Diversity of Uses and Local Knowledge Associated with Wild African Plum Trees, *Dacryodes edulis*, Among Different Ethnic Groups in the Congo Basin

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Abstract: *Dacryodes edulis*, known as the African plum tree, is an important indigenous fruit species in Central Africa that has long been used by humans. Wild individuals of this species are found in forests, whereas cultivated trees are distributed in agroforests and homegardens. As knowledge is sparse regarding local knowledge and uses of wild African plum trees this study fills this gap by collecting and analyzing the knowledge of different ethnic groups in Cameroon and Gabon. Focus groups, field visits, and individual surveys were conducted with 243 participants from the Baka, Fang, Nzime, Bassa, and Obamba ethnic groups. Several vernacular names were reported for wild African plum trees, generally related to their morphology and environment. Fruit size was the most common morphological trait used to identify wild individuals. This study recorded six tree parts and five different use categories, with food being the most common use, followed by medicine. Wild African plum trees have a socio-cultural importance for the Baka who still depend on forests for their livelihood. However, wild trees are not usually included in conservation strategies; hence, the wild form of this species is at risk due to poor regeneration success without human intervention. Recommended measures for sustainable management and conservation of wild individuals of this species are discussed.

Résumé: Dacryodes edulis, encore appelé safoutier ou prunier, est une espèce importante d'arbre fruitier originaire d'Afrique centrale, utilisée depuis longtemps par les humains. Les individus

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sauvages sont retrouvés en forêt, tandis que les arbres cultivés sont dispersés dans les agroforêts et jardins de case. Les connaissances locales et les utilisations des safoutiers sauvages sont peu documentées; cette étude vise donc à combler cette lacune en collectant et en analysant ces données auprès de différents groupes ethniques au Cameroun et au Gabon. Des discussions de groupes, des visites de terrain et des enquêtes ethnobotaniques ont été menées auprès de 243 participants appartenant aux groupes ethniques constitués de Baka, Fang, Nzimé, Bassa et Obamba. Les safoutiers sauvages sont désignés par plusieurs noms vernaculaires liés à leur morphologie et à leur environnement. Cette étude a recensé six parties de l'arbre et cinq catégories d'usages, avec l'usage alimentaire comme le plus répandu suivi de l'usage médicinal. Les safoutiers sauvages ont une importance socio-culturelle pour les groupes ethniques, en particulier pour les Baka qui dépendent encore des forêts pour leur subsistance. Cependant, les populations sauvages de *Dacryodes edulis* ne sont généralement pas incluses dans les stratégies de conservation, et ce compartiment est donc menacé en raison du faible succès de régénération sans intervention humaine. Les mesures recommandées pour leur gestion durable et leur conservation sont discutées.

Keywords: Central Africa, Ethnic groups, Ethnobotany, Morphological traits, Wild form

Introduction

With more than 220 million hectares of tropical forests, the Congo Basin is the second largest tropical forest in the world after Amazonia and represents a hotspot of biodiversity in Africa (FAO and UNEP 2020). Sixty to eighty percent of rural populations in the region depend on the forests and tree resources to meet their daily needs (Betti et al. 2016). As part of these resources, non-timber forest products (NTFPs) contribute to the livelihood of people by providing food, medicine, construction materials, and other socio-cultural assets (Sonwa et al. 2002). Trees provide essential shade for cacao and coffee crops, helping to diversify the products and services generated by agroforests (Jagoret et al. 2014). The use of and high interest in NTFPs have led to commercial activities that generate income for local people (Arnold and Pérez 2001). However, the exploitation of NTFPs for commercial purposes is not always done using sustainable methods (McLain 2005).

Therefore, in the context of increased human population growth and pressure on NTFP resources exploited from natural ecosystems, strategies are required to ensure the sustainable management and conservation of plant species that provide useful products and services for the livelihoods of local populations. Several multipurpose species growing in the wild are being selected based on local knowledge, preserved, and progressively introduced and managed in farmers' plantations for improved quality and production quantity; this is the process of participatory domestication (Leakey et al. 2022). To support this process, current research initiatives have explored the contribution of local knowledge in developing innovations and techniques for domesticating these multipurpose indigenous species through agroforestry (Rasambo et al. 2021; Tchoundjeu et al. 2006). This has partially reduced the dependency of rural communities on selected forest species, hence reducing pressure on natural forests through the creation of alternative supply sources on-farm (Vihotogbé et al. 2014).

African communities have traditional knowledge about the value and properties of many of the NTFPs they use for their daily needs (Moupela et al. 2011). Such knowledge is dynamic and often varies with the socio-cultural and economic context (Yogom et al., 2020). Local Ecological Knowledge (LEK), based on people's direct interactions with their environment, can shed light on ecosystem change and contribute to conservation (Chalmers and Fabricius 2007). Despite the widespread notion that local and indigenous knowledge systems decline with time due to social, economic, environmental, and cultural changes (Cox 2000), a dynamic view of knowledge is gradually emerging from

academic perspectives. LEK is subject to hybridization by integration of new forms of information or of external socio-economic factors (Aswani et al. 2018). Causes of these changes can be multiple and are often examined by relating the variability of traditional knowledge to the factors driving social change (Aswani et al. 2020), or to human adaptive capacity to climate change (Berkes and Jolly 2002). Therefore, understanding the unique value of a specific NTFP species and its important features for local communities is key to informing its sustainable management (Kouyate 2005). Management strategies of NTFPs can only be sustainable if they take into account cultural, social, and economic values and their dynamics over time, as well as the specificities associated with sociodemographic factors (gender, age, and location) (Traoré et al. 2021; Yogom et al. 2020).

Dacryodes edulis (G.Don) H.J.Lam (Burseraceae), known as the "African plum tree" ("prunier," "safoutier," or "atangatier" in French), is present in its wild form in Central African rainforests. Wild African plum trees can be distinguished from the cultivated form based on morphological traits such as tree height as well as the size of fruits and flowers (Mboujda et al. 2022). During Bantu expansion around 3000 BP, the Bantus practiced deforestation for agriculture, cultivating crops such as yam, cowpea and pearl millet, and exploiting species they considered useful (Bostoen et al. 2015). The African plum tree was present around human settlements for at least the past several centuries. It was described in a travelogue from the nineteenth century as trees found around villages and it was noted that the villagers took great care of them (Tuckey 1818). Earlier, the African plum tree was described "as producing plum-like fruits of the color of fire, and an aromatic smell when roasted under hot ashes" (Cavazzi 1690). More recent literature referred to the species as a multi-purpose tree (Awono and Levang 2018; Leakey et al. 2004; Poligui et al. 2013; Waruhiu et al. 2004) valued particularly for the pulp/mesocarp of its fruit that can be eaten raw or cooked, and for the economic value of its fruits traded at local, national, regional, and international levels. Its bark, leaves, stems, and roots are also used for medicine and as firewood (Poligui et al. 2013; Waruhiu et al. 2004). Chemical, biochemical, and nutritional studies have demonstrated the potential value of *Dacryodes edulis* products in cosmetic, agro-alimentary, and pharmaceuticals industries and its possible uses in the production of new foods and other dietary supplements (Leakey et al. 2022). Twenty years ago, the economic value of the African plum tree fruit trade in Europe was estimated at over US$ 2 million/year (Awono et al. 2002). Given the enhanced nutritional, medicinal, and socio-economic value of the species today (Awono and Levang 2018; Leakey et al. 2022; Poligui et al. 2013), understanding the dynamics of local knowledge associated with its domestication history among different ethnic groups and geographical contexts in the Congo Basin is of paramount importance. The broader goal is to promote sustainable development and preservation of indigenous knowledge, in order to inform policies aimed at conserving the diversity of wild and crop relatives contributing to food security (Petersen et al. 2014).

The African plum tree's status as a species that is primarily planted was already noted at the beginning of the twentieth century by Dendrophilus (1933) who observed that *Dacryodes edulis* was essentially a cultivated tree and though, of course, originally a wild species, it is not often found as such in the wild. Its cultivation has now taken another turn with the promotion of participatory domestication approaches that began several years ago and the selection of trees with specific traits, such as large fruit size, pulp color, and taste, which were favored and appreciated by local people for food and markets (Leakey et al. 2004; Waruhiu et al. 2004). Thus, with the development of improved propagation techniques, the species became increasingly integrated into farming systems for enhanced and diversified farmer income sources (Leakey et al. 2004). Previous studies on the importance and uses of cultivated individuals of *Dacryodes edulis* have been conducted in Africa, particularly in Cameroon (Awono et al. 2002; Leakey et al. 2004; Mbeuyo et al. 2013; Noumi et al. 2006; Rimlinger et al. 2019, 2021), but little attention has been paid to the wild form of the species. In the context of rapid socio-cultural and global change, there is a growing concern for the conservation of indigenous NTFP species in order to mitigate the growing risk of losing ancestral knowledge and skills associated with

them (Ouoba et al. 2018; Traoré et al. 2021). This risk is exacerbated by several factors, including firstly, the fact that such knowledge is only transmitted orally in many parts of Africa (Ouoba et al. 2018); secondly, population migration especially concerning young people, thirdly urbanization (Inkoto et al. 2019); and fourthly, loss of cultural identity due to socio-economic change, modernization, colonization, and globalization (Fleury 2002). This study was initiated to document the local knowledge and perceptions of wild African plum trees by some ethnic groups in the species' native distribution areas in the Congo Basin. Such knowledge has the potential to enable the development of tools for the conservation and sustainable use of wild resources for multiple purposes, including their potential in breeding programs. The study also assesses how local knowledge of the wild form of the species varies according to socio-demographic characteristics in selected sites in the Congo Basin. More specifically, three main research questions emerged: (i) Which local knowledge is associated with wild African plum trees by different ethnic groups in the species' natural environment?; (ii) What are the local criteria used by these ethnic groups for identifying and distinguishing wild African plum trees from cultivated individuals?; and, (iii) What are the uses of wild African plum trees? The responses to these questions will contribute to the reconstruction of the domestication history of *Dacryodes edulis* in the Congo Basin.

Materials and Methods

Study Species

Dacryodes edulis is a species in the family Burseraceae, indigenous to Central Africa and the Gulf of Guinea (Onana 2008). The species is found in the wild (Fig. 1) across the humid tropical zone of Central Africa in the Republic of the Congo, Cameroon, Gabon, and the Democratic Republic of the Congo (Onana 2008). *Dacryodes edulis* is widely cultivated in central Africa and found in agroforestry systems such as in homegardens. The cultivated trees of the species can reach 15 m in height with the thickness of the fruit mesocarp ranging from 2 to 10 mm, while the wild trees can reach 25–40 m in height with the fruit mesocarp thickness varying from 0.3 to 7 mm (Mboujda et al. 2022) (Fig. 1a). In Cameroon, the flowering of trees on-farm takes place from December to February and fruits are available from May to October, with a peak production between late July and early August (Kengue et al. 2012). In Gabon, the flowering starts around August and the fruits mature in December. Cultivated fruits are highly variable with differences in size, shape, mesocarp thickness, and color, taste, as well as exocarp color (Ndindeng et al. 2008), whereas wild fruits are rather homogenous for these traits (Mboujda et al. 2022).

Study Area

Data were collected in Cameroon and Gabon (Fig. 2). In Cameroon, the survey was carried out in ten sites selected in the center (Eseka, Yaounde, and Makak), South (Bipindi-Lolodorf, Campo-ma'an, Akom II), and east (Somalomo, Messock, Yokadouma, and Messamena) administrative regions. In Gabon, only one site was investigated: Ngoma in the Haut-Ogooue region. The selection of the sites was based on information gathered from the local stations of the Ministry of Forestry and Wildlife related to the presence or absence of wild African plum trees.

In Cameroon, the most common ethnic groups in the East region are the Baka Pygmies and the Nzime. The climate of the region is tropical humid, with one rainy season between August and November and a dry season between November and March. The area is covered by a mixture of evergreen and moist semi-deciduous forest. Several forestry activities take place in this area where much of the primary forest is gradually being converted into other land uses, including secondary forest, cocoa- or coffee-based agroforestry systems, and woodlots (Gallois et al. 2020). The South region of Cameroon is characterized by a tropical rainforest climate consisting of two rainy seasons, from March to June, and from September to November. In this region, the Fang are the dominant ethnic group. The natural vegetation of the area consists of rainforest and mangroves. The main activities of local communities are the collection of NTFPs and agriculture (Carrière 2003). In the Central region, the most common ethnic groups are the Bassa and the Beti (related to the Fang). The

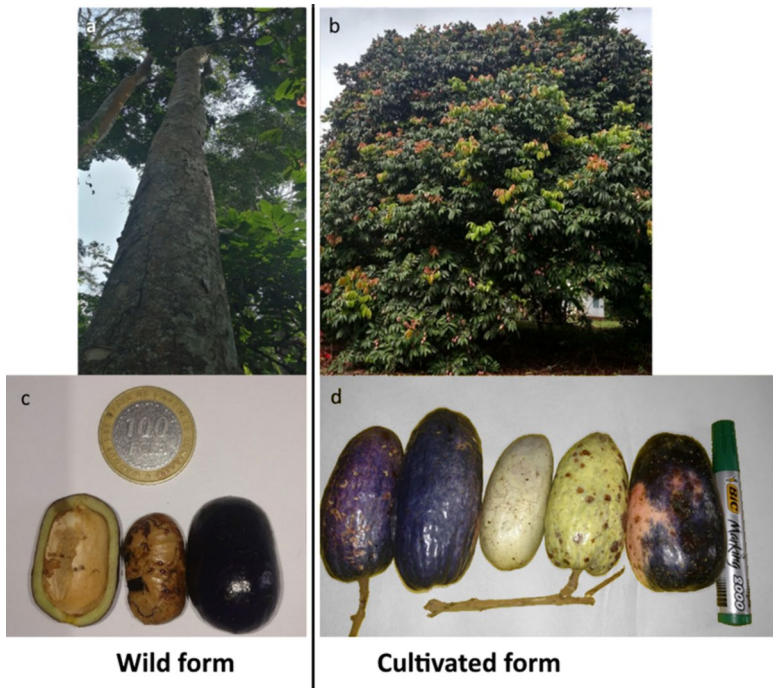

Fig. 1. **a** Stem of a wild African plum tree in the Campo-Ma'an forest (South Cameroon). **b** Cultivated African plum tree growing in a homegarden in Eseka (Centre Cameroon). **c** Fruits collected from a wild African plum tree in the Massea forest (East Cameroon). **d** Fruits collected from different cultivated African plum trees

vegetation type is semi-deciduous forest with a tropical humid climate characterized by a dry season from mid-November to mid-March and a rainy season from March to November. The main activity of the population is agriculture, with palm oil and cacao as the primary cash crops.

In Gabon, over 85% of land in the study area is covered by tropical forest. The Haut-Ogooue region is located in the south of the country and characterized by diverse landscapes. The climate is equatorial, hot, and humid, with two alternating seasons: the wet seasons from October to December and from March to June; and the dry seasons from June to September and December to January. The region is home to several ethnic groups, but the study was carried out among the Obamba group, the main ethnic group around Okondja-Ngoma-Masuku. The population's activities consist of agriculture (mainly subsistence farming of maize, cassava, and banana), fishing, and hunting.

Participant Sampling and Data Collection

The study was conducted from 2018 to 2020 and facilitated by an introduction letter provided by the University of Dschang-Cameroon and mission order delivered by the *French National Research Institute for Sustainable Development* (IRD)-Cameroon to local authorities requesting their assistance and cooperation in carrying out the activity in their constituency. In Gabon, the research permit and mission order were delivered by the *Centre National de Recherche Scientifique* (CENAREST) and the *Herbier National du Gabon* (HNG). Once in the field, we conducted an introductory conversation with the chief of each site in which we explained the objectives and methodology of the research and requested permission to interview resource persons and visit sites with them. The people interviewed gave their written agreement to participate in the

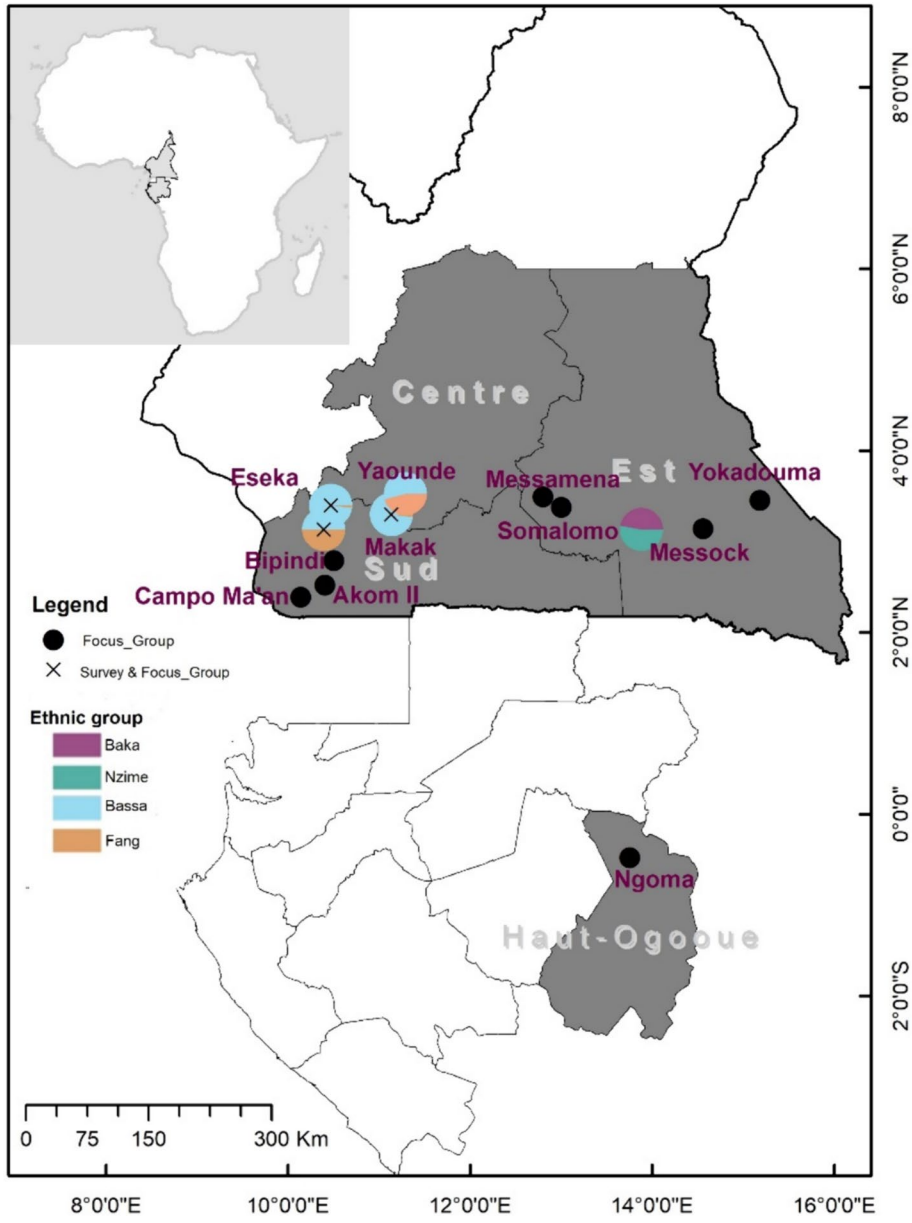

Fig. 2. Location of the study sites with the ethnic groups surveyed; pie charts indicate the ethnic group composition of study participants in each site

survey and an authorization form was signed for the pictures to be taken.

The data were collected by triangulation through a combination of surveys (using semi-structured interviews), focus group discussions, and field visits in forests. Nine focus groups with 132 participants (7–15 people per group) (Table 1) were conducted in French and vernacular languages (depending on the site) with the assistance of local interpreters. Focus groups introduced the research team, the research project, and its objectives to local populations in different

sites. Participants helped researchers understand the local context regarding identification and distribution of wild African plum trees, tree parts collected and their uses, cultivation, and consumption of wild African plum tree fruits.

Semi-structured interviews were conducted with 243 participants from different socio-demographic categories (details in Table 1) purposively selected for their knowledge of the species using non-random snowball sampling with free consent obtained beforehand (Albuquerque et al. 2014), in accordance with the Code of Ethics of the International Society of Ethnobiology (ISE 2006). Participants were selected during focus groups discussion and were then invited to recommend other people (absent from focus groups) they knew who also had good knowledge of wild African plum trees. The new people who were recommended in turn became participants and were encouraged to also recommend others. For each semi-structured interview, the participant's gender, age, and ethnicity were recorded (Table 1).

To assess a participant's understanding of the local definition of wild African plum trees, a multiple-choice questionnaire was used in which each participant chose the definition that best fit their understanding from the following list of propositions: (a) wild African plum trees are not propagated by humans and can be found either in natural forests, fallows, or farmers' fields; (b) wild African plum trees exist only in natural forests; (c) a tree similar to the cultivated African plum tree, but found in the forest; and (d) other reason (participants were then asked to specify).

The free listing method (Quinlan 2005) was used to document local criteria for the

Table 1. Distribution of participants (number of people) according to socio-demographic characteristics within villages and sites for the focus groups (A) and interviews (B)

A. Focus groups					
Region	Site	Ethnic group	Men	Women	Total
Haut-Ogooue	Ngoma	Obamba	4	6	10
Yokadouma	Massea	Nzime	15	2	17
Akom II	Communal forest	Baka	7	8	15
Campo-Ma'an	Mvini	Baka	4	3	7
Messock	Messea	Baka	13	18	31
	Moangue	Baka	8	8	16
Somalomo	Etou	Nzime	7	2	9
Messamena	Bifalone	Baka	8	7	15
Bipindi	Memel I	Baka	8	4	12
B. Interviews					
Region	Site	Baka	Bassa	Fang	Nzime
Messock	Messea	–	–	–	8
	Bandoum	13	–	–	4
	Moangue	21	–	–	26
Bipindi	Memel I	–	17	17	–
Eseka	Eseka	–	50	1	–
Makak	Mbeng		48	1	–
Yaounde	Yaounde	–	20	17	–
Socio-demographic characteristics					
Gender	Men	25	88	22	21
	Women	9	47	14	17
Age (years)	<40	9	35	15	13
	40–60	19	56	7	13
	>60	6	44	14	12
	Total	34	135	36	38

identification and differentiation of wild African plum trees by participants, including the plant parts exploited and their uses; as well as information about the habitat and conservation status of the species. Finally, field visits were carried out with the participants (Albuquerque et al. 2014) at their farms and in the forests with the help of guides and participants who were able to locate wild African plum trees.

Data Analysis

Data from the focus groups was analyzed using the thematic coding method of Miles and Huberman (2003). Data was transcribed for each study site followed by identification of key themes to create a documented archive of exchanges. The key themes that emerged from the discussions were used to support and supplement the results of the individual interviews.

Information from the interviews was categorized by ethnic group, gender, age, and study site. The Beti ethnic group was combined with the Fang because they share similar cultural and historical characteristics and are often considered interchangeably. The nested model was used to show a relationship between ethnic group, age group, and gender in relation to knowledge of the occurrence of the species, using the *dplyr* package (Wickham et al. 2019). To analyze the distribution of answers related to the local definitions of wild African plum trees among different ethnic groups, the χ^2 test was used to determine the relationship between these two categorical variables. In addition, the correlation test was used to plot the level of the relationship between the two categorical variables, local definition and ethnic group, based on the calculated percentage contributions of the Pearson residuals from the χ^2 test with the *Corrplot* package (Wei 2009). The following indices used in ethnosciences were computed to evaluate the relative importance of wild African plum trees for a given ethnic group (Houéhanou et al. 2016) (see Electronic Supplementary Material 1 [ESM 1] for the calculation details). The frequency of citation (FC) refers to the number of times a particular answer or item was cited or mentioned. Reported uses (RU) is the total number of uses cited by all the participants. The use value (UV) is the ratio of the number of uses cited by the participants of one ethnic group by the total number of participants. The cultural importance index (CI) assesses the variation in knowledge between ethnic groups and the species' importance, representing the ratio between the occurrence frequency (number of participants reporting uses per total number of participants) and the number of uses of the species per total number of participants by ethnic group. The fidelity level (% FL) was used for assessing the answer rates per specific use (Gouwakinnou et al. 2011). An alluvial plot helped visualize the relationship between ethnic groups, tree parts collected, and their uses (Bojanowski and Edwards 2016). The Analysis of Variance (ANOVA) model was used to test the significant variation in the mean use category frequencies according to age, ethnic group, and gender, using the *FactoMineR* package (Husson et al. 2016). Mosaic plots made with the *treemap* package (Tennekes and Ellis 2017) were applied to visualize uses by gender and by ethnic group. All analyses were carried out in R version 4.0.4 software (R Development Core Team 2021).

Results

LEK of Wild African Plum Trees

Names and Local Knowledge of the Habitat of Wild African Plum Trees

The majority of participants from all ethnic groups (75%) were aware of the existence of wild African plum trees in forests near their homes. All Baka participants knew about the existence of the species, while fewer participants (varying from 90 to 61%) from other groups were aware of the existence of the species in the wild. The nested model showed that ethnic group, gender, and age influenced significantly (p value < 0.0001) knowledge of the existence of wild African plum trees. For gender, the proportion was found to be significantly greater for men ($p < 0.001$) than for women. As for age, a significantly greater proportion was observed among people older than 60 years ($p \leq 0.001$) and between 40 and 60 years old ($p < 0.05$). The results from the surveys and focus groups showed that the

participating ethnic groups used several local names to refer to the wild form of the species, such as *sa na bélé* (Baka), *asamagoum* (Bassa), and *sa dûk* (Fang) (Table 2).

Fifty-one percent of participants mentioned that they had already found wild African plum trees in the forest. Specifically, the wild trees were found in natural mature forests, secondary forests, fallow lands, and cocoa agroforests (ESM 2). According to the Baka and Nzime ethnic groups, wild African plum trees are found respectively in secondary forests (85% and 84%), fallow lands (100% and 79%), natural mature forests (67% and 79%), and cocoa agroforests (old or new plantations where they were either spared during slashing and burning, or planted) (53% and 79%). These ethnic groups stated that wild individuals of the species were found on hills or flat lands (FC = 61%). In addition, their presence in an area was said to be indicative of good soil fertility (68%). Few participants (less than 3% of Baka, Bassa, and Fang) mentioned that wild African plum trees were mainly found in disturbed areas, sometimes in association with other useful forest species (ESM 3).

Local Definitions of the Wild Form of the African Plum Tree

Definitions of wild African plum trees varied by ethnic group. From the list of options provided during interviews (see "Materials and Methods" section), Bassa and Baka participants gave three different definitions of wild African plum trees, with the most common response being "(b) Wild African plum trees exist only in natural forests" (60% and 56% of participants, respectively), followed by "(a) Wild African plum trees are not propagated by humans and can be found either in natural forests, fallows, or farmers' fields (38% and 29% respectively). For the Nzime and the Fang, (76% and 55%, respectively), the second definition (b) was the most common. Both definitions were chosen by some few respondants from the Baka (15%) and Nzime (6%) (Fig. 3a). The third definition (c) "A tree similar to the cultivated African plum tree but found in the forest" was chosen by very few Nzime (3%) and Bassa (1%) participants. This definition was chosen by the Obamba in Gabon during the focus groups; wild individuals were named either *si'i* or *ozigo/atangatier sauvage* (in French). Field visits revealed that *ozigo* (*Dacryodes buettneri* (Engl.) H.J.Lam) is a forest tree that can be mistakenly identified as the wild African plum tree. The frequency of citation of the different definitions was dependent on the participants' ethnic group (χ^2 test, p value < 0.0001). Positive values (in blue) specify a positive association between the local definitions (a_b) with the Baka, (a) and (b) with the Nzime (Fig. 3b). The remaining associations between local definitions and ethnic groups were negative (in red).

In addition to possible definitions provided by the study authors, other local definitions were recorded for wild African plum trees, such as a "tree planted without the intervention

Table 2. Local names for wild African plum trees by ethnic group (data from focus groups and interviews)

Country	Ethnic group	Local names	Meaning (translated to English)
Cameroon	Baka	*sa na bélé*	Forest African plum tree
		lêka senê na dî	Forest living African plum tree
		mbanya	Toucan African plum tree
		mbamasen	Toucan African plum tree
		osongo/songo	Toucan African plum tree
	Bassa	*asamagoum*	Bird African plum tree
		samagoum	Bird African plum tree
	Fang	*sa dûk*	Forest African plum tree
	Nzime	*sa dûk*	Forest African plum
		esebegnoun	Wild African plum tree
		esanou/esameton	Wild African plum tree
Gabon	Obamba	*si'i*	Forest African plum tree

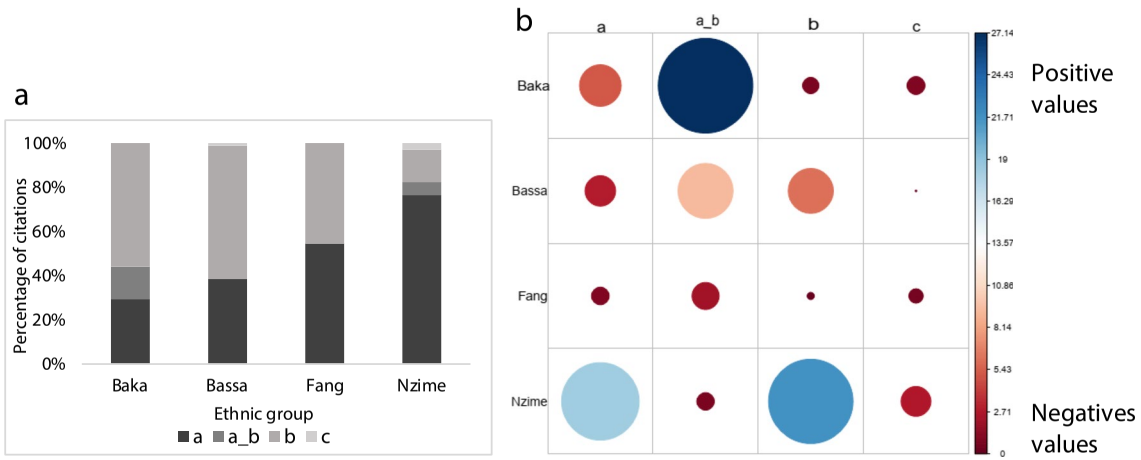

Fig. 3. **a** Local definitions of wild African plum trees according to four ethnic groups based on a list of choices provided to study participants by the authors. Definitions: (a) Wild African plum trees are not propagated by humans and can be found either in natural forests, fallows, or farmers' fields; (b) Wild African plum trees exist only in natural forests; (c) A tree similar to the cultivated African plum tree, but found in the forest; (a_b) refers to participants using both (a) and (b) local definitions. **b** Correlation between local definitions of wild African plum trees and ethnic group obtained by a Pearson's residual correlation test, measuring the difference between observed and expected frequencies in each contingency table cell in the χ^2test (for a given cell, the size of the circle is proportional to the amount of the cell contribution). Positive values (blue) indicate a positive co-variation, and red values indicate a negative co-variation between the residuals and the variable. A negative association between (a) and the Bassa category indicates that the frequencies observed for (a) in this category are generally lower than expected

of man whose crude fruits can become soft in the mouth" (Baka participant); "tree abandoned in the forest and the fruits are eaten by birds" (Bassa participant); "tree is neglected, and planted by birds that disperse the seeds" (Fang participant); and "tree with tasteful fruit but the one in the farm is better" (Nzime participant). Some definitions also identified wild African plum trees as "the tree of birds, squirrels, and toucans who eat the fruit and disperse the seeds in the forest" (Bassa participant, ESM 4).

Preservation Practices of Wild African Plum Trees

No planting practice was mentioned for wild African plum trees by 99% of the participants. Only one participant from the Bassa ethnic group in Bipindi reported attempting planting fruits from the wild African plum tree, though only one seedling thrived but was eaten by animals and did not survive. Baka (11% of those who participated in the focus group) in the communal forest of Akom II reported, "We don't plant the small forest plum tree here. We only plant the ones from the village, we take the seeds from Akom II and plant them here." Another Baka participant explained, "We have never tried to plant the forest plum [tree]; it is already hard to plant the ones from the village, so how can you dare planting the ones from the forest?" The participants from Gabon (Obamba) stated, "we have never tried to plant '*wild atangatier*'; but we believe the seeds from its fruits can grow like any other fruit tree." About 84% of the participants mentioned that wild African plum trees will be extinct in their habitat over the next few years because of habitat degradation. Hence, 83% of the participants also recognized the need to plant more wild African plum trees for future generations.

Finally, according to participants, depending on the plant part needed, wild African plum trees can be replaced by several other forest species from the Burseraceae Family. For instance, bark from *Canarium schweinfurthii* Engl. and *Dacryodes macrophylla* (Oliv.) H.J.Lam can be substituted for the same medicinal purpose according to the Baka ethnic group (ESM 5).

Identification and Differentiation Criteria Related to Wild African Plum Trees

Identification Criteria of Wild African Plum Trees

Tree parts that are used by local people to identify wild African plum trees were the fruits (FC = 69%), the leaves (FC = 38%), and the bark (FC = 8%). The Baka, Fang, and Bassa recognized the wild tree in its habitat respectively by the small size of its fruits (100%, 58%, 67%) and leaves (97%, 28%, 33%), and by the aromatic smell of its bark (24%, 11%, 7%). The same characteristics were cited in the focus groups where the Obamba (Gabon) used the fruit size and smell to identify the *ozigo* trees in the forest.

Differentiation Criteria Between Wild and Cultivated African Plum Trees

The distinction between wild and cultivated African plum trees was mainly based on morphological characteristics of the fruit, such as the smaller size, acidic taste, and blackish color of wild fruits (Fig. 4, ESM 6).

Phenology (FC = 58%) was another differentiation criterion as wild African plum trees were said to flower at different times and hence bear fruits later than cultivated ones. Fruit production was a third differentiation criterion (FC = 55%). Wild African plum trees were described as having irregular annual fruit production. Among the ethnic groups, the Baka (82%), Fang (57%), and Nzime (50%) perceived that wild African plum trees had good production, although it varied from one year to the next. Baka participants said: "production depends on the year, as this year [2019] there will not be many fruits." Some participants also mentioned that wild African plum trees have smaller leaves than cultivated trees (FC = 30%). Finally, wild African plum trees were distinguished by their greater height and diameter (35%) than cultivated ones. Participants in the Obamba focus group also said, "wild individuals have a greater height and diameter than an *atangatier* that lives in the village."

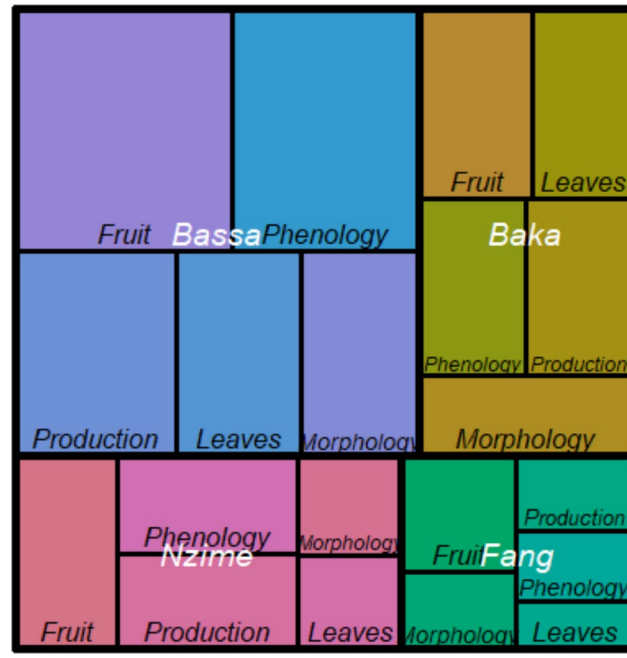

Fig. 4. Criteria used by the different ethnic groups (Bassa, Nzime, Fang, Baka) to differentiate between wild and cultivated trees of *Dacryodes edulis*. The size of each rectangle is proportional to the frequency of citation of the criterion by each ethnic group. Production refers to a subjective estimate of the quantity of fruits produced by the tree per year

Uses of Wild African Plum Trees

Tree Parts and Their Uses According to Ethnic Group

The fruit was the tree part most frequently used by all ethnic groups, followed by the bark, wood, leaves, sap, and roots. The Baka (100%), Nzime (55%), and Fang (50%) used the fruits. The Obamba cited wood most frequently during focus group discussions. The ethnobotanical indices showed a diversity of uses of wild African plum trees by ethnic group (Table 3). Forty percent of the participants mentioned uses that can be grouped into five use categories: food, medicine, firewood, socio-cultural uses, and trade. Sixty percent did not mention any uses for the wild form of the species. Use categories mentioned varied from three to five for the different ethnic groups, with the highest value observed for the Fang (5) and the lowest value for the Baka (3) and Nzime (3). The most important use categories for the Baka, Bassa, Fang, and Nzime were food and medicine. The highest cultural importance index was observed for the Baka (2), followed by the Fang (0.6). Concerning reported uses, the highest number of uses were mentioned by the Bassa (92), followed by the Baka (68) (Table 3).

Table 3. Ethnobotanical use indices according to four ethnic groups

Ethnic group	UC	RU	UV	CI
Baka ($N=34$)	3	68	0.05	2
Bassa ($N=135$)	4	92	0.01	0.2
Fang ($N=36$)	5	44	0.2	0.6
Nzime ($N=38$)	3	28	0.1	0.4

UC number of use categories, *RU* number of reported uses, *UV* use value, *CI* cultural importance index, *N* number of participants

As a food, the fruit of wild African plum trees can be softened in the mouth and eaten, or boiled/roasted before eating. The Obamba group said, "we eat the fruits; their taste is acidic and differs from the village ones." Thirty-eight percent of participants had already consumed the plums of wild trees. The Baka (68%), Fang (31%), Bassa (21%), and Nzime (16%) mentioned that the fruits from some wild trees can have a good taste.

Fruits from wild trees were rarely sold and were therefore not considered as a source of

income generation; only one Fang participant reported that he often sells the fruits in plates generally called *kombo*. Focus group participants mentioned that the timber from wild African plum trees can be processed into lumber and used in house construction (Obamba). The sap can be used as glue for kitchen tools or candles by the Baka, and as incense (a socio-cultural use) by the Fang and Bassa (Fig. 5, ESM 7). Other socio-cultural uses were mentioned during the focus groups, such as the use of the bark for wine fermentation by the Baka, Nzime, and Fang. Leaves were used by the Baka for washing dishes. For medicinal use, the participants listed 13 diseases (ESM 8) that could be treated by the wild form of the species using seven methods of preparation: decoction (28%), trituration (26%), mastication (15%), purging (13%), maceration (11%), infusion (4%), and concoction (2%).

The four collection methods mentioned by participants for tree parts were gathering, cutting, debarking, and scraping. Tree parts were not collected systematically, and no specific period is allocated to their collection. Fruits and leaves were collected under the tree (36%) or picked directly from the tree (29%) by all ethnic groups. Bark was removed by scraping to extract sap (3%) and peeling the bark from the stem of the trees (18%). Cutting trees (14%) allowed harvest of the wood or the roots.

Shared Uses of Wild African Plum Trees Among the Ethnic Groups

The fidelity level, which reflects agreement among the Baka, Fang, and Nzime for a given use category, was high for food, medicine, and firewood uses (Table 4). A higher level of fidelity was observed for food use across the Baka, Nzime, and Fang; and a higher FL was observed for medicine in the case of the Baka. Finally,

Table 4. Fidelity level (specificity of uses of wild African plum trees, in percentage of different uses by ethnic group)

Ethnic group	Food	Medicine	Firewood	Socio-cultural uses[a]
Baka	100	59	41	0
Bassa	21	23	16	7
Fang	47	39	28	2
Nzime	53	16	2	0

[a]Socio-cultural uses refer to various other uses: e.g., sap used as incense, glue, or bark for wine fermentation

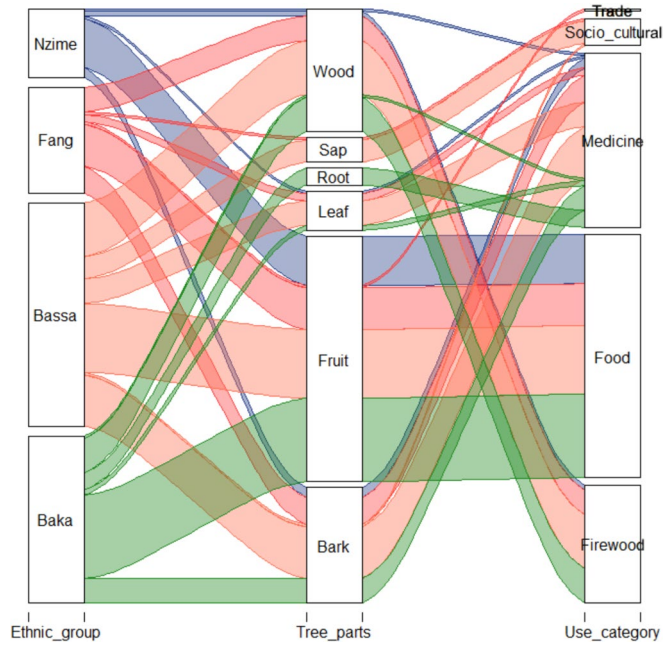

Fig. 5. Alluvial plot of wild African plum tree parts and their uses by four ethnic groups. The thickness of each line represents the proportion of participants for each ethnic group interviewed who cited a tree part and their associated uses. Each ethnic group is indicated by a different color throughout the alluvial plot

the Baka (33%) mentioned that they preferred to use the tree parts of wild African plum trees for medicine. During their focus group, they mentioned that tree parts from wild African plum trees were more effective medicine than those from cultivated ones.

Relationship Between Socio-Demographic Factors (Ethnic Group, Gender, Age) and Use Categories of Wild African Plum Trees

We found no relationship between use category and ethnic group (p value = 0.10). In each ethnic group, a relationship was found between gender and use category (p value = 0.0003). On average, men cited more uses than women. The Baka, Nzime, and Bassa showed similarity between the use categories cited by men and women. Among the Fang, women did not report uses within the socio-cultural category (ESM 9).

We found no significant relationship among use categories of wild African plum trees and participants' age classes (< 40, 40–60, and > 60 years old). However, participants between 40 and 60 years old cited the highest number of uses for wild African plum trees. People older than 60 more frequently reported food and firewood uses, while people younger than 40 more frequently mentioned medicinal and socio-cultural uses (ESM 10).

Local Perceptions on the Importance of Wild African Plum Trees

Due to its medicinal, food, and socio-cultural uses, the Baka (100%), Fang (36%), and Nzime (34%) stated that wild African plum trees were important to them. Other participants (Baka (9%), Bassa (84%), Fang (66%), and Nzime (45%)) indicated that they did not attach any particular importance to wild African plum trees because their surrounding forest environment contains many other useful species producing various products that are used on a daily basis. A total of 73% of participants, among which 82% of the Baka, 55% of the Nzime, and 25% of the Fang, ranked the species last after other species used daily such as *Irvingia* spp. and *Cola* spp. (ESM 11). Nzime (7% in the focus group) stated, "all forest species are important according to the season. But the wild African plum cannot be classified because trees do not produce every year, and even those around the house do not produce every year." Moreover, no particular attention is given to wild African plum trees by the Nzime ethnic group; one Nzime participant for example declared, "the tree is in the forest, stays in the forest, without need for special maintenance or attention." The Baka (76%) and Nzime (61%) recognized varieties within wild African plum trees based on fruit taste, fruit size, and fruit color. Ninety percent of the Bassa and 83% of the Fang did not identify varieties within the species. The majority of Nzime participants (82%) stated, "wild African plum [trees] are different from cultivated ones."

Discussion

General Aspects of the Local Knowledge of Wild African Plum Trees

Local communities in Africa have traditional knowledge about the NTFPs that are present in their surrounding environment (Ambé 2001). A majority of the participants from the ethnic groups surveyed know and use wild African plum trees, but the proportion of participants possessing this knowledge varied between groups. The knowledge of the occurrence of wild African plum trees was influenced by gender, age, and ethnic group. Men appear to have more knowledge than women, people aged between 40 and 60 years and those aged 60 and above appeared to have significantly more knowledge of wild African plum trees, and membership in a particular ethnic group influenced this knowledge. This could be explained by traditional gender roles which can influence the participation of men and women in specific activities related to the environment, like hunting or cutting trees to establish a new plantation. People aged between 40 and 60 years, and those older than 60, usually have acquired more experience and knowledge over the years. Their longevity in the community is likely to contribute to ongoing exploration of natural resources, including wild African plum trees. Finally, it seems that certain ethnic groups have more experience with the species than others. For example, all participants from the Baka ethnic group knew the existence and location of wild African plum trees in their natural environment. The Baka are hunter-gatherers and still depend on forests for their livelihoods (Duda 2017).

Wild African plum trees are known by different names by different ethnic groups, reflecting a long-term history of knowledge of the species. The names often relate to fruit size and habitat. Thus, the Baka designate wild African plum trees as *sa na bélé* meaning "African plum tree living in the forest." The Obamba and some Nzime and Bassa recognized wild African plum trees as a species different from the cultivated form, with the same morphological characteristics but living in the forest. Studies conducted in Cameroon on African plum ethno-varieties showed that the Beti (Central region) most frequently named the trees' varieties according to fruit size and taste of the mesocarp (Lemoine et al. 2023). This type of nomenclature is also used for other species, such as plantains in Cameroon, which are named according to their shape and color (Mengue Efanden et al. 2003). In Burkina Faso, farmers named ethno-varieties of *Vitellaria paradoxa* C.F. Gaertn. according to fruit and pulp characteristics (Karambiri et al. 2017).

Besides their names, various local traits/criteria are used to describe wild African plum trees. Overall, they are described as trees living in natural or secondary forests, not planted by humans, with small fruits commonly consumed by birds and small mammals. There is a similarity between the Baka and Nzime ethnic groups for the local definitions given to wild African plum trees. This similarity could be explained by their common environment, as these two groups live in the same geographic areas and could be exposed to the same resources. These two ethnic groups have frequent cultural interaction and trade with each other. Also, the fidelity level results showed that the Baka and Nzime shared specific uses for the tree parts of wild African plum trees, which can be translated into a particular local knowledge of their properties and characteristics, as well as some cultural practices associated with them. Moreover, Baka and Nzime descriptors for wild African plum trees are similar to those described by Parker et al. (2010) in their study of wild individuals of *Chrysophyllum cainito* L. in Panama where they used Indigenous knowledge to distinguish between wild individuals living in natural (not necessarily primary) forest, and planted individuals found in agroecosystems managed by humans. In the present study, wild African plum trees were also recognized as trees growing in old plantations, specifically by the Nzime and Fang. This raises the possibility that wild African plum trees could have initially been planted by humans in anthropized habitats, which were later naturalized and where the trees are now growing spontaneously without human management. This situation can lead to the appearance of a "wild" form of the species (Gros-Balthazard et al. 2016).

Identification and Discrimination Criteria for Wild African Plum Trees

The ethnic groups surveyed mentioned some morphological characteristics that allow them to identify wild African plum trees in their environment. These characteristics are related to their fruits and leaves, which are smaller in size as compared to those of cultivated trees, and the smell of the bark. Another species, *ozigo* (*Dacryodes buettneri*), was considered and described by the Obamba ethnic group as the wild African plum tree due to the similar shape, size, and odor of the fruit. However, during field visits both species were identified and differentiated based on the morphology of their tree parts. The morphology of the bark, stem, and leaflets of the *ozigo* is similar to that of wild African plum trees with some minor distinctive variations. For example, the outer bark of the *ozigo* tree is yellow-gold in color and scales into long, broad blades, while its height and diameter can reach 20 m and 190 cm respectively, and its leaflets are ferruginous on the underside. Wild African plum trees have bark that is grey spotted with green and is slightly scaled, and their height and diameter can rarely attain 20 m and 150 cm, while the underside of the leaves is usually covered with fine short hairs. These morphological characteristics are similar to cultivated trees, except for the height and diameter, which are much smaller (Onana 2008). In addition, the flowering and fruiting phenology can be used to differentiate between wild and cultivated forms of the African plum tree.

Uses of Wild African Plum Trees

Five use categories were identified for wild African plum trees which demonstrate its importance for the ethnic groups surveyed. The

cultivated African plum tree has four common categories of uses (food, medicine, trade, firewood) but its socio-cultural use is poorly documented (Noumi et al. 2006). The use categories of cultivated individuals are more focused on fruit consumption and sale (Rimlinger et al. 2021). The socio-cultural uses of wild African plum trees, which may be more related to traditional and local cultural practices, are rarely mentioned. These categories of use were observed to vary according to the context, with different ethnic groups having different perceptions of the use and value of wild African plum trees. The overlapping uses of wild African plum trees among the ethnic groups are for food and medicine. NTFPs are known as an important source of medicine for the health of local people who often find themselves unable to access modern medical care (Lawin et al. 2019; Zerbo et al. 2011). The Baka had a higher cultural importance index for wild African plum trees compared to the other ethnic groups. This can be explained by the Baka's higher dependence on forest resources for their daily needs in contrast to the other ethnic groups who are predominantly farmers.

The most common tree part harvested was the fruit. The mesocarp was used as food and rarely offered for trade. The second most commonly used parts were the bark and leaves, which are used as medicine.

The fruits of wild African plum trees are consumed mainly by the Baka and Nzime, especially during periods of low crop production or food scarcity, and when they are far from their homes (Ambé 2001; Berihun and Molla 2017; Cruz et al. 2013; Mawunu et al. 2016). This could indicate a comparable appreciation of the nutritional value of fruits from both cultivated and wild individuals, and the potential for wild African plum trees to meet the food needs of the population. In addition, fruits of wild African plum trees can be classified as a superfood due to their oil composition with a high content of fatty acids and vitamin E (Mboujda et al. 2022). Consumption of these fruits can help improve food security in areas where the availability of a nutritious variety of foods is limited and can provide health benefits to the population (Shrestha and Dhillion 2006).

For cultivated African plum trees, widespread uses are the consumption and sale of fruits (Noumi et al. 2006). The cultivation intensity of African plum trees is constantly growing in Cameroon's central area (Makenene), where 80% of the farmers sell their fruit crops (Rimlinger et al. 2019, 2021). Fruits from wild African plum trees are rarely traded and hence do not provide household income. This is probably because the fruit size of wild trees is small compared to the fruit of cultivated individuals; they are half the size of the cultivated fruit size (Mboujda et al. 2022). Moreover, wild African plum trees are located far from the village and produce small quantities of fruits with a sour taste.

Despite the cultural diversity, uses of wild African plum trees are homogeneous across the ethnic groups sampled in the present study. A possible reason for this could be that social and cultural groups now migrate and link up with others and therefore share their traditional knowledge, values, and rituals (Gbesso et al. 2015). Differentiated roles and responsibilities can influence men's and women's knowledge, experiences and perception of a species' uses. The survey showed differences between age groups, but these differences were not statistically significant. Elders possessed more knowledge than young people. One possible factor explaining this difference is the diversity of activities such as agriculture and trade which can affect their dependence on the forest resources. Changing dietary habits and a decline in the use of wild species can also be factors that could justify this difference (Shrestha and Dhillion 2006). In addition, oral transmission (Ouoba et al. 2018), migration and urbanization, and loss of cultural identity due to modernization (Inkoto et al. 2019) can explain more limited knowledge of young people (Fleury 2002).

Some parts of other plant species belonging to the Burseraceae family can be used as a substitute for wild African plum trees by local people for their daily use (fruits, bark, and sap). Ethnobotanical surveys on *Canarium schweinfurthii*, a potential substitute species in Cameroon and Burkina Faso, showed that the fruits were sold and eaten, the sap was used for candles, and the bark was employed in traditional medicine by local people (Traoré et al. 2021; Tsewoue et al. 2019). *Dacryodes buettneri* (Oliv.) H.J.Lam is exploited for its wood and the fruits are often consumed (Todou 2015). Forest species belonging to the Burseraceae Family appear therefore to be important to local people within their natural environment.

As compared to NTFP species that are useful on a daily basis, wild African plum trees could be ranked as one of the least important despite the high cultural importance index observed among the Baka ethnic group. This would suggest that, in comparison with other species, wild African plum trees are less useful for the daily needs of the ethnic groups surveyed in this study. The cultural importance of wild African plum trees could be independent of its ranking in the list of species of daily use according to specific criteria. Assessment of the importance of species can vary according to parameters like availability, accessibility, food preferences, artisanal practices, medicinal needs, and other practical aspects. For the Baka, it is possible that wild African plum trees provide special benefits and value which are not captured by the criteria used to list useful species. It could have symbolic, spiritual, cultural, or social values that are highly appreciated by the Baka community.

Local Ecological Knowledge of Wild African Plum Trees

In general, picking fruits, collecting leaves, debarking, felling, and scraping are different techniques used to harvest parts of wild African plum trees. The tree is rarely exploited for its wood. This suggests that the wild form of the species is primarily threatened due to poor natural regeneration in its natural environment rather than overexploitation. Techniques such as debarking and scraping can cause enormous damage to the tree, leading to its death. The removal of the bark of *Canarium schweinfurthii* for the production of exudates (flammable resin) was found to be harmful to the trees' survival (Traoré et al. 2021). The study by Yogom et al. (2020) has also shown that the removal of the bark of *Garcinia kola* Heckel by local people using a destructive technique has caused a reduction of the species' populations in the wild. A previous study of the germination of seeds of wild African plum trees in a semi controlled environment showed a high germination percentage (Mboujda et al. 2022), but environmental conditions in the natural forest habitat could contribute to low survival of seedlings affecting their regeneration potential (Doucet et al. 2016).

According to study participants, no special attention was paid to wild African plum trees in their forest habitat and, hence, their cultivation was hardly practiced by the local populations, despite their knowledge of the species' importance. This is consistent with the spontaneous growth and lack of maintenance observed in other species with traditional uses (Vroh et al. 2014). This could be explained by several factors such as availability of other food and income sources, low demand and trade value for its products, or just a lack of interest in planting the species.

According to the different ethnic groups, wild African plum trees can be found in natural and secondary forests, fallows, and agroforests and its presence indicates a fertile habitat. Some NTFPs can be found in new plantations or agroforests when they are deliberately conserved by farmers during field establishment. The presence of some species in the environment can be an indicator of soil fertility and thus contribute to the selection of sites for the establishment of new plantations (Carrière 2003).

The wild form of the species is not commercially exploited and, according to participants' perceptions, it is likely to become extinct in the future. The conversion of forest areas to other land uses such as plantations and the poaching of animals involved in its seed dispersal may contribute to its long-term decline. Dolley et al. (2020) have shown that the low density of trees in natural forests is due to exploitation for timber and fruit collection which can disturb the natural regeneration of the species. There is a need to further domesticate the African plum tree through selection of more trees, spread of improved plant propagation techniques and integrated management in agricultural landscapes (and value addition of its products) because its fruits are sold and provide income to households. It could also be important to conserve and regenerate the wild form of the species as a potential source for genetic resources for future breeding and improvement programs.

Conclusion

Wild populations of cultivated species are often studied because, as crop wild relatives, they are considered either a potential genetic reservoir or a reference point for assessing morphological/genetic differences that have arisen after domestication. The inclusion of local knowledge about

such wild populations is rare and often serves as a means to understand (over)exploitation. Departing from both approaches, this study sought to collect local knowledge about wild African plum trees in Cameroon and Gabon in order to understand if and how wild trees are still being used. Demonstrating the multiple uses of wild African plum trees, even in theory for groups not directly linked to the forest, helps to recognize and acknowledge the importance of wild forms of this species, which is an essential first step in conserving biodiversity. The importance of maintaining Local Ecological Knowledge (LEK) lies at the intersection of the conservation of forest ecosystems threatened by timber exploitation and conversion for agricultural purposes and livelihoods that maintain contact with these ecosystems, particularly through the collection of non-timber forest products. Cooperation between different stakeholders and local communities is needed to develop sustainable conservation and management strategies.

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Author Contribution

Franca Mboujda, Marie-Louise Avana-Tientcheu, Jerome Duminil, and Stephanie Carrière designed and carried out the experiments. Franca Mboujda and Aurore Rimlinger analyzed and interpreted the results. Franca Mboujda wrote the first drafts of the paper under the supervision of Stephanie Carrière. Aurore Rimlinger, Jerome Duminil, Avana-Tientcheu Marie-Louise, Archange Boupoya, Christian Moupela, and Christopher Tankou contributed with revisions and advice on content. All authors have read and accepted the submission of this version of the manuscript.

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Data Availability

Data that support this study are available from the corresponding author upon request.

Declarations

Ethics Approval

For each site, data collect was facilitated by an introduction letter provided by the University of Dschang-Cameroon and mission order delivered by *the French National Research Institute for Sustainable Development* (IRD)-Cameroon to local authorities requesting their assistance and cooperation in carrying out the activity in their constituency. In Gabon, the research permit and mission order were delivered by the *Centre National de Recherche Scientifique* (CENAREST) and the *Herbier National du Gabon* (HNG) national herbarium. Once in the field, we conducted an introductory conversation with the chief of each site in which we explained the objectives and methodology of the research and requested permission to interview resource persons and visit collection sites with them. The people interviewed initially gave their written agreement to participate in the survey and an authorization form was signed for the pictures to be taken.

Competing Interests

The authors declare no competing interests.

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