faso is done by a sustainable practice that maintains the tree alive and exploitable for long years (Guinko and Ouédraogo 2005). It is important to document this practice to promote sustainable exploitation of sap in the palm population.

Other scientists were interested in the environmental patterns of the palm population's structure. Most of them studied the spatial pattern of palms (Barot et al. 1999a; Idohou et al. 2016a; Salako et al. 2018b). They mostly found that palms have an aggregative spatiality (Barot et al. 1999b; Salako et al. 2018b) with intraspecific competition between stages (Barot and Gignoux 2003) for *B. aethiopum*. However, there is no association between doum palm and other species (Idohou et al. 2016a), suggesting that heterospecific tree density may negatively influence palm structure. Salako et al. (2015; 2017) showed that elephants' influence on *B. aethiopum* structure in Benin causes a critical issue of conservation in protected areas. Besides, land use types and agricultural systems influence palms structure (Idohou et al. 2016a, b, c; Madelaine et al. 2008). For instance, the density of *B. aethiopum* was higher in protected areas than in agrosystems in Benin (Salako et al. 2019b). The influence of climate on palms structure has been sustained by many publications (Idohou et al. 2016a; Salako et al. 2018b). However, soil moisture and soil temperature affect the spatial abundance of *B. aethiopum* at Lamto Forest in Cote d'Ivoire (Douffi et al. 2018). In opposite, Kouassi et al. (2008) found no influence of soil moisture on rattans densities. That may be explained by the different ecology of those palm species. *B. aethiopum* with palmate leaves and erect solitary stem occurs in dry area although rattans with pinnate leaves and climbing growth form are mostly confined in swampy areas and occur in rivers border.

Impact of climate change on the distribution of palms

At the continental scale, climate constitutes the only strong environmental control of palm species distributions in Africa (Blach-Overgaard et al. 2010). Concerning the most important climatic predictors of African palm distributions, water-related factors were most important for 25 of the 29 species analysed (Blach-Overgaard et al. 2010). Thus, climate change could influence the future distribution of palms. Indeed, on average, African palm species may experience a decline in climatic suitability in $> 70\%$ of their current ranges by 2080 (Blach-Overgaard et al. 2015). In West Africa, palms distributions are governed by a combination of effects of climate (temperature and precipitation) and substrates (soils) and others ecological factor as Vegetation indices and gross primary productivity (Idohou et al. 2016b, c). The impact of climate variables on palms distribution suggests that climate change will probably influence palms distributions. Unfortunately, Idohou et al. (2016b) concluded that palm species distributions would remain largely stable under future climate forecasts in West Africa. However, some species are expected to experience some retraction of present-day distributional areas. In Benin, Idohou et al. (2016c) showed that wild palms responded differentially to different suites of environmental factors. Indeed, some species showed best model performance with Vegetation indices, Gross Primary Productivity and Soil (*B. aethiopum*), others with Gross Primary Productivity and Soil (*H thebaica*. *R. sudanica*) or Vegetation indices and Gross Primary Productivity (*P. reclinata*), or with only soil factor (*E. macrocarpa. L. opacum. Raphia hookeri* and *R. vinifera*) (Idohou et al. 2016c). In West Africa, most palm species' highest-priority areas are located along the coast (from Guinea to Nigeria) (Idohou et al. 2016b). The decrease in habitat suitability of *B. aethiopum* was pronounced in the semi-arid zone where the species is currently widely distributed (Salako et al. 2019b).

Local Perceptions and conservation practices of palm trees

Understanding local people's perceptions are important to make well-planned conservation actions. However, they inform about people's ecological knowledge. Indeed, many studies have been carried out to describe the technics of sap extraction (Onuche et al. 2012; Sambou et al. 2002) and the pattern of exploitations or transformation (Gbesso et al. 2017, 2013). Some other studies were interested in local ecological knowledge as interactions implying palms (Houndonougbo et al. 2017; Yameogo et al. 2016).

Concerning palm tapping, Onuche et al. (2012) identified three methods: the inflorescent flower, the terminal budding, and the tree felling methods. Ikegwu (2014) described these methods focusing on oil palm and *Raphia* tapping. The tree felling and the final budding methods are destructive because they lead to the death of the tapped trees (Onuche et al. 2012). The terminal budding method allowed obtaining at average 10 l per day per tree, but it leads to the death of the exploited trees after 35–40 days (Sambou et al. 2002).

There is no particular restriction for the exploitation of palm tree *B. aethiopum,* and only cutting down needs village chief or ranger authorization in Benin (Gbesso et al. 2017). There is contradictory interest in palm resource management between actors (Gbesso et al. 2017), making well conservation practice more difficult. In the contrary, *Borassus* species are protected in Burkina Faso.

People perceived interactions that imply palms. For local people in Burkina Faso, *B. akeassii* affects soil fertility by falling and decomposing fruit and leaves, which allowed the best development of the culture around palm trees (Yameogo et al. 2016). Besides, good coexistence between *B. akeassii* roots and culture ones and agricultural practices allowed the best development of palm (Yameogo et al. 2016).

Propagation of palms tree in West Africa

It is known that palm propagate mostly by seed germination. However, palm seeds germination was confronted to dormancy, embryo immaturity, seed coat impermeability, and physiological events during seed storage (Idohou et al. 2015b; Moussa et al. 1998). It is reported that high temperature pretreatment was essential for the germination of *E. guineensis* seeds (Labro et al. 1964; Rees 1961, 1962). The excellent germination rate of *E. guineensis* seeds was obtained by dry hot pretreatment at 40 °C for 80 days afterward cooled at the optimum seed moisture content (Rees

1961, 1962). Rabéchaud (1962) described five stages in *E. guineensis* seed germination. Currently, germination of *E. guineensis* has been mastered, and this palm has successfully grown and introduced in many areas for cultivation. Concerning savanna palms, namely *B. aethiopum*. *H. thebaica*. *P. reclinata* and *R. sudanica*. their germination is cryptogeal and occurs in two stages (Tahir et al. 2007). Among these savanna palms, *H. thebaica* attempts to draw more attention. Indeed, Moussa et al. (1998) carried out the dormancy of doum palm seed and obtained good results for seed soaking pretreatments. Based on fruit characteristics, Idohou et al. (2015b) identified three morphotypes related to phytodistricts in Benin and their influence on germination rate and seedlings growth of *H.thebaica*.

Knowledge gaps and future perspectives

Despite a lot of contributions to assess the diversity of west Africa palm flora (Ake Assi 1995; Ake Assi and Guinko 1996; Russell 1965; Tuley 1995; Stauffer et al. 2017), this diversity remains less known in West Africa, especially in arid and semi-arid regions, due to some taxonomic confusion among species (Ake Assi and Guinko 1996; Mogue Kamga et al. 2019). For instance, Mogue Kamga et al. (2019) concluded recently to a misidentification of *R. vinifera* and think of this species' presence in Burkina Faso, which is not yet confirmed so far. Therefore, we need to make an effort in collecting palms specimen in West Africa, which will contribute to the diversity knowledge in that region. To better understand the palm flora diversity, there is a need to embark in some taxonomic revision (e.g. genus *Raphia*) to clarify some species' position (Helmstetter et al. 2020). Taxonomic revision is necessary for identifying the species and implementing strategies of conservation of the diversity of the palm flora.

Previous studies identify morphotypes within palm species (Idohou et al. 2015b; Salako et al. 2019a) with no environmental drivers. Therefore, there is a need to assess the genetic diversity of palm species to understand the basis of this morphological variation. However, the identification of morphotypes focused on fruit morphology; there is also a need to assess the functional traits following the Leaf Height Seed scheme to highlight the variation pattern of traits.

The uses of palms have been extensively explored in West Africa (Camara et al. 2017; Guinko and Ouédraogo 2005; Michon et al. 2018; Ouattara et al. 2015; Salako et al. 2018a; Yaméogo et al. 2008), but some ethnobotanical data are still needed to understand the perceptions of the importance and the dynamic of palms. However, the uses of some taxa (e.g. rattans and *Raphia*) need to be documented in West African communities. All these ethnobotanical data are necessary to direct sustainable management and conservation of palms in West Africa by identifying the threats these species are undergoing and highlighting the traditional conservation strategies undertaken by local people. Future studies must also address the species' resilience capacities to promote a better conservation plan of palms in West Africa. This could be assessed through population structure, functional traits, and ecological niche modelling approaches. The population structure should assess the resilience capacities at the population level while the functional traits approach helps identify these capacities at the individual level. The palm distribution needs further investigation to understand the pattern of palms distribution in the Sahel and identify the priority area of conservation at the local scale. Indeed, the current distribution study of palms focused on the coastal areas as Benin (Idohou et al. 2016c) or to regional scale as West Africa (Idohou et al. 2016b). In general, the plants in dry and humid regions of the tropics might respond differently to climate and land-use changes. It is urgent to carry out the distribution of palms in dry area and identify priority area for its conservation in the context of climate and anthropogenic changes.

Conclusion

This analytical review provides evidence that palms are under-investigated in West Africa. From the 108 research articles published between 1930 and 2019, we identified 25 palm species belonging to 12 genera and five growth forms, three sexual patterns, and two leaves forms. The growth forms are dominated by erect and solitary palm, and the pinnate leaves are the most dominant among leaves forms. Only *Raphia* are hapaxanthic, and monoecy is dominant. Most of the reported studies focused on ethnobotany, population structure, and biochemical aspects. There is clear evidence of a link between used parts and uses categories and species growing in dry areas are among the most important in West African palm literature (*Borassus aethiopum*, *Elaeis guineensis*, *Borassus akeassii* and *Hyphaene thebaica*). The population structure of palms is driven by environmental factors (climate and land use) and anthropogenic pressure (sap tapping and fruit exploitation). Despite these studies, there are knowledge gaps regarding genetic drivers of morphotypes, capacities resilience of these species to manifold pressure, including climate change and carbon stock estimation. The latter is essential to highlight the contribution of these species to climate change mitigation. Future studies should also focus on arid and semi-arid areas to contribute to the specimen collection in West Africa.

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Declarations

Conflict of interests Authors declare that they have no conflict of interest.

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