Taxonomy, ecology, harvesting methods, ethnopharmacological use, trade and prospects for sustainable management of *Prunus africana* (Hook. f.) Kalkman (*Rosaceae*)

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Review

Abstract

Background: *Prunus africana* (Hook. f) Kalkman has been the spotlight of foresters and scientists for several decades. However, the knowledge about this plant, which is classified as endangered by the International Union for Conservation of Nature (IUCN), is patchy. This article provides a bibliographic review for the current knowledge on *Prunus africana*, focus on harvesting methods, ethnobotanical and ethnopharmacological use, trade and stakeholder involvement in the sustainable management of this species.

Methods: The literature cited was obtained from Google Scholar, PubMed, JSTOR and Scopus databases. A total of 122 documents (scientific articles, reports and thesis) were consulted. Grey literature was used in addition to published scientific research.

Results: Knowledge on the ethnobotanical and ethnopharmacological importance of *P. africana* has developed considerably in recent years. *Prunus africana* is known in more than 22 countries and is for the use of utilized for its bark, which is used on

medicinally to treat various diseases. The literature shows the climatic diversity of *P. africana* habitats (altitude, rainfall and temperature) in African countries. Currently, eight techniques are used to harvest the bark of *P. africana*: 1/2, 2/4 opposite, 3/4, 4/8, complete debarking, 1/4 felling and 3/6. Six techniques have been categorized as illegal (felling, complete debarking, 3/6, 3/4, 1/2, 1/4), while two have been presented as legal (2/4 and 4/8). While international trade in *P. africana* is regulated to ensure sustainable management, the impact of exploitation and trade in products destined for local markets is not yet known and evaluated in the literature on this species. The article raises concerns about the impacts of medicinal use, logging, land-use and land-cover change, deforestation, habitat fragmentation and climate change on the conservation and endangerment of *P. africana*.

Conclusion: Future research should be conducted to improve knowledge on ecology, genetics and phylogeny, phenology, harvesting techniques that promote natural regeneration after debarking, and vulnerability of *P. africana* to climate change to promote sustainable management of this species.

Keywords: *Prunus africana*, harvesting methods, ethnobotanical and ethnopharmacological use, trade, sustainable management

Background

The African cherry, *Prunus africana*, is a tree widely distributed in Africa, occurring in the mountainous regions of central, eastern and southern Africa as well as on the islands of Bioko, Sao-Tomé and Grande Comores (Kalkman 1965; Bile *et al.* 2024). It has a long history for is traditional use and is the source of a non-timber product (bark) that has entered international trade (Stewart 2003). Since the 1960s, bark extracts have been shown to be effective in the treatment of benign prostatic hyperplasia (Komakech and Kang 2019). In fact, commercial use began in Cameroon in the 1970s (Rubegeta *et al*. 2022; Ndeby-Bile *et al.* 2022) and in the DRC and Uganda in the 1980s (Ingram *et al.* 2014; ICCN-CITES 2022).

Due to the sustainable trade concerning in *Prunus africana*, the species was added to the Red List of Threatened Species in Appendix II in the category "Endangered" at the 9th Conference of the Parties to the CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) in 1995 (Betti and Ambara 2013; Betti *et al*. 2014; Mpouam *et al*. 2022). In 2007, trade was suspended in other countries, including the Democratic Republic of Congo, Cameroon, Uganda, Burundi and Madagascar (Stewart 2003; Muhesi *et al*. 2023b).

Data on *P. africana* in Africa is inconsistent as it has been reported in various surveys in the region of some countries such as Cameroon (Hall *et al*. 2000; Ngueguim 2020; Wete *et al*. 2022; Bile *et al*. 2022) in the Democratic Republic of Congo (Wilungula *et al*. 2013; ICCN-CITES 2022, Muhesi *et al*. 2023a), Madagascar (Rabamanjara 2013), Kenya (Koro *et al*. 2016) and Burundi (Betti 2013). The World Health Organization (WHO) estimated at least 80% of the world's population especially in low- and middle-income countries rely on herbal medicines for primary health care (Omara *et al*. 2023). The use of ethnomedicinal plants in the management of ailments in rural communities continue to gain prominence due to their availability, affordability, perceived effectiveness and cultural acceptability (Obakiro *et al.* 2020; Schultz *et al.* 2020). This article provides updated data on *P. africana* trade statistics, harvesting methods, stakeholders involved in harvesting and trade, and prospects for sustainable management of the species. The study further emphasizes the importance of conserving this medicinal plant amidst the growing destruction of natural resources for settlement. This study aims to update the research in order to make more realistic proposals for sustainable management.

Biology of *Prunus africana*

Taxonomy of *Prunus africana*

Prunus africana (Hook. f.) Kalkman (formerly *Pygeum africanum* or *Laurocerasus africana* (Hook. f.) Browicz), commonly known as African cherry, African plum, African plum or bitter almond, belongs to the family *Rosaceae*, subfamily *Amygdaloideae* syn. family *Rosaceae*, subfamily *Amygdaloideae* syn. *Prunoideae*, subgenus *Laurocerasus* (Rubegeta *et al*. 2023). The species was first described by Hooker (1864), who gave it the name *Pygeum africanum* and classified it in the family *Chrysobalanaceae*. After a new classification by Kalkman (1966), the species name was changed to *Prunus africana* (Hook. F.) Kalkman (Rosaceae) due to the phylogenetic relationship with other species of the same genus. The description by Bussmann *et al*. (2021) is as follows:

Kingdom: *Plantae*
Phylum: *Magnoliophyta*
Sub-branch: *Rosophytina*
Class: *Rosopsida*
Subclass: *Rosidae*
Order: *Rosales*
Family: *Rosaceae*
Subfamily: *Amygdaloidea*
Genus: *Prunus*
Subgenus: *Laurocerasus*
Species: *Prunus africana* (Hook. f.) Kalkman (1965)

The genus *Prunus* is the largest member of the subfamily. There are 400 species in this genus, including another African species, *Prunus crassifolia* (Haum.) Kalkman, which has a more restricted range and grows between 800 and 3000 m altitude, although it can be considered a variety of *Prunus africana* (Magarita *et al*. 1999).

Morphological characteristics

P. africana has an epigeal germination. From juvenile stage it has a bare boot, smooth bark with conspicuous lenticels, a round cross-section and an upright growth habit. Mature trees reach a height of 30 m to 40 m and a diameter of 0.4 to 1.5 m (Wete 2022). Small *P. africana* trees have been observed on lava flows (less than 5 m). The boot of the tree is straight, often grooved, with simple serrations at the base or four buttresses with a concave or convex profile, 8 to 10 cm thick, sometimes branching "V"-shaped towards the ground, spreading 1 m from the tree and up to 1 m high (Ngueguim 2020). *P. africana* is an evergreen species with a straight, cylindrical boot. The color of the bark varies from dark brown to blackish. The bark is soft, thick and fibrous, longitudinally fissured in young trees or peeling off in regular rectangular patches in older trees (Wilfried *et al*. 2020). The bark of *P. africana* has a thick (approx. 15 mm) reddish-pink to brown disc, with a bitter characteristic, subtle odor. A color less exudate emerges from one bark disc, which becomes cloudy when exposed to light and has an odor strongly reminiscent of cyanide (Bussmann *et al*. 2021).

Anatomical and mechanical characteristics of wood

Evenly golden brown, diffuse-porous, without annual rings, with rare thin, prominent bands of zoned parenchyma. Sapwood and perfect wood are well differentiated; pale brown sapwood and brown perfect wood with pink veins. Slightly radially flattened fibers, straight fibers, sometimes twisted and interwoven. Medium-hard, heavy grain, medium to fine, specific gravity 0.72 - 0.76 g/cm^3 (Magarita *et al*. 1999).

Ecology of *P. africana*

The seedlings of the species develop best with an annual rainfall of 2,000 to 3,000 mm and an average annual temperature of 18 to 26°C. It has been observed that the seedlings develop best at an air temperature between 24 and 29°C (Komakech *et al*. 2017). *P africana* requires sufficient light for good growth and survival (Muhesi *et al*. 2023). The wavelength of radiation required for good plant growth is around 680 nanometers. Light appears to be a crucial factor for seedling growth and development, as seedlings wilt under 30% light incidence, while internode development continues normally under 40 shade (Sunderland and Nkefor 1997).

Spatial Distribution

Prunus africana occurs in Bioko, Burundi, Cameroon, Congo, Côte d'Ivoire, Democratic Republic of Congo, Ethiopia, Swaziland, Kenya, Madagascar, São Tomé, South Africa, Tanzania, Mozambique, Equatorial Guinea and Uganda (Hall *et al*. 2000) (Figure 1). Muhesi and Mate (2018) report its occurrence in 22 countries, most of which are in East Africa. This wide distribution in Africa and Madagascar is significantly influenced by altitude, temperature, rainfall, soil type and cloud cover. It grows at altitudes between 700 and 3,000 m (Wete *et al*. 2020; Mpouam *et al*. 2022), with average annual temperatures between 18°C and 26°C. The average annual precipitation in this area is around 2,000 mm. These different pedoclimatic parameters explain why its natural range includes western, eastern, central and southern Africa as well as the Indian Ocean (especially Madagascar and the Comoros) (Hall *et al*. 2000). The specific characteristics of the distribution areas in certain countries are shown below and in Table 1.

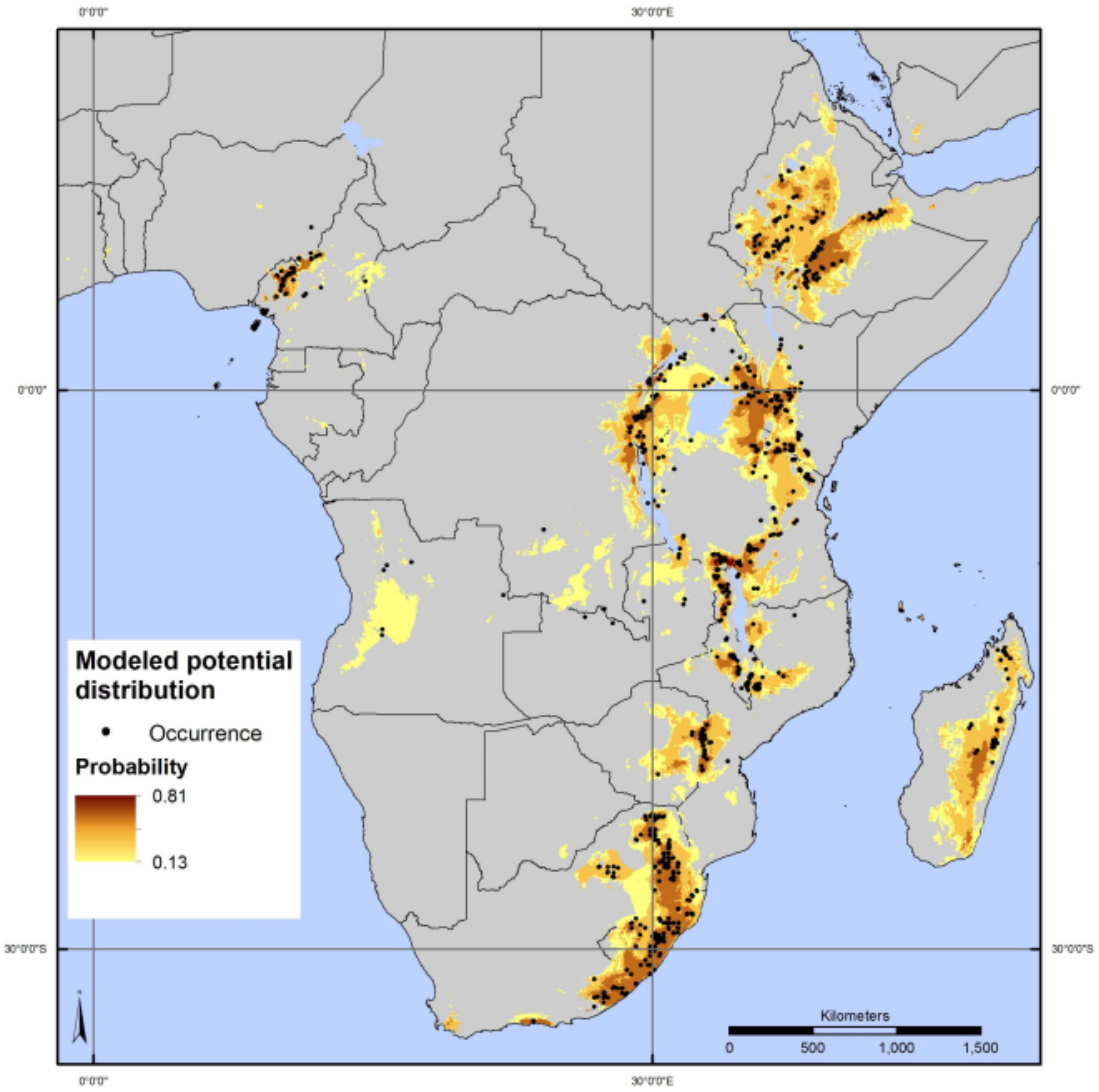

Figure 1. Spatial distribution of *P. africana* in Africa (Vinceti *et al*. 2013)

Democratic Republic of Congo

Prunus africana has been reported found in five provinces: Lualaba, Ituri, Tanganyika, North Kivu and South Kivu. It has been recorded in 11 deforestation sites in these provinces, namely: Walikale, Masisi, Rutshuru, Lubero and Beni (in North Kivu province), Kabare, Kalehe, Walungu and Uvira (in South Kivu), Kaniama (in Tanganyika), Irumu (in Ituri) and Sandoa in Lualaba (ICCN-CITES 2022). In its range, *Prunus* populations are discontinuous and fragmented at the forest level (Muhesi *et al*. 2023a). The altitude at which specimens of this species can be observed varies between 1,500m and 2,750m under humid tropical microclimate conditions. The species occurs in montane forests and on slopes as well as in forest galleries, where *P. africana* is often accompanied by species such as *Podocarpus milanjanus*, *Podocarpus usambarensis*, *Harungana montana*, *Hagenya abyssinica* (with which *P. africana* is often confused by farmers). It is also found in the dry forest galleries of Katanga at an altitude of 950 m. It has also been observed in the Mabalako-Kashebera block in North Kivu at an altitude of less than 1000 m, but with thinner bark (1 cm) than the thick bark of mountain *P. africana* (probably due to adaptation to the low temperatures at high altitude). Clear genetic and chemical differences in the bark of *P. africana* populations in the DR Congo have been observed (Kembelo 2008).

Burundi

Prunus africana occurs in protected areas in general and in particular in Kibira National Park, which borders Nyunguwe Montane Forest in Rwanda, Bururi Nature Reserve and Ruvubu National Park (Betti *et al*. 2015). The preferred habitat is semi-caducous forests and forest galleries on mountain slopes between 800 and 2,700 meters above sea level (Betti 2013).

Cameroon

This species grows from an altitude of 700 meters. It is generally found between 600 m and 3,000 m altitude, but very frequently between 1,000 m and 2,500 m (Ndam *et al*. 2000). Wilfrid *et al*. (2022) report that *Prunus africana* occurs in the mountains of Amadoua and Tchabal Mbayo at altitudes between 1,400 and 2,100 meters. State forests include production forests, protected areas and forest reserves (Nzweundji *et al*. 2020). *Prunus africana* occurs in both permanent and non-permanent forests. In the Mount Cameroon region, the species is found in state forests (Mount Cameroon National Park), municipal forests, community forests and private forests. In the north-west and south-west, *Prunus africana* is found in protected areas, community forests and communal forests, while in the Adamaoua deforestation units the species is found exclusively in state forests (Wete 2022).

Tanzania

In most cases, they are found in tropical mountain forests characterized by heavy rainfall at altitudes of 1500-2300 m in the Kilimanjaro Forest Reserve, Kidagadi, Udzungwa Forest, Kidogoko, Meru Forest, Shuma Magamba (Kadu *et al*. 2011). In the high forests, the foliage is open, the branches often hang down, but in the grasslands the tree is rather round and compact (Gilica 2018). *Prunus africana* grows naturally on Kilimanjaro, Pare, East and West Usambaras, Nguru and Uluguru. It is also found on the Mufindi and Mahenge escarpments (Ronoh *et al*. 2018).

Uganda

P. africana generally occurs in regions with high rainfall. In some areas, however, the species has become rare due to overexploitation (Dawson and Powell 1999). *P. africana* grows in Ugandan rainforests at altitudes between 1,100 and 2,200 m (Galabuzi *et al*. 2021). It is common in mixed forests, on forest edges and in gallery forests. The largest specimens grow in the forests of Bwindi and Kalinzu and on parts of Mount Elgon (Muchugi 2006).

Kenya

P. africana occurs in moist, evergreen riparian forests, often in remnant stands or on forest edges, between 1350 and 2750 m above sea level (Gladis 2020). It is common in the forests of Mount Kenya, Aberdares, Kakamega and Cherangani (Nguta 2012). It is also found in Timboroa, Nandi and western Mau forests as well as Kakamega forest (Farwig *et al*. 2008). In south-eastern Kenya, *P. africana* occurs naturally in the Taita hills of the highly fragmented moist cloud forests (Koros *et al* 2016; Onyango *et al.* 2018).

Equatorial Guinea

The recent volcanic origin of the Bioko Islands has created an extremely rugged topography with peaks up to 3,000 meters high (Pic de Basile, 3008 m near Malabo), separated by deep gorges. This abrupt topography combined with the oceanic winds from the south-west creates a wide variety of habitats in which *Prunus africana* also occurs (Clemente *et al*. 2008). In Equatorial Guinea, this species is only found on the island of Bioko at altitudes of 1,000 to 1,800 meters (Ondo 2008; Vinceti *et al*. 2013).

Ethiopia

The species is currently scattered in some parts of the country in the remaining fragments of Afromontane wet and dry forests in the altitude range of 1350-2450m (Tadesse *et al*. 2021; Amsalu and Regassa 2022) and in the dense wet forests of Menagesha, Munessa, Shashemene at altitudes of 1700 to 2500m (Wubet *et al*. 2003). The Badale site is located in the dry Afromontane forests with altitudes between 2100 and 2700 m, average rainfall of 1250 mm and average temperatures of 15 to 20°C, while the Badale site is located in the typical humid Afromontane forests with altitudes between 1500 and 2500, average rainfall of 1500 - 2000 mm and average temperatures of 18 to 20°C (Gure 2004; Kassa *et al*. 2020).

Malawi

Prunus africana occurs in the Nyika National Park, in the north in the Misitu forests in the Chitipa and Chisenga regions, in the juniper forests in the Rumphi region, in the center in the forests of Wilindi, Chinthembwe Mission, Msitu wa Lengwe forests in the Dedza Mountains, Dedza-Chiwamba, Ntchisi and Ntcheu-Kalichelo Hills regions, and in the south the species is found in Mount Zoman, Phalombe, Thondwe, Katsonga, Domasi, Mpita, Mount Mulanje, Mount Chiradzulu, Mount Zomba and the Likhubula Valley (Simkoko *et al*. 2021). Additional information on *P. africana* in other countries is presented in Table 1.

Table 1. Range of *P. africana* in selected African countries

Countries	Zones and specifications	Altitude (m)	Reference
Madagascar	*Prunus africana* is native to sub-humid forests. This species is also found in the following protected areas and other important sites: Ambatovy, Ambohitantely, Analamazaotra, Ankaratra, Manjakatompo, Tsaratanana and Zahamena.	500-2500	Kadu *et al*. (2012) ; Ranaivoson (2020)
Zimbabwe	*Prunus africana* is found in the Chirinda Forest Reserve, the Nyanga National Park and the Chimanimani Chimanimani Valley domain.	1716-1880	Jimu (2011) ; Jimu *et al*. (2013)
Nigeria	*Prunus africana* is located in the Nyaki Forest Reserve and Mambila Plateau, South-East Nigeria	-	Jimua and Ngoroyemo (2011)
South Africa	*Prunus africana* is distributed in the Mpumalanga Mpumalanga and KwaZulu-Natal regions	-	Barbara *et al*. (2013)
Rwanda	Specimens of *Prunus africana* can be found in Nyungwe Natior Park Nyungwe and Gishwati-Mukura National Park adjacent Kibira National Park in Burundi and in south-western Lake Kivu, on Mont Virunga	-	Vestine *et al*. (2019) Ingaviro *et al*. (2019)
Lesotho	*P. africana* is also reported in the collection from the Rock pools, Sehlabathebe. However, inventories show the disappearance of this species in this region. One specimen has been reported from Maphotong Gorge.	-	Betti (2008) ; Golding (2002)
Swaziland	*Prunus africana* can be found in the forests near Malolotja (Forbes) and Mbabane	-	Cunningham (2006)
Sao Tomé Principes	*Prunus* is located in Central Principe, near the the volcanic plugs of Joao Dias Pai e Filho and Sao Tomé	1200-1400	Cunningham (2006)
Soudan	Some specimens on the Imatong Mountains	-	Cunningham (2006)
Angola	Presence reported in the Bailundu highlands and Moco Mountains	-	Betti (2008)
Mozambique	Presence on Chiperone and Chimanimani mountains and Mount Gorongosa	-	Golding (2002)

Reproduction

P. africana plants can be grown from seeds, which are produced around the fifteenth year, or from wildlings (Berens *et al*. 2014). In full light, growth is quite fast and can reach a height of 10 m after 5 years, with an annual diameter growth of 1 cm per year (Sacande *et al*. 2004). At 18 years, the tree can be 14 m tall and have 37 cm diameter as reference (Cunningham *et al*. 2015). A mature tree can reach 10 to 40 m in height and have a diameter of 40 to 150 cm (Mpouam *et al*. 2022). The mortality rate of adult trees in natural populations is estimated at 1.5 % per year (Wete *et al*. 2020). Deforestation can lead to a mortality rate 50 times higher than the natural mortality rate for trees with a diameter of more than 30 cm (Tchoundjeu 2002). In natural deforested stands, the diameter structure of *P. africana* is not exponential (Wilfried *et al*. 2022). This distribution is characterized by an accumulation of individuals in small diameter classes below 50 cm and a persistence of large diameter adult stems. This persistence of large trees is justified by the longevity of the species, as mentioned by Hall *et al*. (2000). This type of structure is generally observed in helophytes where the establishment of new seedlings is sporadic or irregular (Fashing 2004).

Phenology

In the DR Congo, *P. africana* flowers in January and February in North and South Kivu and in May and June in Katanga (Kembelo 2008). The flowering period is the longest phenological stage and extends over six months (July to December). Tadjuidje (2011) has shown that in the south-west and north-west, *P. africana* flowers in December and January, fruits in February and matures in March-April, followed by fruit (seed) dispersal in March-April. In Madagascar, the phenological events take place at different times depending on the area. In Bealalana and Manditsara, for example, flowering takes place in August-September and fruit ripening in December, while in Moramanga and Anosibe an'Ala, flowering occurs in January-February and fruit ripening between March and April (Anonymous 2022).

Plant organs used and harvesting technics

The bark is used in traditional and modern medicine for the treatment of malaria, sexual infections and benign prostatic hypertrophy (Muhesi *et al*. 2023b). The wood of *Prunus africana* is used for timber building, carpentry and handicrafts. The techniques used in Cameroon and DR Congo to harvest the bark of *P. africana* are based on the best practices developed by PLANTECAM (Plante Camerounaise) between 1972 and 1987, which had a monopoly on the harvesting of this plant (Wilfrid *et al*. 2022). They also draw on the experience of the Mont Cameroun project of August 2001, which was led by a group of institutions including the International Centre for Research on Agroforestry (ICRAF), the Department for International Research and other organizations (LBG, UWB and CERUT) (Hall *et al*. 2000; Betti *et al*. 2019).

Method 1: 2/4 opposite

In the "2/4 against" method, the tree is debarked from chest height to the first branch. Indeed, *Prunus* industry players are convinced that a combination of rights exclusive harvesting, certified harvesters, known techniques and a revised, conservative standard based on research wherever possible can be sustainable (Ingram *et al*. 2009). In the DR Congo, the two-quarter technique was developed by the two operating companies (ETs Kahindo Muvunga SA and Plavuma SA) with the support of CIPPAGRI in collaboration with the management authority and the scientific authority and has proven successful to date (Muhesi *et al*. 2023b).

The following revisions to the standard and practices are therefore recommended: The minimum DBH (Diameter Breast Height) for harvesting should be increased to 40 cm (Cunningham and Mbenkum 1993). The rotation period should be increased to 8 years, with the remaining two quarters harvested in the same way. After the second 8-year period, i.e. after 16 years, the previously harvested part is harvested again. This means that there is an 8-year cycle for harvesting the same tree and a 16-year cycle for harvesting the same part of a tree. Before the second harvest, the health of the tree must be checked. The quotas for the second harvest (8 years) should be based on monitoring the health of the tree (Cunningham *et al*. 2015).

Method 2: 4/8

It applies to trees with a diameter of more than 60 cm, measured at a height of 1.30 meters above the ground. The boot is divided into eight equal vertical strips. Debarking is carried out on 4 strips, 2 by 2, so that each debarked strip is separated from its neighbor by a non-debarked strip. Debarking is carried out with a machete from 1.30 meters above the ground to the first branch. The debarked starts with cross cuts, followed by vertical cuts to demarcate the part to be removed. The demarcated part of the bark is struck with a 5kg mallet, which lifts the bark off the boot. The bark is then easily separated from the tree with a machete (Ndam *et al*. 2000). The size of the tree determines the number and dimensions of the removal strips (Wete 2022). The removed bark is collected and tied into bundles, which are then transported on people's backs. The smallest pieces of bark are collected in sacks. The harvested bark is not subjected to any special treatment, apart from the removal of mosses, ferns, lichens and other impurities. The bark is then cut into small pieces, dried, shredded and stored in bags (Mpouam *et al*. 2022).

Method 3: Felling

For planted trees, a similar system for bark production of *Acacia mearnsii* is proposed. In this system, successive tree plantations are either cut down or felled and then completely stripped of their bark (Cunningham *et al*. 2015). The wood can then be sold as firewood, poles, and stems or for other purposes. All previous studies on *Prunus africana* show that its high-quality hardwood and considerable growth rates make it at least as attractive to smallholders as fast-growing species such as eucalyptus and that it offers good economic returns (Franzel *et al*. 2014).

The administrative authorities in Madagascar and Kenya have also decided in favor of this harvesting method. The harvesting of privately owned *Prunus africana* can be an easier harvesting system if the replacement load is different from that of *Prunus* in natural forests, provided that the harvesting of privately owned *Prunus africana* is based on registration and control. National and individual regeneration plans and measures that at least guarantee the preservation or augmentation of the felled tree population should be favored. This is also a practical way to avoid arduous bark harvesting and high mortality rates, even with so-called "normal" harvesting techniques (Ingram *et al*. 2009). Figure 2 illustrates the different methods of debarking *P. africana*, classified into two categories: recommended and non-recommended.

Figure 2. Harvesting technics: (a) Felling, (b) Standing debarking, (c) 2/4 opposite, (d) method 4/8, (e) messy debarking and (f) total debarking

Multiple uses of *Prunus africana*

Prunus africana is used for its bark in medicine and its wood in cabinet-making and handicrafts.

Uses of *P. africana* wood

P. africana is used in households as a source of energy (firewood and charcoal), as a building material for houses (poles, rafters, etc.) and in crafts (making wooden chairs, beds, furniture, mortar, etc.). Stewart (2003) reports that in eastern DR Congo, *P. africana* produces firewood, construction timber (lorry bodies, beer boats, bridges, cabinets and furniture, roof supports, window and door frames, cutting blocks, behave supports, etc.) and is used in handicrafts (making mortars and pestles) (Muhesi *et al*. 2023a). The wood is used for the manufacture of carts, carts, furniture and huts, interior finishing products, agricultural tools, tool handles, sporting goods and turning tools (Stewart 2009). *Prunus africana* is also cultivated in agroforestry as a honey plant (Zocchi *et al*. 2020).

Uses of *P. africana* in traditional medicine

In addition to the use of wood, *P. africana* is also used as an extremely versatile and effective medicinal plant to combat many diseases (Afiong *et al.* 2024b), which is not a new phenomenon, especially in Africa due to the inaccessibility of modern health care for some population groups (Focho *et al*. 2009; Koros *et al*. 2016). The stem bark is dried and then pulverized into a decoction which is then used to treat many health problems, mainly orally (Nyamai *et al*. 2015; Koros *et al*. 2016). Leaves, roots and stem bark are the main components of *P. africana*, which are used medicinally throughout its range (Koros *et al*. 2016). The bark is used for the treatment and therapy of numerous diseases, including benign prostatic hyperplasia (BPH), chest and intercostal pain, respiratory diseases, gastrointestinal disorders, acquired immunodeficiency syndrome (AIDS) (Gail *et al*. 2015), diabetes, erectile dysfunction, fever, gonorrhea, high blood pressure, kidney disease, malaria, prostate cancer, laxatives, skin infections, typhoid fever, ulcers, urinary tract diseases and inflammation (Mwitari *et al*. 2014; Tugume *et al*. 2016; Ibrahim *et al*. 2016). Although the stem bark is mainly used, the roots, leaves and fruits are also used to treat benign prostatic hypertrophy, urinary tract disorders, gastrointestinal complaints, fever, chest and intercostal pain and to increase appetite (Ochwang'I *et al*. 2014, Kassa *et al*. 2020).

Ethnopharmacological use of *P. africana*

According to the literature, the bark of *P. africana* contains numerous bioactive phytochemical compounds, including terpenoids such as ursolic acid (PubChem CID: 64945), oleanolic acid (PubChem CID: 10494) and β-amyrins (PubChem CID: 73145); flavonoids, especially ferulic acid (PubChem CID: 445858) (Madivoli *et al*. 2012); phytosterols, including β-sitosterol (PubChem CID: 222284); fatty acids, including lauric acid (PubChem CID:3893) and myristic acid (PubChem CID:631192); tannins (Mutuma *et al*. 2020), including araric acid (PubChem CID: 78435), and N-butylbenzene sulfonamide (Pub Chem CID 19241) (Nyamai *et al*. 2015; Komakech *et al*. 2017). The synergistic interactions of these phytochemicals have made *P. africana* an effective traditional remedy for many diseases and conditions, including infectious diseases (Ngule *et al*. 2014). Numerous preclinical and clinical studies have shown that the phytochemicals of *P. africana* have anticancer (Mwaura *et al*. 2020), anti-inflammatory, antimicrobial and antiviral effects (Karani *et al*. 2013; Ngule *et al*. 2014).

Treatment of prostate cancer

In recent decades, several plants (including *P. africana*) have been confirmed to contain chemopreventive and therapeutic agents for various types of cancer, particularly prostate cancer (Cunningham *et al*. 2016). Evidence of ethnobotanical use of *P. africana* for the treatment and management of cancers and related diseases has been documented in many communities over the years (Omara *et al*. 2020). A study by Ochwang'I *et al*. (2014) shows that traditional healers in Kakamega County, Kenya, use the decoction of the bark to treat cancers, including prostate cancer, and other urological symptoms. Another study conducted by Tugume *et al*. (2016) in communities around the Mabira Central Forest Reserve in Uganda also confirmed the use of *P. africana* in the treatment of cancer and related diseases. Furthermore, the anticancer and antitumor effects of P. africana are due to the presence of numerous vital phytochemicals (Thompson *et al*. 2019). Beta-sitosterol and unsolid acid have anti-inflammatory effects on the prostate, which may lead to anti-prostate cancer activity (Nyamai *et al*. 2015). The antitumor and hypocholesterolemia effects of the bark extract on the prostate are also attributed to the presence of ferulic acid esters and their derivatives (Rousseau *et al*. 2017). Ethanolic extracts of stem bark show 50 growth inhibition of the human prostate cancer (PC-3) and prostate lymph node carcinoma (LNCaP) cell line at 2.5 µl/ml and also induced significant apoptosis in both cell lines (PC-3 and LNCaP) at 2.5 µl/ml compared to control cells (Komaketch *et al*. 2020). The in-depth study by Komakech *et al*. (2017) showed that *P. africana* has great potential for prostate cancer chemoprevention and chemotherapy due to the presence of phytochemical compounds. In vitro studies showed that ursolic acid downregulated B-cell lymphoma 2 (BCL-2), leading to apoptosis in PC-3 cells. In addition, β-sitosterol and ferulic acid induced apoptosis in PC-3 and LNCaP prostate cancer cells. Thus, tartaric acid and N- were shown to suppress estrogen receptors and consequently reduce the proliferation of PC-3 cells (Komakech *et al*. 2019, Komakech *et al.* 2022).

Treatment of benign prostatic hyperplasia (BPH)

In traditional medicine, *P. africana* bark decoction has been used to treat this disease since time immemorial (Tchoundjeu *et al*. 2002; Koros *et al*. 2016b). The stem bark can be pulverized and boiled in water to make a decoction, or the pulverized bark can be used to make capsules and administered orally for this purpose (Nyamai *et al*. 2015). Muhesi *et al*. (2023a) have also shown that *P. africana* stem bark decoction is used by forest communities in North Kivu, DR Congo, for the treatment and management of Benign Prostatic Hyperplasia (BPH).

Diabetes treatment

P. africana is one of the herbal medicines sold in local markets for the treatment of diabetics (Mwitari *et al*. 2014). The extract of this species has shown to be able to reduce the enzyme dipeptidyl peptidase-4 (DPP-4), which is known to be essential for the activation of glucagon-like peptide (GLP-1), leading to increased insulin production in the body; an essential factor in the treatment of type 2 diabetes mellitus due to controlled glucose levels in the body (Lodhi and Singhai 2013). Consequently, the ability of *P. africana* to increase GLP-1 activity motivates the use of this plant in traditional medicine for the treatment of diabetes mellitus. Early treatment with this plant completely suppressed oxidative stress in diabetic bladders and slowed the process of diabetic cytopathy when adult male rats were fed 100mg/kg *P. africana* in peanut oil daily for 4 weeks after the induction of diabetes in them (Wang *et al*. 2010). In addition, aqueous and ethanolic extracts of *P. africana* showed significant hypoglycemic activity in alloxan-induced diabetic rats (Mwitari *et al*. 2014).

Treatment of malaria

In a study by Njoroge (2012) on the diversity and use of ethnophytotherapeutic antimalarials among the Kikuyu in central Kenya, *P. africana* is one of the most important plants used by the community for the treatment and management of malaria. A similar study by Syamasamba *et al*. (2022) in Butembo city, DR Congo, also confirmed the use of extracts of this species by traditional practitioners for the treatment of malaria. In most cases, the stem bark is ground into a powder and used to prepare a decoction or infusion, which is then administered orally to treat the disease (Syamasamba *et al*. 2022). In the

province of North Kivu in the Democratic Republic of Congo, people living in and around the forests where *P. africana* is found also treat malaria by drinking decoctions made from the bark and other organs of this species (Muhesi *et al*. 2023a). Traditional practitioners in tropical and subtropical Africa also use extracts of this species to treat patients who present with symptoms of malaria (Gakuya *et al*. 2013; Abera 2014; Afiong *et al*. 2024a).

Treatment of gastrointestinal diseases

The bark of the strain of *P. africana* is used in Africa to treat diarrhea and abdominal complaints (Mwitari *et al*. 2013). A study by Jiofack *et al*. (2008) showed that a decoction of the bark can be used for heartburn and gastralgia (stomach pain and the like). Amri and Kisangau (2012) also showed that the decoction of the bark of *P. africana* is administered in villages near Kimboza Forest Reserve in Morogoro, Tanzania to treat stomach ache. This observation was confirmed by an in vitro study by Ngule *et al*. (2014), in which the hydromethanolic extract of *P. africana* bark showed strong antibacterial activities.

Treatment of skin infections

In Kenya, the community living near the Nandi forest uses herbal preparations of *P. africana* as topical applications to treat many skin diseases, including fungal infections due to the strong antifungal activity of the tannins of this plant (Koros *et al*. 2016).

Treatment of chest pain and respiratory diseases

The use of decoctions of *P. africana* bark for the treatment of chest pain and respiratory diseases such as asthma, allergies and inflammatory diseases is widespread in African communities. In Kwazulu-Natal, South Africa, a decoction of stem bark was used to treat intercostal pain (Barbara *et al*. 2013). A similar ethnobotanical study by Rubegete *et al*. (2017) also confirmed the use of stem bark decoction in the treatment of intercostal pain and related ailments in Africa.

Wound healing

P. africana is one of the plants commonly used for wound treatment in many African communities. The presence of secondary metabolites such as tannins, alkaloids, flavonoids and saponins in *P. africana* (Ngule *et al*. 2014) could be the cause of its wound healing effect. As antioxidants, flavonoids can scavenge free radicals and are therefore able to prevent oxidative damage in the cells and have a strong anti-inflammatory effect (Ngule *et al*. 2014); a basis for wound healing.

Actors involved in the *Prunus africana* circuit

Stakeholders in the *Prunus africana* value chain include grassroots organizations, the public and private sectors, research institutes and national and international partners involved in at least one segment of the chain from production to marketing and consumption.

International organizations

They are involved in international environmental policy. In the case of *Prunus africana*, these are the IUCN, the ITTO and CITES (Awono *et al*. 2016).

International Union for Conservation of Nature (IUCN)

The IUCN is the global authority on the state of nature and the measures needed to conserve it. Our experts are organized into six commissions dealing with species survival, environmental law, protected areas, social and economic policy, ecosystem management, education and communication. The IUCN's ability to inform and strengthen conservation efforts worldwide is based on its ability to bring together a wide range of stakeholders and provide them with the latest scientific knowledge, objective advice and real-world experience. It is a neutral forum in which governments, non-governmental organizations, scientists, businesses, local communities, indigenous groups, religious organizations and others can work together to develop and implement solutions to environmental problems (Assembe 2008). *Prunus africana* has been on the IUCN Red List of Threatened Species since 1998, although it is recognized that an update is necessary. Since 1995, the IUCN has included *Prunus africana* in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). This means that the species is not necessarily threatened with extinction, but could become so if trade is not strictly controlled by annual quotas. CITES is legally binding on governments and does not replace national laws, but provides a framework for implementation in national legislation (Ingram *et al*. 2015).

Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)

This international convention, which came into force in 1975, regulates international trade in plants and animals threatened with extinction through trade by listing them in one of three appendices (I, II or III). To implement the Convention, each Party

must establish a management body and at least one scientific authority and regulate trade through a permit system. If trade threatens the survival of a taxon in the wild, it may be proposed for listing in the Appendices by one or more CITES Parties, either at a Conference of the Parties (hereinafter: "COP") or, if one of the Parties is a range state, unilaterally and at any time, but in Appendix III. For species listed in Appendices I and II, controls are carried out to ensure sustainability and to ensure that a specimen has not been obtained in violation of national laws, while for species listed in Appendix III, controls are only required in relation to the violation itself. The Convention does not allow Parties to adopt "more stringent measures", such as imposing stricter import and export obligations (Groves and Rutherford 2015). The purpose of CITES is to regulate international trade in rare or endangered species. In this sense, CITES is both a regulatory system that mitigates the World Trade Organizations (WTO) principle of absolute freedom of international trade (Lex Mercatoria) and a system to protect wildlife and plant resources to promote sustainability. To this end, the CITES legal system relies on specific techniques set out in the text of the Convention, as well as practical standards derived from numerous resolutions and decisions of the Conferences of the Parties. Hence the recognized complexity of the CITES legal system, which includes standards and implementation mechanisms derived from the decisions and resolutions of the Conferences of the Parties (Ekane 2008). The signatory countries to this Convention are obliged to adopt national legislation in which they must take into account the conditions contained in this Convention for the export, import and re-export of these endangered species (Cunningham *et al*. 2016).

International Tropical Timber Organization (ITTO)

The ITTO Tropical Tree Species Compliance Program aims to ensure that international trade in CITES-listed tropical tree species is compatible with their sustainable management and conservation. The specific objective of the program is to assist national CITES authorities and the private sector to meet the requirements for the management and regulation of trade in CITES-listed tree species, provide capacity building support and undertake specific studies where information is lacking to develop a better global framework for the collection and analysis of information related to the biology and management of tree species and trade in tropical forest products. The main species recorded to date are *Pericopsis elata* (Afromosia or Assamela), *Prunus africana* (*Pygeum*) and *Diospyros* spp. (Ebony) in Central Africa and Madagascar; *Swietenia macrophylla* (Bigleaf Mahogany), *Cedrela odorata* and other *Cedrela* spp. (Cedars) in Latin America; and *Dalbergia* spp. (Rosewood) in Africa and Latin America. In Southeast Asia, these include *Gonystylus* spp. (Ramin), *Aquilaria* spp. and *Gyrinops* spp. (Agarwood) (Cocquyt *et al*. 2012).

The main range states exporting large quantities of the above species are is Cameroon, Democratic Republic of Congo, Madagascar and Republic of Congo in Africa; in Asia, Indonesia and Malaysia; and in Latin America, Bolivia, Brazil, Guatemala, Honduras, Paraguay and Peru. The direct beneficiaries of this program are the public authorities and private operators in the timber sectors of the range states. Indirect beneficiaries are other CITES Parties and ITTO members that exploit these species commercially and will benefit from capacity building and increased awareness. Countries that are or could become significant exporters of products from CITES-listed tree species have access to this support programmed (Emmanuel *et al.* 2023).

Administration

At central level

The Congolese Institute for Nature Conservation is the management body in the Democratic Republic of the Congo responsible for (ICCN-CITES, 2022):

- Issuance of CITES permits by this ACNP (Avis de Commerce Non Préjudiciable),
- Tracking the quotas allocated to each zone as specified in the ACNP,
- Ensure harvesting is done as prescribed in the ACNP,
- Track exports from the ACNP,
- Ensure compliance with partnership agreements between rights holders and exporters,
- Submit a report to the scientific authority.
-

Decentralized services

- Monitoring of harvesting operations by ACNP,
- Ensuring compliance with deliveries and product routes by ACNP,
- Raising awareness and informing operators about ACNP and its impact,
- Ensuring the traceability and legality of operations carried out under this ACNP,
- - ensuring the routine and quarterly monitoring of operational activities,

- Reporting any irregularities to the management body.

Responsibilities of the economic operator

The economic operator is responsible for:

-Complying with ACNP regulations,

- Complying with the applicable forestry regulations,

- Reporting any misunderstandings or problems to the administrative authority and the scientific authority,

- Co-operating with the Management Authority and the Scientific Authority in the sustainable management of CITES species.

Export and import of *Prunus africana*

International level

According to CITES data, Cameroon has always been the world's largest exporter of *Prunus*, with an average share of 47% of total exports between 1995 and 2013. Other major exporters are DR Congo (16%), Kenya (14%), Madagascar (7%), Uganda (5%), Equatorial Guinea (5%) and Congo (3%). Between 1995 and 2004, Cameroon had a 38% share of the world market. After 2004, Cameroon's share increased as other exporting countries reduced their production, so that Cameroonian exports accounted for 65% of global exports between 2004 and 2013 (Figure 3). Although 23 countries import *Prunus* bark, only a few countries dominate the trade (Cunningham *et al*. 2016). Australia and India are the newcomers to the market, importing mainly since 2007.

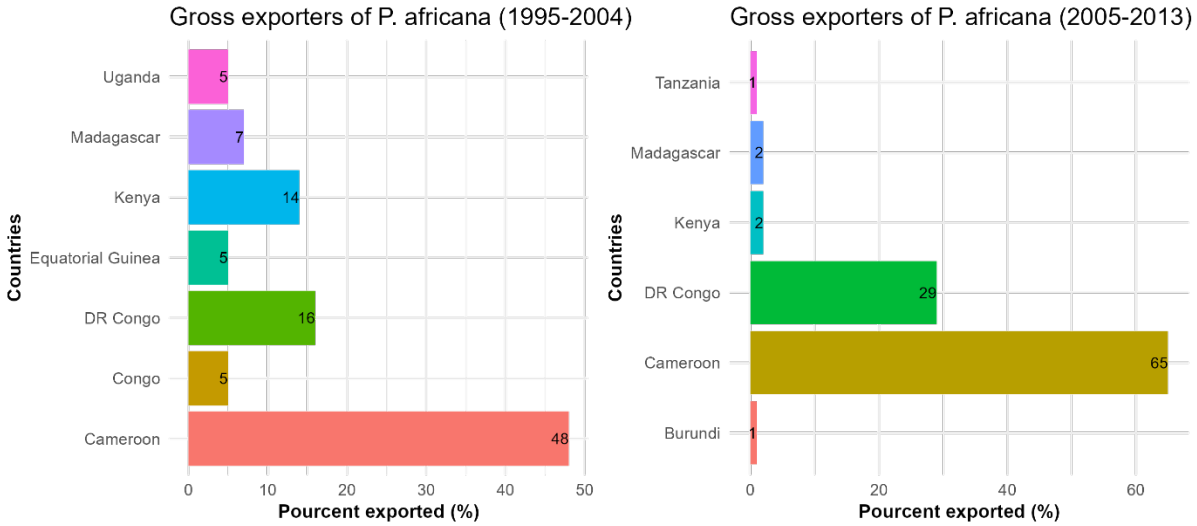

Figure 3. Gross exporters *Prunus africana* between 1995 and 2013 (Source: WCMC CITES Database 2014)

Although data on the units and types of export are sometimes unrecorded and dubious, the majority (over 80%) of *Prunus* exported by producing countries is dried bark. Exports of processed *Prunus* (powder, extracts or derivatives) come only from Madagascar, Cameroon and, to a very limited extent, Uganda, Equatorial Guinea, Congo and the Democratic Republic of Congo. Since the suspension of imports to the European Union (UE) in 2007, no powder or processed extract has been exported from Cameroon or Madagascar (Cunningham *et al*. 2016). *Prunus* bark exporters reported that demand for processed bark is more dependent on buyer requirements than supply. This is partly because importers are wary of processed derivatives due to substitution issues with other substances in the past and bark is easier to visually verify (Muhesi *et al*. 2023a). Regional trade in Africa is not recorded in the WCMC-CITES database, but has been surmised (Cunningham 2006). Signs of possible border trade between Nigeria and Cameroon have also not been detected since 2009 (Ingram *et al*. 2015). Armed conflict and porous borders between Burundi, Rwanda and the Democratic Republic of Congo, as well as between South Africa and Swaziland, would also facilitate these trade routes (CITES 2006). Studies and interventions over the past decade have improved knowledge of the environmental, social and economic impacts of changes in the behavior and management of conservation and trade of this species, particularly international trade. Between 2008 and 2017, more than 99% of France imports of African plums contained bark. In addition, 3404 kg of plum extracts were imported by France. Imports increased until 2014, decreased in 2015 and stabilized at 520000 to 540000 kg per year. Due to the decline in stocks of the species, several trade suspensions were imposed during this period. From 2009, the export of specimens from the DR Congo, Equatorial Guinea and Tanzania was suspended. The DR Congo was authorized to resume trade in 2012, subject to an export quota. Originally set at 72,000 kg, this quota was increased to 232,000 kg per year in 2015 (ICCN-CITES 2022). France

did not report any imports of *P. africana* from the Democratic Republic of Congo between 2009 and 2012, but then resumed imports within the quota in 2013. Between September 2007 and March 2011, imports into the European Union were banned following a negative opinion from the Scientific Review Group (SRG), which nevertheless approved the conditional import of 505 tons of old stocks from 2007 to 2009. France then issued five import licenses for 420,000 kg of these African plum stocks. Imports from Uganda were authorized by the GES in 2008, subject to an export quota of 75893 kg (which was increased to 252000-267000 kg in 2012 and again in 2016). CITES data shows that France imported 129600 kg from Uganda in 2010 (i.e. a quantity above the quota) (Bodecker *et al*. 2014). Therefore, special attention is recommended to ensure that imports of this species are legal, sustainable and traceable (Lorélie *et al*. 2021). Figure 4 presents the principal importing countries for *P. africana* bark between 1995 and 2013. France dominates with 64%, followed by Spain (26%). Other countries only represent 10% of imports.

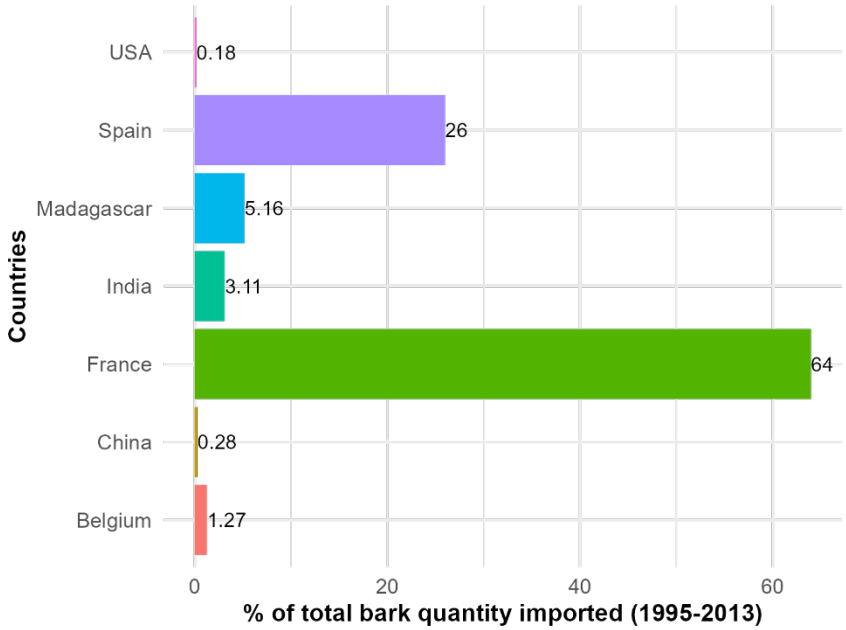

Figure 4. Major importing countries (Source: WCMC CITES Database 2014)

National and local trade in *Prunus africana*

The bark of *P. africana* is sold in its raw form in some markets in the regions where it is produced. Travelling traders also sell it in other parts of the country where it is used as a traditional medicine. The international trade in *P. africana* bark is handled by two traders. Each lot of bark requires a CITES permit issued by the Congolese Institute for Nature Conservation, the CITES Management Authority for the flora in the DR Congo (ICCN-CITES 2022). A CITES permit can be issued for a batch of bark that is not exported for various reasons (withdrawal of a customer, etc.). Therefore, there is often a difference between the export statistics available at the level of the managing authority (theoretical quantity of product exported) and those available at the level of the Directorate General of Customs and Excise. This situation often embarrasses the administrative body when we go from one year to the next and there are unloaded stocks, as the quota is annual. These barks are exported to several countries, namely France, Spain, USA, Belgium, Morocco, Bulgaria and Madagascar as well as China (Cunningham *et al*. 2016). In order of relative importance in terms of exported quantities, France is by far the largest importer with a share of 60%, followed by Spain with 34% (Emmanuel *et al*. 2023).

In the DR Congo, the bark is exported in its raw state. Table 2 shows the quantities of bark exported by the DR Congo from 2003 to 2006 before the suspension of trade, with the total quantity estimated at 1380 tons of bark. After the suspension was lifted, the two companies exported 1082.5 tons of bark between 2011 and 2022 for an average of 63.68 tons per year (Figure 6). A significant proportion of DR Congo's *P. africana* bark production is delivered to EUROMED/Spain, ALCHEM INTERNATIONAL/India and SYNKEM (Figure 5).

Table 2. *Prunus africana* exports from 2003 to 2006 in DR Congo before trade suspension (Nyimi 2008)

Year	Exporters	Importers	Quantity of bark (tons)
2003	PLAVUMA /DRC	France	400
		India	40
		Madagascar	70
2004	PLAVUMA /DRC	Spain	80
	ESCO KIVU/DRC	France	70
	UNION IS	India	80
	STRENGTH/DRC	Belgium	60
		Madagascar	220
2006	PLAVUMA /DRC	France	120
		Madagascar	240

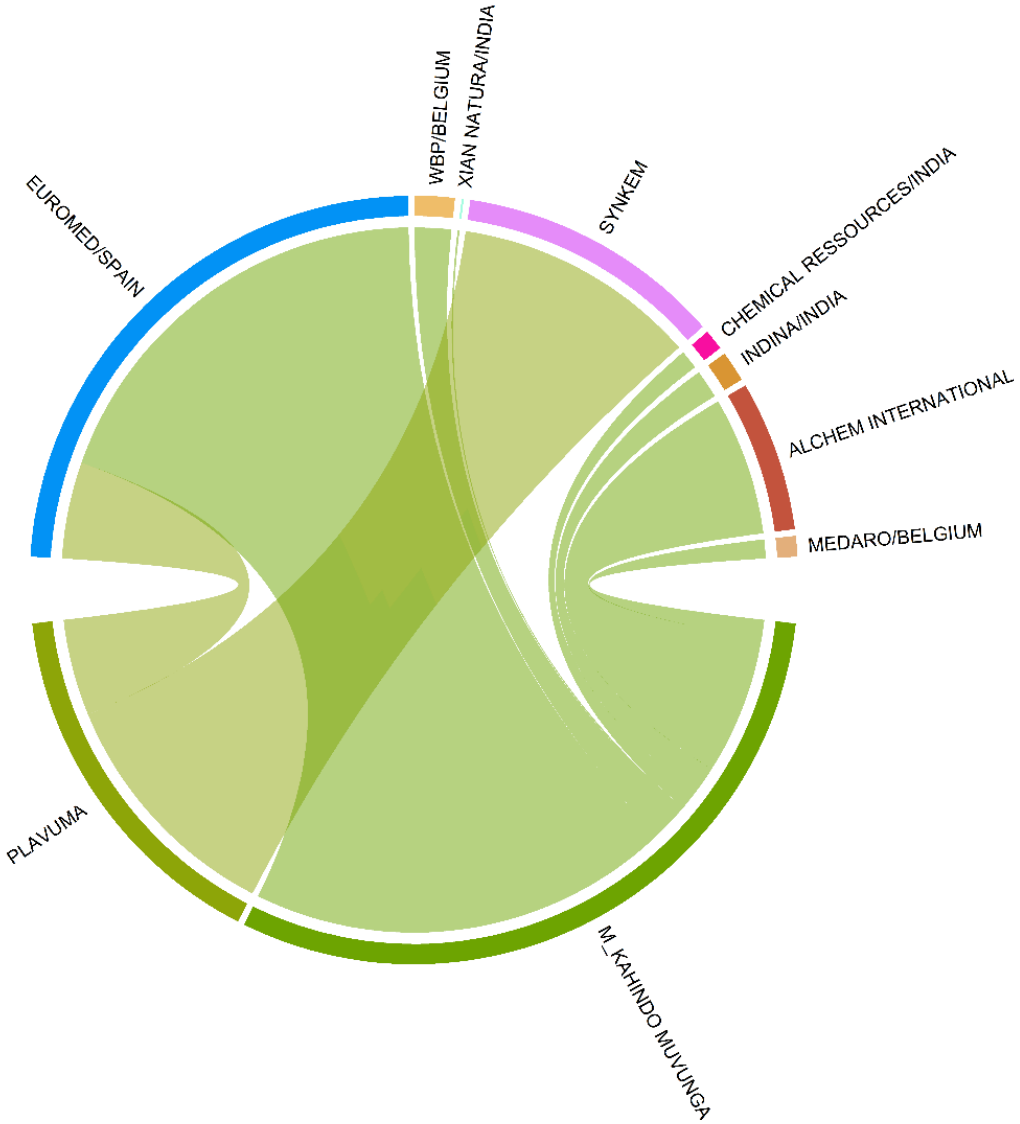

Figure 5. *Prunus africana* export and import companies after the lifting of the DR Congo suspension (period 2011-2022)

For the period 2011-2022, the major importers of *P. africana* bark from the Democratic Republic of Congo were Spain (51%), France (24%), India (20%) and Belgium (5%).

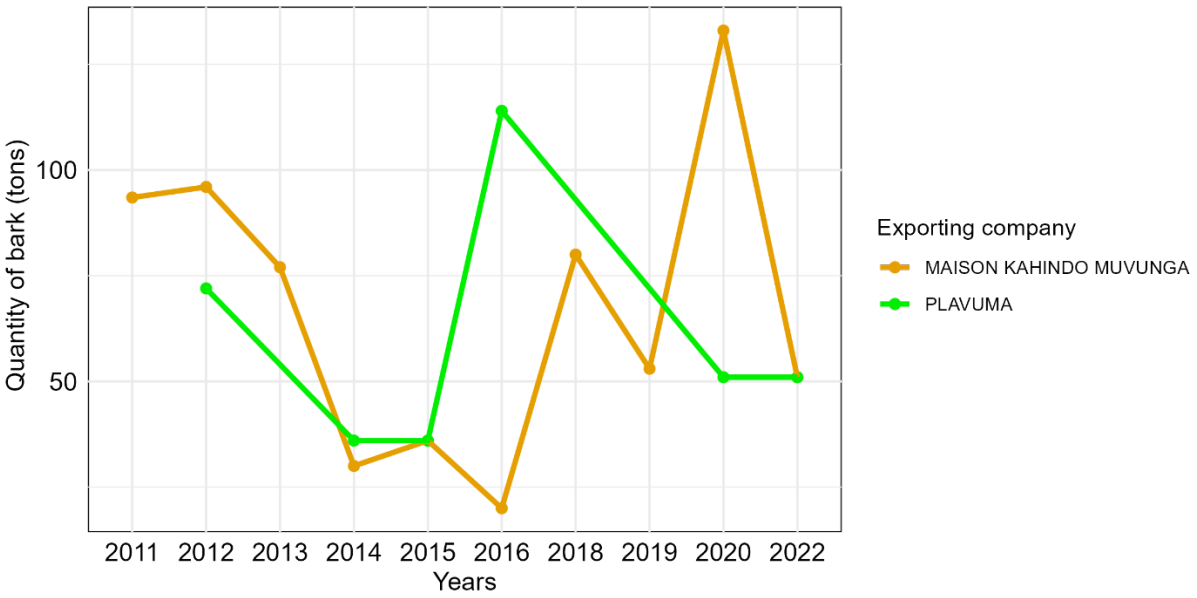

Figure 6. Exportation of *Prunus africana* after the lifting of the suspension in the DR Congo (period 2011-2022)

Ecological implications of *P.* africana

The occurrence of *Prunus africana* in natural forests is sensitive to the disappearance of seed-spreading animals. Human activities, especially harvesting, grazing and fire, also affect the growth, mortality and reproduction of trees and seedlings (Stewart 2009). These factors also have a negative impact on forest regeneration and habitat loss (Kadu *et al*. 2012). One solution is to specifically protect mature "mother" trees' as part of local management plans (Cunningham *et al*. 2016). Concerns about the impact of logging practices on other species or entire ecosystems have been raised but not quantified (Cunningham *et al*. 2015).

Impacts on nature conservation

Natural changes in climate over the last millennia have influenced where *Prunus africana* grows and how genetic diversity occurs (Vinceti *et al*. 2013). For example, the genetic profile and biochemical content of *Prunus* bark vary between Central Africa, the East and West Rift Valley, Southern Africa, and Madagascar (Kadu *et al*. 2011). The main differences are between Madagascar, East Africa, and West Africa (Muchugi *et al*. 2006; Kadu *et al*. 2012). There are also differences between mountain ranges in some countries. For example, in Cameroon, *Prunus africana* in Adamaoua is slightly different from that in the North-West and South-West highlands, and in Uganda, between Kibale National Park and Virunga National Park in Ruwenzori in North Kivu, Kahuzi-Biega and Itombwe in South Kivu (Wilungula *et al*. 2011). Cultivated trees are usually (but not always) derived from locally harvested seedlings and seeds, and therefore often have similar genetic and biochemical profiles to naturally occurring trees in the same region (Kadu *et al*. 2012; Ingram *et al*. 2015). Climate change forecasts indicate that the main exporting countries most likely to be adversely affected by a loss of natural habitats suitable for *Prunus* are Tanzania, Madagascar, Cameroon, DR Congo, and Uganda (Vinceti *et al*. 2013).

Prospects for sustainable management of *P. africana*

Important questions are raised in the literature to ensure sustainable international trade in *Prunus africana*. The first issue relates to the fact that consensus is needed on whether wild harvesting is realistically sustainable, as there is growing evidence that the nature of the tree, harvesting methods, the generally remote and inaccessible location in the mountains, and the difficulties in establishing and maintaining legal and customary arrangements that ensure sustainable harvesting are not sufficient (Assembe 2008; Ndedy-Bile *et al.* 2022).

The second issue requires an international scientific consensus on appropriate inventory methods for the species in the wild (in protected and unprotected areas) and for the cultivated *Prunus africana*. The method must strike a balance between scientific soundness, cost and time, and the involvement of local communities to promote ownership and knowledge of locally owned and managed resources (Dawson and Powel 1999).

The third question assumes that effective management of the species and its ecosystem must be ensured. Experience, particularly in Cameroon, shows that building the capacity of management authorities, introducing new systems and

conducting inventories takes time. However, the pressure on the natural habitats harboring *Prunus africana* is considerable and requires a careful conservation approach that also takes into account the livelihoods of local communities and tree owners. Where implementation is low and corruption and profits from trade are high, there is a significant risk that governance arrangements, which on paper appear to fulfil CITES requirements, have failed (Cunningham *et al*. 2015). Monitoring and enforcement, funded by revenue from this resource, appear to be key elements of viable governance arrangements (Page 2003).

The fourth question highlights the importance of recognizing that different governance arrangements entail different trade-offs between the benefits of trade for different stakeholders and the conservation of species and ecosystems. Restricting access to the resource can help governments to control large, often remote areas more easily. Mandatory inventories increase market entry costs for (small) companies (Cunningham *et al*. 2016). They can lead to monopoly or oligopoly situations, as in Kenya, Cameroon, Uganda and the Democratic Republic of Congo, where national markets are or have been dominated by a small number of traders and/or exporters. This control can penalize tree owners and farmers, community resource owners and managers, and harvesters. However, access to wild trees can be monitored and controlled more closely than when many market players have access to an area, as was the case in Cameroon (Ingram *et al*. 2015).

The fifth question raises a debate about the ability of the species to adapt to local climate change, which will be crucial for the future availability of wild populations. The identification of priority populations and the implementation of strategies for their protection and management will be important to counteract the predicted negative impacts of climate change on the mountain forest ecosystems in which *Prunus africana* grows.

The sixth question emphasizes the need to ensure that the cultivated bark reaches the international market (Gyau *et al*. 2012). The available data suggest that cultivation can reduce the pressure on *Prunus africana* in natural forests, provided the following conditions are met:

i) Improved traceability systems from planted trees to exporters and ports monitoring natural forests to ensure that wild *Prunus africana* is not sold as cultivated timber. This includes standardizing the type of products made from this species and calibrating the units of measurement used in international trade registers.
ii) Promoting the registration and inventory of cultivated trees would allow a better understanding of the current extent of cultivation in all producing countries.
iii) Favorable national and international policy and regulatory frameworks, including ownership regimes for trees, that allow bark from cultivated trees to be registered and sold internationally at high prices.
iv) A bark price that is high enough to ensure a good economic return for farmers.
v) Awareness of the fact that cultivation can benefit different interest groups (i.e. not necessarily the poorest or those living close to the forest) and can create perverse incentives for wild harvesting (for the landless and those with less money).
vi) Increased collaboration with the pharmaceutical and medicinal plant industries to ensure that cultivation program are targeted to areas and trees where the properties of the active ingredients meet the industry's specifications.
vii) Tax and policy incentives to encourage the cultivation and trade of cultivated bark so that it is at least as attractive as wild collection.

Control, traceability and monitoring system

This section sets out how to trace, monitor and control the exploitation of *Prunus africana*. The aim is to provide a workable, robust and transparent adaptive monitoring system that follows all *Prunus africana* exploited from the tree to export. It allows a periodic assessment of the impacts of harvesting to determine the impact of the current harvest protocols on the species and ecosystem, and if the management plan is successful. The system should ensure sustainability by providing information that supports timely corrective action to ensure that the resource is not over-exploited.

Appraisal of current monitoring and traceability system

As concerns have grown over the last decade about the unsustainable exploitation of *Prunus africana* bark, to the extent that Minister in charge of forests admits that the exploitation of *Prunus* has not been monitored and controlled well by its local services (Awono *et al*. 2016). Unsustainable exploitation has very rarely been sanctioned, prohibitions have been short lived and often harvesting has continued and fines have been very small compared to profit from illegal harvesting, with experience indicating that both traditional and administrative sanctions and controls have always not acted as barrier to illegal or unsustainable harvesting (Wete *et al.* 2022). The current situation of monitoring and traceability in *Prunus* sector is analyzed in Table 3.

Monitoring procedures

The main elements of the system are shown in Table 4. The monitoring procedure operates each time *Prunus* is harvested at any PAU or by any registered owner. There are also long-term procedures annually and every 5 years. The procedure is based upon and traceable though a set of Monitoring Forms in duplicate (1 for permit holder, 1 for regional Ministry in charge of forests delegation and 1 for Ministry in charge of forests delegation CITES Management Authority which accompany the *Prunus* harvested from the field or forest to the point of export. A copy of the Monitoring Checklist can subsequently be provided to CITES and to the importer. The annual report produced for CITES by the Management and Scientific Authorities can be based on an aggregation of the data from all Monitoring Forms (Ingram *et al*. 2009; Mpouam *et al*. 2022).

Table 3. Strengths and weaknesses of current monitoring and traceability system

Strengths	Weakness
Existence of a department that allocates permits	Permits allocated and monitored at central level in Kinshasa
No inventory based quota	Often no inventory check before issuing permit
Willingness of *Prunus* actors and permit holders to inventory stocks	No proper description of the site where a permit allocated
Willingness of Prunus harvesters and permit holders to respect harvesting norms if each site is allocated to one permit holder alone for a longer period	Many permit holders in the same area for Prunus harvesting, leading to unsustainable harvesting and no accountability
Willingness of DRC CITES Plant Scientific Authority to work/collaborate with Ministry and other CITES organs	No formalized procedure for collaboration on daily basis with Minister in charge of forests and Plant scientific Authority
Willingness of the focal person at CITES Plant Scientific Authority to set up a Scientific Advisory Committee, develop an annual work plan and search for funding within Minister in charge of forests and Prunus actors and undertake additional study to understand CITES	Limited expertise at country CITES Plant Scientific Authority
Willingness of relevant actors to discuss the issue and link inventory to agreeable Prunus management plan	The *Prunus* Platform initiative is largely lead by international organizations

Traceability

These monitoring forms and checklist, together with the Annual Exploitation Permit provide a traceable document that can be sent with the *Prunus africana* to the importers, monitoring agencies such as TRAFFIC, as well as CITES and the EU-CITES authority. It demonstrates the legality of the product and its source of origin (either an inventoried site with a quota or a privately registered source), the link with the PAU and *Prunus* Management Plan, the exploitation quota therein and that it has been harvested according to the harvesting norm. The data contained in these documents should be incorporated into the national database for forest products, as part of national monitoring for Special Forestry Products and for CITES (ICCN-CITES 2022).

Community or Council Forest participatory monitoring

A participatory monitoring system is recommended for all *Prunus africana* from PAUs from which the source of origin is a Community or Council forest. This is out of the scope of this national *Prunus* management plan, but is an issue for incorporation in the Community forest or council forest Management Plans (Betti *et al*. 2022). It is recognized that participatory monitoring of tagged trees for harvesting techniques and respect of exploitation quota can contribute to the stability of the institutions responsible that manage *Prunus* (normally the Forest Management Institution or council) the accrual and distribution of benefits, and combating illegal exploitation. Assuming that the inventory was conducted with input from local beneficiaries and CF managers, monitoring that includes these stakeholders can also be more time effective and reinforce the official controls by Ministry (Tassiamba *et al*. 2022). The tagging system proposed has an added advantage of involving users and beneficiaries, and simple to understand for actors who may have low literacy and numeracy. Monitoring should be during harvest periods. Transparency and accountability should be enhanced as one copy of the Monitoring Form is kept by the harvesting and PAU permit holder (Ingram *et al*. 2015).

Long term monitoring

Long term monitoring is necessary to ensure any period adjustments in harvest norms, quotas or inventories. This may be based on the results of ongoing monitoring of PAUs, of research programs conducted by academic institutes and international

organizations, from any decisions or information originating from the CITES Secretariat or other countries with *Prunus africana*. Long term monitoring is therefore proposed annually and on a five years basis (Ingram *et al*. 2009).

Annually

Annual reviews of the PAUs (PAU Management Plan Approval, Monitoring forms and PAU Annual reports) and comparison of privately owned registered *Prunus* annual permit with the quantities exploited and exported will be performed by ministry to ensure that quantities harvested are within the annual quotas. The national quota for *Prunus africana* harvest requested annually to CITES will be based on the sum of all PAU quotas plus the total sum of *Prunus* from registered private owners. This will be revised annually and actual harvested monitored against exports. Periodic adjustments in PAU or private owned permits may be made by Ministry, in consultation with Plant Scientific Authority, in the following cases. Where the results of any monitoring surveys or independent studies indicate unsustainable exploitation of *Prunus africana*. Where PAU operators or private owners are unable to counter illegal harvesting their zone of operation. Due to exceptional circumstances e.g. droughts, pests, fires etc. which damage significant quantities of *Prunus africana* in distribution countries (Ingram *et al*. 2009; Wete *et al*. 2022).

New governance mechanisms

Trade in *Prunus* across Africa to date has not had a good track record in being conducted sustainably. National regulations have been enacted to protect the species in many countries, many stimulated by CITES and IUCN listings. For example, *Prunus* has been classed as a "Special Forestry Product" in Cameroon since 2006, and is specifically regulated by the Madagascar and Kenya Forest Acts and the DR Congo Forest Code (Betti and Ambara 2013). Guidance and national management plans to meet CITES requirements are however at varying stages of development, approval and implementation in Equatorial Guinea, Cameroon Madagascar, DR Congo and Uganda (Cunningham *et al*. 2014). Learning from the experiences of countries currently implementing plans which meet the CITES significant trade review and non-detriment findings could be enhanced. For example, by exchanges similar to the CITES Naivasha 2008 meeting (Ingram 2015). Most countries have monitoring systems based on quota-based permits and in-the field monitoring of tree status by state agencies, and by projects and students which are generally one-off evaluations (Mbongo 2020). Alternative monitoring systems based on genetic (DNA) traceability are planned to be investigated by an ITTO-CITES program with the government of countries *Prunus* distribution in 2015. Critical to the workability of such systems will be a reasonable cost to implement and ability to conduct DNA analysis nationally in origin countries. Other alternatives for monitoring may be possible for example voluntary certification systems, such as the Fair Wild Standard for medicinal plants, information and communication technology and bar-coding - but are not known to have been tried or implemented (Chupezi *et al*. 2004; Cunningham *et al*. 2016).

Table 4. *Prunus africana* monitoring system

Monitoring Parameter	Indicator	Responsibility	Monitoring location	Form/Tools
Trees harvested in natural forest harvest are identifiable and actual period of rotation known	Tree tagging and record keeping	Harvester and PAU permit holder Ministry monitoring	PAU Natural forest	Bark harvesting and tagging form
Prunus africana trees and approx quantity of bark to be exploited from farms or plantations in any given year is known.	Number of stems Approx annual quantity harvestable per Region	Private owners	Privately owned on field/plantation	Registration
All PAUs granted are known, the length of permit and permit holding entity is known.	Permit for PAU for a qualifying entity	Minister in charge of forests (Interministrial committee	PAU	Minister in charge of forests, Interministerial committee decision on PAU permits granted
MinFoF and Regional Authority can verify that all PAUs to be exploited in any given year have a Management Plan + inventory and quota	Sustainable quota in tonnes wet weight in approved PAU Management Plan	Plant Scientific Authority	PAU Regional level	Inventory Norm PAU Management plan approval
The quantity of Prunus africana exploitable from PAUs, the permit holder and authorised harvesters in any given year is known	Quota wet weight prunus bark per PAU zone per annum	PAU permit holder (enterprise/community/forest/ council)	PAU Regional level National level	PAU permit PAU Management plan approval/Approved CFSMP
The quantity of Prunus exploited in any given year from each Region and by each permit holder is known.	Quantity and source of wet weight Prunus per Region and per permit holder	Permit holder, Minister in charge of forests, régional autorities/controls	PAU Regional level	Origin PAU approval Minister in charge of forests /SGFIF database
The wet weight quantity of bark harvested at any one PAU in any given year is known.	Random test of norm on 10% of trees in any 1 PAU zone	Minister in charge of forests, Regional autorities and harvester	PAU Regional level	Harvest
The harvest technique used conforms to norms.	Random test of norm on 10% of trees in any 1 PAU zone	Minister in charge of forests, Regional autorities and harvester	PAU Regional level	Harvest norm Bark havesting
Prunus is only harvested by trained, certified harvesters	Tagged trees, registered harvester, training modules	Minister in charge of forests	PAU Regional level	Bark harvesting Certification
All prunus on route form forest/plantation to processing and export locations can be traced to a PAU or register private holder	Random controls by MinFoF Brigade du Control, MinFoF at Port of Douala and any controls at Council checkpoints	Permit holder, Minister in charge of forests, régional autorities and control, brigade	PAU Regional level	Transport

Quantity of Prunus harvested is traceable from the tree to exporter to point of export and importer.	Quantity, transporter and method of transport for wet weight Prunus	Permit holder, Minister in charge of forests, régional autorities/controls	PAU, Regional level, National	Harvest, Transport, Export PAU Report
The origin and legality of all prunus exported from Cameroon is known.	Quantity and type of dry weight prunus exported	Permit holder, Minister in charge of forests, régional autorities and control, brigade	PAU Regional level National level	Origin, Export Minister in charge of forests /SGFIF database, CITES annual report, WCMC database

Sanctions

Using the proposed monitoring scheme, controls can be made. When infringements are found, strict sanctions are necessary given the long and repeated history of unsustainable harvest over the last two decades in all the landscapes of countries. The following sanctions are recommended (Betti *et al*. 2019; Wete *et al*. 2022) (Table 5).

Table 5. Following sanctions

Infringement	**Sanction**
Harvesting from protected areas	Confiscation and fine plus suspension of annual permit
Unsustainable harvesting (non-compliance with harvest norms) for up to 10% of trees monitored.	Fine
Unsustainable harvesting of over 10% of trees monitored.	Suspension of annual permit
Prunus harvested is not accompanied by signed forms	Confiscation and fine
Use of untrained harvesters	Fine
Harvesting outside of PAU or registered privately owned *Prunus* permit	Fine
Harvesting more than annual quota	Fine
Harvesting of non-registered private *Prunus*	Confiscation and fine

Recommendations

Implementing a new regime to manage and exploit *Prunus africana* sustainably is a challenge for all actors involved in the chain; communities, community forest institutions, traditional authorities, harvesters, nurseries, tree and plantation owners, permit holders, processing and export enterprises, the pharmaceutical and health industry, the government and regulators such as CITES and the EU, research and support organizations. To make it work, a coordinated effort and communication between all is necessary. The three years long process leading to this Plan has shown that such collaboration, trust and comprehension between actors is possible and emerging (Ingram *et al*. 2009; Ingram *et al*. 2015). Given the 30 years history of both exploitation and unsustainable harvests in Cameroon, the country has both much to learn and to offer to other African states embarking on similar Management Plans. The plan aims to have a positive economic, social and health impact on thousands of livelihoods of those in both country and worldwide that depend on country *Prunus africana*. Specific recommendations to ensure successful implementation of this plan include (Mbongo 2020).

1. This Management Plan presents recommendations for technical aspects and institutional and regulatory issues. Implementation of institutional aspects is essential for this Plan to work.
2. Plantations should be encouraged, with technical and material incentives provided to divert focus from wild resources.
3. The radical changes proposed in this National Management Plan will need commitment, strong controls and monitoring and extensive changes in both attitudes and behavior.
4. Improved traceability is key to the success of the Plan and essential to build country international image.
5. Distinguishing between active ingredients in wild *Prunus* and that plantation is a key aspect in long term sustainability.
6. Speedy implementation of this Plan is essential to avoid losing the valuable international market for *Prunus* extract based pharmaceutical and health products to alternative natural or synthetic products.
7. Carbon sequestration and avoided deforestation funds from *Prunus* plantations should be explored as potential source of funding for farmers and the government.
8. The challenges of increased costs due to the procedures for PAUs, investments in plantations, inventory and management plans, controls and monitoring compared to its current market value where these aspects have not been accounted for, will have to be addressed by actors at all part of the chain, whilst keeping the product competitive to alternatives.
9. Actors at all stages of the chain all benefit from continued collaboration and exchange of information on the sector, practices prices and developments.
10. Securing land title and protecting *Prunus africana* resources in non-permanent forests needs to be addressed.
11. The PAU system proposed should be open to all enterprises and organization, offering a fair opportunity for smaller and community-based organization to compete for PAU titles, whilst maintaining fair competition to enable an open access market and support fair product prices.
12. Certification of *Prunus africana*, although not unsuitable for the pharmaceutical market, maybe an option for the health and botanical products market. Recent studies and market links directly with Cameroon could enhance this and add to the traceability process.

13. Promoting exchanges of information on technical, price and buyers between groups of harvesters, nurseries and governor's community forests, councils, private owners)
14. The challenge of establishing a stable and fair, equitable relationship between harvesters and buyers of *Prunus* bark has to be overcome.

Conclusions

The medicinal plant *P. africana* has been used in the management of various diseases in world but most of its pharmacological activities have been validated. Due to the risk of overexploitation and extinction, *P. africana* was included in Appendix II of CITES. *P. africana* is a tree whose bark is valued for its active ingredient that treats many diseases, including prostate cancer. In recent years, ethnobotanical and ethnopharmacological knowledge of *P. africana* has developed considerably and the number of diseases that can be treated with extracts from the bark or other organs of this species has increased. Following the suspension of several exporting countries for non-compliance with CITES regulations on the utilization of *P. africana*, international trade in bark has resumed in many countries after quotas were established on the basis of utilization and management inventories. The literature consulted raises numerous questions and perspectives for the conservation and sustainable management of *P. africana*. For example, improved traceability systems are needed from planted trees to exporters and harbors, monitoring natural forests to ensure that wild *P. africana* is not sold as cultivated. This includes the standardization of products made from this species and the calibration of units of measurement used in international trade registers. While certain aspects of *P. africana* are more or less well studied (ethnobotanical uses, morphological and anatomical characteristics of the tree, distribution area, etc.), there are still many gaps that require further research. Future research could therefore focus in particular on the following:

-Updating the geographical distribution of the species in the tropical forests of Africa;
-Molecular phylogeny may help to understand the relationship and differentiation of *P. africana* with other species of the genus *Prunus*;
-Vulnerability of *P. africana* to different climate change scenarios in each distribution area of the species;
-Detailed knowledge of the temperament of the species by quantifying the vessel diameters from pith to bark;
-Detailed knowledge of the phenology of the species based on habitat diversity and climate variability in its range;
-Improve harvesting techniques to promote natural regeneration after bark in natural forests and forest plantations;
-Improving knowledge of the species' dispersal and fruiting in natural forests and forest plantations;
-Establishing a clear policy and traceability system for *P. africana* bark at local, national and international levels. These new scientific studies will help to improve the sustainability of *Prunus africana.*

Declarations

List of abbreviations: Not applicable
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Consent for publication: Not applicable
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