Actualisation du statut de vulnérabilité des espèces ligneuses exploitées en Afrique centrale

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RESUME

La liste rouge de l'UICN joue un rôle crucial dans la sensibilisation de l'opinion publique aux menaces subies par les espèces animales et végétales. Les espèces exploitées pour le bois d'œuvre ne font pas exception. Or les évaluations de certaines d'entre elles remontent à plus de 20 ans et ont été réalisées selon des méthodologies qui ne sont plus en adéquation avec les normes actuelles.

Dans le cadre de ce projet, 21 espèces ont été retenues en fonction de l'ancienneté de leur évaluation et de leur importance économique. Le critère A3 de l'IUCN a été principalement utilisé. Il s'agit d'évaluer la réduction de la population prévue (RPP), déduite ou supposée dans le futur (sur un maximum de 100 ans) en intégrant l'effet de l'exploitation forestière et de la perte ou de la détérioration de la qualité de l'habitat. Pour modéliser l'évolution des populations dans les concessions forestières, les données mobilisées proviennent de 98 unités forestières d'aménagement représentant environ 22 millions ha des forêts tropicales d'Afrique centrale.

Selon le critère A3, lorsque la RPP est supérieure ou égale à 30%, l'espèce est considérée « vulnérable (VU) ». Elle est considérée « en danger (EN) » si la RPP ≥ 50% et « en danger critique d'extinction (CR) » si RPP ≥ 80%. Des informations complémentaires sur l'écologie ont également été considérées dans la définition du statut de conservation de chaque espèce. Sur cette base et après la tenue d'un atelier de validation : (i) trois espèces ont été jugées menacées et classées « **vulnérables** » : *Entandrophragma candollei* (Kosipo), *Erythrophleum ivorense* (Tali), *Triplochiton scleroxylon* (Ayous). (ii) Seize espèces n'ont pas été jugées menacées, dont - neuf espèces sont classées « **presques menacées** » : *Bobgunnia fistuloides* (Pao rosa), *Cylicodiscus gabunensis* (Okan), *Entandrophragma cylindricum* (Sapelli), *Erythrophleum suaveolens* (Tali), *Lophira alata* (Azobé), *Millettia laurentii* (Wengué), *Prioria balsamifera* (Agba / tola), *Terminalia superba* (Limba / fraké), *Tieghemella africana* (Douka) et - sept espèces sont classées en « **préoccupation mineure** » : *Afzelia bipindensis* (Doussié), *Aucoumea klaineana* (Okoumé), *Dacryodes igaganga* (Igaganga), *Entandrophragma utile* (Sipo), *Milicia excelsa* (Iroko), *Pterocarpus soyauxii* (Padouk), *Testulea gabonensis* (Izombé).

Enfin, les données pour les deux espèces de Zingana, *Microberlinia bisculata* et *Microberlinia brazzavilensis,* étaient insuffisantes pour réaliser ces analyses. Toutefois, une actualisation du statut de conservation de *Microberlinia bisulcata* a été réalisée en 2021 (https://www.iucnredlist.org/species/30441/67802206).

1 Contexte et objectif

Le classement des essences tropicales sur la Liste rouge de l'UICN est le principal motif engendrant les réactions négatives de plusieurs organisations qui appellent au boycott des bois tropicaux. Le principal but de cette liste est d'alerter la communauté internationale sur les menaces encourues par certaines espèces afin que des politiques de conservation adéquates soient développées. Pourtant, l'UICN met elle-même en avant les limites de sa Liste rouge : (i) « une catégorie applicable à l'échelon mondial ne correspond peut-être pas à une catégorie nationale ou régionale pour le même taxon » ; (ii) « les taxons devraient être réévalués à intervalles appropriés » ; (iii) « les données qui servent à évaluer les taxons sont souvent estimées avec une incertitude considérable… ».

Certaines évaluations d'espèces d'Afrique centrale exploitées pour leur bois d'œuvre remontent à plus de 20 ans. Ce contexte renforce le besoin d'une actualisation du statut de vulnérabilité des essences ligneuses exploitées et exploitables en Afrique centrale, sur la base de données scientifiques et représentatives de l'état des populations aux échelles sous-régionales, voire locales. **Une mise à jour du statut de conservation UICN des essences exploitées d'Afrique centrale est donc nécessaire.**

Le projet vise à évaluer le statut de vulnérabilité de 21 essences commerciales d'Afrique centrale exploitées et à promouvoir sur la base d'indicateurs robustes. Il s'agira spécifiquement de (i) compiler les données écologiques, (ii) évaluer leur statut de vulnérabilité via un ensemble d'indicateurs exprimant les risques réels ou potentiels à long terme, et (iii) proposer des recommandations adaptées aux différents contextes de légalité forestière en Afrique centrale.

2 Sélection des espèces

Lors d'un atelier de lancement du projet regroupant les principales parties prenantes, 21 espèces ont été sélectionnées en considérant l'ancienneté de leur évaluation (sur plus de 20 ans) et leur importance économique (volumes commercialisés). Ces 21 espèces sélectionnées étaient classées dans cinq catégories (Least Concern–LC, Near Threatened–NT, Vulnerable–VU, Endangered–EN, Critically Endangered–CR) (Tableau 1).

Tableau 1 - Liste des 21 espèces sélectionnées et leur statut de conservation IUCN avant le projet selon le critère A1 (réduction de la population observée, estimée, déduite ou soupçonnée dans le passé).

Essence	Nom scientifique	Catégorie de l'IUCN	Niveau de l'évaluation	Année	Critère
Agba	*Prioria balsamifera*	EN	Global/Afrique	1998	A1cd
Ayous	*Triplochiton scleroxylon*	LR/lc	Global/Afrique	1998	-
Azobé	*Lophira alata*	VU	Global/Afrique	1998	A1cd
Douka	*Tieghemella africana*	EN	Global/Afrique	1998	A1cd
Doussié	*Afzelia bipindensis*	VU	Global/Afrique	1998	A1cd
Fraké	*Terminalia superba*	-	-	-	-
Igaganga	*Dacryodes igaganga*	VU	Global/Afrique	1998	A1cd+2cd
Iroko	*Milicia excelsa*	LR/nt	Global/Afrique	1998	-
Izombé	*Testulea gabonensis*	EN	Global/Afrique	1998	A1cd
Kosipo	*Entandrophragma candollei*	VU	Global/Afrique	1998	A1cd
Okan	*Cylicodiscus gabunensis*	LR/lc	Global/Afrique	2018	-
Okoumé	*Aucoumea klaineana*	VU	Global/Afrique	1998	A1cd
Padouk	*Pterocarpus soyauxii*	-	-	-	-
Pao rosa	*Bobgunnia fistuloides*	LR/lc	Global/Afrique	2010	-
Sapelli	*Entandrophragma cylindricum*	VU	Global/Afrique	1998	A1cd
Sipo	*Entandrophragma utile*	VU	Global/Afrique	1998	A1cd
Tali	*Erythrophleum suaveolens*	LR/lc	Global/Afrique	2019	-
Tali	*Erythrophleum ivorense*	LR/lc	Global/Afrique	2019	-
Wenge	*Millettia laurentii*	EN	Global/Afrique	1998	A1cd
Zingana	*Microberlinia bisulcata*	CR	Global/Afrique	2000	A1c+2c
Zingana	*Microberlinia brazzavillensis*	VU	Global/Afrique	1998	A1c

3 Synthèse des informations écologiques des espèces

Plusieurs documents (monographies, articles scientifiques, livres, autres documents) ont été utilisés pour synthétiser les informations sur la caractérisation écologique de chaque espèce. Cette synthèse bibliographique a été réalisée en utilisant les mots-clés spécifiques dans les moteurs de recherche suivants : Orbi (ULiège), Libnet (ULiège), Scopus, Google Scholar, Agritrop (CIRAD) et les archives du laboratoire de foresterie tropicale de Gembloux Agro-Bio Tech (Université de Liège, Belgique).

Les informations écologiques détaillées de chaque espèce sont compilées dans la fiche de l'espèce (voir en annexe).

4 Distribution géographique des espèces

La distribution spatiale est un paramètre clé intervenant dans l'évaluation des statuts de vulnérabilité. Pour chaque espèce l'aire de distribution a été définie à partir des données d'occurrences provenant des bases de données internationales de RANBIO (https://gdauby.github.io/rainbio/index.html) et du Conservatoire et Jardin botanique de Genève (http://www.ville-ge.ch/musinfo/bd/cjb/chg/index.php?lang=fr) (Figure 1).

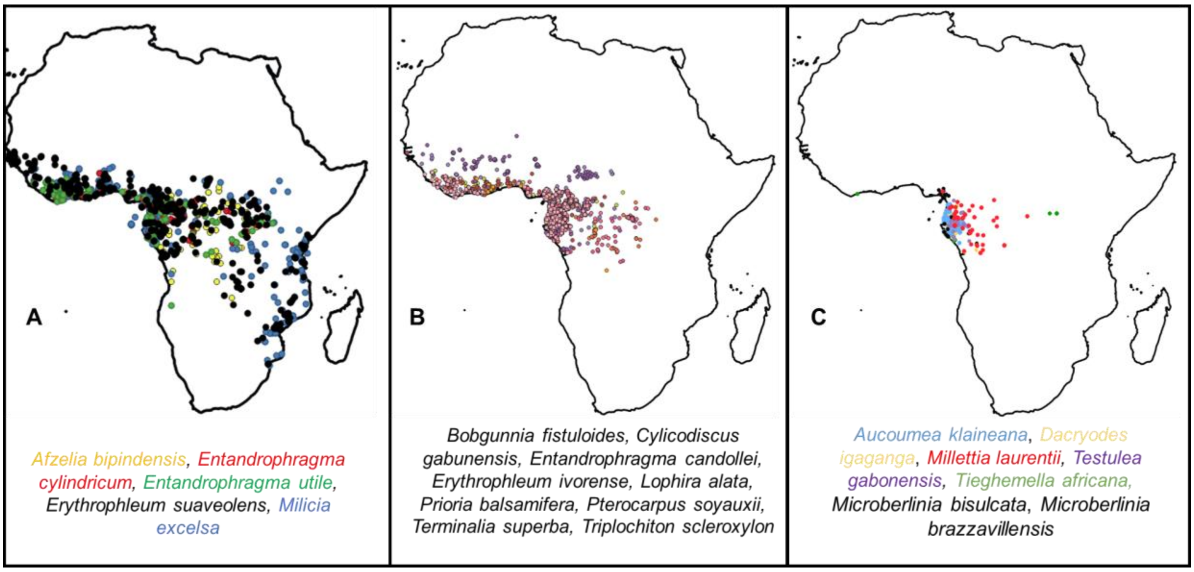

Figure 1 - Localisation géographique des 21 espèces (A) espèces distribuées en Afrique centrale, Afrique de l'ouest et Afrique de l'est, (B) espèces distribuées en Afrique centrale et Afrique de l'ouest et (C) espèces exclusivement distribuées en Afrique centrale

5 Utilisation du critère A3 de la liste rouge de l'UICN

Le critère A3 a été utilisé pour analyser le statut de vulnérabilité de19 espèces. Par manque de données liées à une distribution spatiale très restreinte, les deux espèces de Zingana (*Microberlinia bisulcata* et *Microberlinia brazzavillensis*) n'ont pas été prises en compte dans cette analyse.

5.1 Méthode

Le critère A3 de la Liste rouge de l'UICN traite de la réduction de population projetée, déduite ou suspectée d'être atteinte à l'avenir, mesurée sur 10 ans ou trois générations, selon la plus longue des deux, mais jusqu'à un maximum de 100 ans. Il est basé sur (i) un indice d'abondance approprié au taxon, (ii) une diminution de la zone d'occupation (AOO), de la zone d'occurrence (EOO) et/ou de la qualité de l'habitat, (iii) des niveaux potentiels d'exploitation, et /ou (iv) les effets des taxons introduits, de l'hybridation, des agents pathogènes, des polluants, des concurrents ou des parasites. En vertu du critère A3, un seuil quantitatif spécifique indiquant la réduction de la population doit être atteint pour se qualifier pour l'une des catégories de menace. Ces seuils sont de 80 % (CR), 50 % (EN) et 30 % (VU). Lorsqu'une espèce n'atteint pas ces seuils, elle peut être classée comme Préoccupation mineure (LC) ou Quasi menacée (NT) en fonction de la probabilité d'atteindre dans un avenir proche le seuil minimum de 30 % de la réduction population projetée, inférée ou suspectée.

Nous avons adopté le critère A3 pour évaluer la réduction de la population prévue (RPP) dans le futur (jusqu'à un maximum de 100 ans) de chaque espèce, basé sur (ii) une diminution de la zone d'occupation (AOO), de la zone d'occurrence (EOO) et/ou de la qualité de l'habitat, (iii) et des niveaux potentiels d'exploitation. L'aire de répartition géographique des espèces se situait dans trois régions (Afrique centrale, Afrique de l'Ouest et Afrique de l'Est). Selon chaque région, des données spécifiques (surface forestière, affectation des terres, taux annuel de déforestation, données démographiques des populations d'arbres.) ont été utilisées. Ainsi, les RPP ont été estimées pour chaque région avant d'être globalisées.

5.1.1 Afrique centrale

Dans cette région, la forêt se répartit entre : les aires protégées, les forêts de production (concessions forestières) et le domaine forestier non permanent (tableau 2). Trois RPP différentes ont ainsi été estimées : RPP_{pa} en aires protégées, RPP_{pf} en forêts de production et RPP_{np} en domaine non permanent. Ces trois estimations différentes de la RPP ont été pondérées par leurs superficies forestières relatives, puis ajoutées pour estimer la RPP_{C} en Afrique centrale.

5.1.1.1 Aire protégée

Les pays d'Afrique centrale ont alloué une plus grande proportion de leurs terres à la conservation que dans les autres régions tropicales, avec un succès de conservation relativement élevé (Laurance et al., 2012). En effet, la plupart des aires protégées ont résisté à l'attribution des permis de l'industrie extractive, à la conversion des terres et à l'intrusion de la chasse (Abernethy et al., 2016). En conséquence, nous avons estimé que la population de chaque espèce dans les aires protégées (FRMI, 2018) de son aire de répartition resterait stable dans les 100 ans prochaines années. Dans ces conditions, il a été émis l'hypothèse que la RPP dans les aires protégées pour chaque espèce serait de 0%, suggérant aucune réduction de population dans le futur. Cette hypothèse est bien entendu critiquable mais elle nous parait suffisamment conservatrice. En effet, de nombreuses espèces commerciales sont héliophiles et de nombreuses aires protégées sont constituées de mosaïques forêts – savanes. Des essences comme l'Okoumé, l'Azobé, le Tali pourraient même voir leurs populations augmenter dans de telles aires protégées.

5.1.1.2 Forêts de production

A) Données d'inventaire forestier

Pour quantifier l'évolution des populations des espèces ligneuses, les modèles matriciels sont largement utilisés (Picard and Liang, 2014). Ces modèles doivent être alimentés pas des données d'abondance.

Les densités par classe de diamètre ont été estimées à partir des données d'inventaires forestiers qui ont été réalisés dans 98 unités forestières d'aménagement (UFA) de différentes sociétés d'exploitation forestière dans cinq pays (Cameroun, Gabon, République centrafricaine, République démocratique du Congo, et République du Congo). La plupart des sociétés forestières ont suivi un protocole d'inventaire standardisé (Réjou-Méchain et al., 2011). Ces données d'inventaire forestier couvraient environ 22 millions d'hectares, soit 46% des forêts de production d'Afrique centrale (Tableau 2).

La population de chaque espèce a été décrite au temps *t* par un vecteur N_t correspondant à la densité (nombre d'arbres ha^{-1}) dans chaque classe de diamètre (à partir de 20 cm de diamètre à plus de 120 cm).

Tableau 2 - Nombre (Nb.UFA) et superficie en hectares des unités forestières d'aménagement échantillonnées et proportion relative entre la surface échantillonnée et la surface forestière totale. Superficies totales des différentes allocations forestières par pays (Cameroun, RCA : République centrafricaine, RDC : République démocratique du Congo, EG : Guinée équatoriale, Gabon et RCongo : République du Congo) et proportion relative entre la surface de chaque allocation forestière et la surface forestière totale, NA = Absence de données.

	Echantillonnage		Surface de différentes allocations forestières[1] (Proportion %)		
Pays	**Nb. UFA**	**Superficie (Proportion %)**	**Forêt de production**	**Aire protégée**	**Domaine non-permanent**
Cameroun	22	2 148 944 (12)	8 011 000 (43)	2 193 000 (12)	8 437 000 (45)
RCA	7	2 165 837 (32)	3 084 000 (45)	303 000 (4)	3 527 000 (51)
RDC	15	4 348 051 (5)	9 483 000 (9)	10 329 000 (10)	82 010 000 (81)
EG	NA	NA	1 036 000 (50)	448 000 (22)	579 000 (28)
Gabon	46	8 765 623 (40)	14 936 000 (67)	2 676 000 (12)	4 713 000 (21)
RCongo	8	4 005 312 (24)	10 481 000 (61)	2 392 000 (14)	4 244 000 (25)

B) Données démographiques

La mortalité, le recrutement et la croissance des arbres sont trois processus centraux pour prédire la dynamique des forêts tropicales humides et l'estimation de ces trois processus nécessite un suivi à long terme (Picard and Gourlet-Fleury, 2008). Ces processus déterminent l'évolution de la population d'espèces dans le peuplement forestier.

Le modèle matriciel d'Usher a été utilisé pour simuler l'évolution du taux de reconstitution de l'ensemble de la population et du stock exploitable de chaque espèce après exploitation en Afrique centrale. Suivant l'hypothèse du modèle d'Usher, entre t et t+1, un individu peut soit rester en vie dans la même classe, soit rester en vie et passer à la classe supérieure, soit mourir ; il ne peut pas monter de plus d'une classe ou reculer, c'est-à-dire que l'individu est exempt de rétrécissement de diamètre (Picard et al., 2012). Le modèle matriciel d'Usher (U) considère trois paramètres (mortalité, recrutement et taux de croissance constants dans le temps) pour estimer les probabilités de transition :

$$U = \begin{pmatrix} q_1 + g_1 & g_2 & \cdots & \cdots & g_I \\ p_1 & q_2 & 0 & \cdots & 0 \\ 0 & \ddots & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & p_{I-1} & q_I \end{pmatrix}$$

où q_i est la probabilité pour un individu de rester en vie dans la classe i entre deux pas de temps consécutifs, p_i est le taux de transition ascendante (la probabilité pour un individu de passer de la classe i à la classe i +1), et g_i est le taux recrutement (Picard & Liang, 2014).

[1] FRMI (2018)

- Mortalité des arbres

Peu d'études ont rapporté des estimations des taux annuels de mortalité en Afrique centrale. Les données sur la mortalité des arbres sont encore rares et ne permettent pas de modéliser précisément ces taux pour chaque espèce et classe de diamètre. Dans l'état actuel des connaissances, il semble raisonnable d'utiliser un taux annuel de mortalité fixe de 1 % pour toutes les espèces et toutes les classes de diamètre, en accord avec les résultats de Ligot et al. (2022) sur 21 180 arbres appartenant à 42 espèces d'arbres d'Afrique.

- Recrutement des arbres

Le recrutement annuel se définit comme étant la proportion d'arbres intégrant annuellement la population étudiée. Il dépend donc de la régénération des espèces. Dans cette étude, il a été considéré comme l'apport annuel moyen de nouveaux individus dans la première classe diamétrique, 20-29,9 cm. Les événements de recrutement, comme les événements de mortalité, sont peu fréquents et donc difficiles à modéliser (Karsenty and Gourlet-Fleury, 2006). Pour modéliser le recrutement, nous avons testé deux approches. La première approche considère que le taux de recrutement est de 1 %, soit la même valeur que pour le taux de mortalité. Cette première approche est très pessimiste car elle considère que les arbres exploités ne seront pas remplacés et donc que la population va diminuer au cours du temps. Elle a été appliquée à des espèces dont la dispersion des graines est liée à des populations animales en régression (*Bobgunnia fistuloides* dispersé par l'éléphant de forêt) ou dont la fructification est très épisodique (*Triplochiton scleroxylon*). La deuxième approche considère que le taux de recrutement maintient un nombre constant d'arbres dans la première classe de diamètre. Cette deuxième approche concerne les espèces qui peuvent coloniser des milieux ouverts (*Aucoumea klaineana* qui peut coloniser les savanes encore abondantes dans son aire de distribution) et/ou un bon nombre de tiges dans les deux premières classes de diamètre (*Entandrophragma* spp.).

Selon Claeys et al. (2019) les taux de mortalité et de recrutement projetés en 2099 ne seraient pas différents de ceux observés aujourd'hui. Ainsi, l'hypothèse sur le recrutement et le taux de mortalité a été utilisée dans le futur (jusqu'à 100 ans).

- Croissance des arbres

Nous avons ajusté des modèles de croissance pour chaque espèce en utilisant les données des zones exploitées et non exploitées des dispositifs du réseau DYNAFAC couvrant les cinq pays d'Afrique centrale. Des modèles linéaires polynomiaux du second degré (sans effet aléatoire) ont été ajustés pour les espèces suivies dans un seul site tandis que des modèles mixtes polynomiaux du second degré (avec un effet de site aléatoire) ont été ajustés pour les espèces suivies dans plusieurs sites (Tableau 3).

Tableau 3 - Modèle et coefficients estimés (a, b et c) pour 18 essences de bois africaines. n = Nombre d'arbres, n.Site = Nombre de sites, ac = Accroissement en cm.an^{-1}, D = Diamètre initial en centimètre.

Essence	n	n.Site	Modèle	a	b	c
Agba	91	1	ac ~ D + D^2	0.094	0.024	-0.00021
Ayous	882	8	ac ~ D + D^2 + (1|site)	0.688	0.002	0.00001
Azobe	1179	6	ac ~ D + D^2+ (1|site)	0.035	0.017	-0.00011
Douka	35	2	ac ~ D + D^2 + (1|site)	0.545	0.0000	-0.000002
Doussié	477	7	ac ~ D + D^2 + (1|site)	0.218	0.001	-0.000001
Igaganga	390	1	ac ~ D + D^2	0.19	0.009	-0.00008
Iroko	54	4	ac ~ D + D^2+ (1|site)	1.333	-0.02	0.00009
Kosipo	822	6	ac ~ D + D^2 + (1|site)	-0.07	0.016	-0.000065
Limba	858	7	ac ~ D + D^2 + (1|site)	0.911	-0.01	0.00003
Okan	965	5	ac ~ D + D^2 + (1|site)	0.36	0.009	-0.000055
Okoume	57	1	ac ~ D + D^2	-0.247	0.032	-0.00028
Padouk	2001	12	ac ~ D + D^2 + (1|site)	0.292	0.008	-0.000068
Pao rosa	111	3	ac ~ D + D^2 + (1|site)	0.083	0.014	-0.00016
Sapelli	1666	7	ac ~ D + D^2 + (1|site)	-0.007	0.022	-0.00015
Sipo	448	6	ac ~ D + D^2+ (1|site)	0.167	0.018	-0.00010
Tali_ivo	384	2	ac ~ D + D^2 + (1|site)	0.832	-0.007	0.000021
Tali_sua	1647	6	ac ~ D + D^2 + (1|site)	0.517	0.003	-0.000058
Wenge	94	2	ac ~ D + D^2 + (1|site)	0.205	0.005	-0.000039

C) Paramètre d'exploitation forestière

Les probabilités de transition de trois paramètres (mortalité, croissance et taux de recrutement) ont permis de constituer la matrice de récolte. Les opérations d'exploitation ont été modélisées à l'aide des paramètres d'exploitation (diamètre minimal de coupe, intensité de coupe et taux de dégâts d'exploitation). Les diamètres minimaux de coupe de chaque espèce ont été obtenus à partir des arrêtés d'application des administrations forestières (DME : diamètre minimum d'exploitation) au niveau des pays et celui retenu dans le plan d'aménagement (DMA : diamètre minimum d'aménagement, avec DMA ≥ DME) au niveau des exploitants forestiers. Au niveau de l'Afrique centrale, nous avons pondéré les valeurs DME et DMA à la superficie occupée par chaque espèce dans chaque pays et entreprise forestière (Tableau 4). L'intensité de coupe, qui définit la proportion d'arbres abattus parmi les arbres de diamètre supérieur au DME ou DMA, a été donnée par les exploitants forestiers, et elle a également été pondérée au niveau de l'Afrique centrale pour chaque essence (Tableau 4). Enfin, dans l'état actuel des connaissances, il apparaît raisonnable de retenir un taux fixe de dommages causés par l'exploitation de 7 % de la population initiale qui disparaît (Durrieu de Madron et al., 2000a). Cette valeur correspond à l'exploitation moyenne d'un arbre par hectare.

Tableau 4 - Valeurs pondérées au niveau de l'Afrique centrale de trois paramètres d'exploitation pour 19 essences de bois. DME = Diamètre minimum d'exploitation en centimètre, DMA = Diamètre minimum d'aménagement en centimètre, IC = intensité de coupe en pourcent.

Essence	DME	DMA	IC
Agba	80	80	71
Ayous	65	90	82
Azobe	75	85	63
Douka	85	85	25
Doussié	70	70	68
Igaganga	60	60	52
Iroko	80	85	79
Izombe	80	80	74
Kosipo	80	90	86
Limba	60	75	67
Okan	65	85	53
Okoume	70	70	70
Padouk	70	75	69
Pao rosa	65	65	66
Sapelli	85	85	86
Sipo	80	90	83
Tali_ivo	55	75	40
Tali_sua	65	75	60
Wenge	60	65	62

D) Paramètre de simulation

Pour quantifier la réduction de population prévue, les simulations doivent être effectuées sur des individus matures et sur trois générations avec un maximum de 100 ans pour chaque espèce. Nous avons estimé les individus matures et la durée des générations pour chaque espèce, comme recommandé par les lignes directrices de l'UICN.

Un individu mature est un individu capable de se reproduire (fertile). Pour quantifier les individus matures pour chaque espèce, nous avons utilisé les données phénologiques obtenues à partir de 6000 observations du réseau DYNAFAC. Nous avons utilisé la méthodologie de Ouédraogo et al. (2018) pour estimer le diamètre de reproduction, soit le diamètre obtenu après régression logistique de la probabilité d'être fertile et le niveau de 50% a été adopté pour chaque espèce. Le diamètre minimum des individus matures pour les 19 espèces varie de 20 à 80 cm (Tableau 5).

La durée de génération a ensuite été calculée comme le rapport entre le diamètre moyen des individus matures compte tenu de la structure de la population et l'accroissement moyen pour chaque espèce. La durée de génération pour les 19 espèces varie de 79 à 210 ans (Tableau 5).

Tableau 5 - Données phénologiques et dendrométrique de 19 essences de bois. n = Nombre d'arbres, Monito = Période de suivi des arbres en mois, D = Gamme de diamètre des arbres suivis en centimètre, Dmat = Diamètre des individus matures, Dmat_mo = Diamètre moyen des individus matures, Accr = Accroissement moyen en $cm.an^{-1}$, Age = temps de génération, NA = Absence de données.

Essence	n	Monito	D	Dmat	Dmat_mo	Accr	Age
Agba	92	NA	NA	55	81	0.66	123
Ayous	493	72	10-150	65	93	0.78	120
Azobe	410	76	10-130	35	63	0.49	129
Douka	32	12	25-150	80	105	0.50	209
Doussié	95	192	14-123	20	42	0.21	195
Igaganga	48	NA	NA	35	54	0.43	126
Iroko	152	204	10-160	20	58	0.53	111
Izombe	NA	NA	NA	20	58	0.40	130
Kosipo	57	72	12-162	65	86	0.43	199
Limba	331	72	10-116	20	65	0.47	140
Okan	182	168	10-220	20	79	0.67	117
Okoume	105	NA	NA	25	54	0.69	79
Padouk	180	204	10-103	35	60	0.49	123
Pao rosa	9	NA	NA	20	59	0.32	186
Sapelli	478	204	10-179	35	79	0.63	127
Sipo	23	204	10-112	20	69	0.50	137
Tali_ivo	445	204	10-130	20	73	0.52	139
Tali_sua	445	204	10-130	20	66	0.47	141
Wenge	90	NA	11-100	35	55	0.26	211

Etant donné que le temps de génération des 19 espèces varie de 79 à 210 ans (avec une seule espèce dont la valeur est de moins d'un siècle), les simulations ont été faites sur 100 ans pour toutes les espèces. Le cycle de rotation moyen (c'est-à-dire la période entre deux opérations d'exploitation successives) est de 28 ans (FRMI, 2018). Un cycle de rotation de 25 ans a été utilisé pour permettre quatre simulations afin d'atteindre 100 ans (25, 50, 75 et 100 ans), comme demandé selon le critère A3 de l'UICN.

La réduction de la population (RPP) de chaque espèce a ensuite été calculée comme la différence entre le nombre initial d'individus matures et le nombre prévu d'individus matures après 100 ans rapportée au nombre initial. A titre d'illustration, la Figure 2 montre la RPP dans les forêts de production pour l'Okoumé (*Aucoumea klaineana*) avec un recrutement constant et le Pao Rosa (*Bobgunnia fistuloides*) avec un recrutement à 1%.

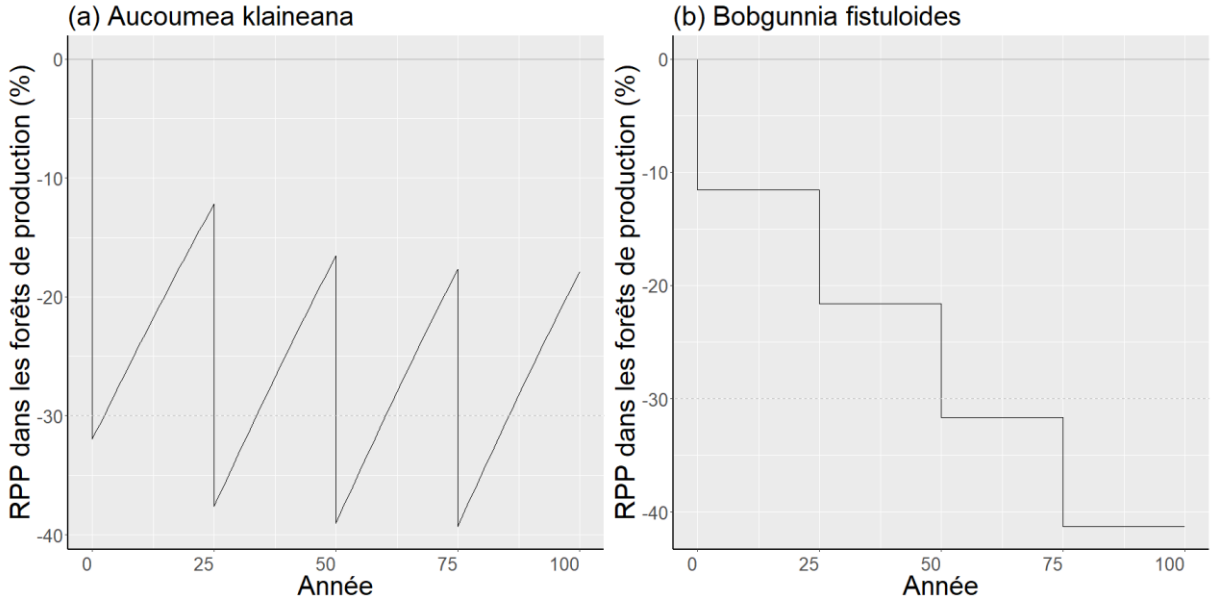

Figure 2 - Simulations de la réduction de population projetée (RPP) sur 100 ans à partir du diamètre des individus matures pour (a) L'Okoumé (*Aucoumea klaineana*) dans les forêts de production avec un recrutement constant et (b) le Pao Rosa (*Bobgunnia fistuloides*) dans les forêts de production avec un recrutement à 1%.

5.1.1.3 Domaine non-permanent

Les principales menaces dans le domaine non-permanent sont la perte d'habitat due à la destruction des milieux naturels liée à la croissance démographique, telles que l'urbanisation, l'expansion de l'agriculture, la collecte de bois de feu. A cela s'ajoute l'exploitation forestière illégale et la surexploitation des produits forestiers non ligneux (Bradshaw et al., 2009). Selon FRMI (2018), l'exploitation forestière illégale concerne 46 % de la production totale. Ce taux de l'exploitation illégale varie d'un pays à un autre en Afrique centrale. En fonction de la présence de l'espèce dans les pays en Afrique centrale, le taux de l'exploitation illégale de chaque espèce a été adapté (Tableau 6).

Tableau 6 - Estimation du taux d'exploitation illégale pour 19 essences en fonction de la présence dans les pays d'Afrique centrale.

Essence	Exploitation illégale (%)	Exploitation légale (%)
Agba	46	54
Ayous	46	54
Azobe	46	54
Douka	10	90
Doussié	46	54
Igaganga	11	89
Iroko	46	54
Izombe	10	90
Kosipo	46	54
Limba	46	54
Okan	20	80
Okoume	24	76
Padouk	46	54
Pao_rosa	24	76
Sapelli	46	54
Sipo	46	54
Tali_ivo	15	85
Tali_sua	46	54
Wenge	36	64

Dans ce contexte, il a été émis l'hypothèse que le pourcentage de l'exploitation légale et illégale correspondait également au pourcent de RPP respectivement. Par exemple, il y a 54% de RPP provenant des forêts de production et 46% de RPP provenant de l'exploitation illégale dans 100% de RPP due à l'exploitation forestière pour les espèces distribuées dans tous les pays d'Afrique centrale (Agba, Ayous, etc.). Etant donné que la RPP des forêts de production associées à sa superficie forestière était connu, la RPP et la superficie forestière d'exploitation illégale ont été déduits en pondération par ceux des forêts de production.

La superficie restante du domaine non permanent a été considérée comme la superficie qui était liée au taux de déforestation actuel de 0,35 % an^{-1} en Afrique centrale (Vancutsem et al., 2021). Il s'agit d'une valeur prudente puisqu'elle diminuera probablement à l'avenir (Swamy et al., 2018). Le pourcentage de l'exploitation illégale et le taux de déforestation ont été ajustés en fonction de la zone d'occupation de chaque espèce en Afrique centrale.

5.1.2 Afrique de l'Ouest et Afrique de l'Est

Dans ces deux régions, les forêts ne sont généralement pas gérées en concessions, et la grande partie de la forêt tropicale a été transformée en zones cultivées (Nix, 2019). Compte tenu du degré élevé d'anthropisation de cette zone, les principales menaces sont la perte d'habitat due à la destruction des milieux naturels et à l'exploitation forestière illégale. Les arbres étant fréquemment exploités dans les champs, le taux de déforestation lié à la production agricole a été considérée comme une approximation du prélèvement d'arbres. Ainsi, les zones forestières d'Afrique de l'Ouest (15 600 000 ha) et d'Afrique de l'Est (6 400 000 ha) ont été soumises à un taux de déforestation annuel constant de 1,20% an^{-1} et 1,53% an^{-1} respectivement (Vancutsem et al., 2021). Considérer que ce taux de déforestation sera constant au cours des 100 prochaines années, alors qu'il devrait diminuer, est une mesure de précaution raisonnable intégrant toutes les formes d'exploitations forestières (légales et illégales).

5.1.3 Calcul du RPP global

Les trois RPP (RPP_C en Afrique centrale, le RPP_W en Afrique de l'Ouest et le RPP_E en Afrique de l'Est) ont ensuite été pondérés par leurs superficies forestières relatives :

$$RPP = \frac{(S_C \times RPP_C) + (S_W \times RPP_W) + (S_E \times RPP_E)}{S_C + S_W + S_E}$$

où S_C, S_W et S_E sont respectivement les surfaces forestières d'Afrique centrale, d'Afrique de l'Ouest et d'Afrique de l'Est.

Le critère A3 basé sur (c) un déclin de la zone d'occupation (AOO), de la zone d'occurrence (EOO) et/ou de la qualité de l'habitat ; et (d) les niveaux potentiels d'exploitation, a été calculé comme suit :

30%≤PPR<50%, l'espèce est considérée comme Vulnérable (VU)

50%≤PPR <80%, l'espèce est considérée comme En Danger (EN)

PPR ≥ 80%, l'espèce est considérée comme en danger critique d'extinction (CR)

5.2 Résultat de la réduction de la population prévue (RPP)

Pour deux espèces (*Dacryodes igaganga* – Igaganga et *Milicia excelsa* – Iroko), il a été estimé que les effectifs augmenteraient au cours du siècle à venir (valeur positive du RPP dans le tableau 7). Pour les 17 autres espèces, la RPP globale a varié de 2 à 40% avec le diamètre minimum d'exploitation (DME) et de 1 à 37% avec le diamètre minimum d'aménagement (DMA) (Tableau 7). Parmi les 17 espèces, seules trois espèces (*Entandrophragma candollei* – Kosipo, *Erythrophleum ivorense* – Tali_ivo, *Triplochiton scleroxylon* – Ayous) ont des valeurs ≥ 30% (Tableau 7).

Tableau 7 – Synthèse des paramètres d'exploitation et réduction de population projetée selon le diamètre minimum d'exploitation et selon le diamètre minimum d'aménagement pour 19 essences de bois. DME = Diamètre minimum d'exploitation en centimètre, DMA = Diamètre minimum d'aménagement en centimètre, IC = Intensité de coupe en pourcent, Dmat = Diamètre des individus matures en centimètre, Recrut. = Type de recrutement, RPP = Réduction de population projetée en pourcent, Conce = Forêt de production, AF_cent = Afrique centrale, Global = Échelle globale.

						RPP (%) avec DME			RPP (%) avec DMA		
Esssence	DME	DMA	IC	Dmat	Recrut.	Conce	AF_cent	Global	Conce	AF_cent	Global
Agba	80	80	71	55	constant	-39.37	-21.74	-20.08	-39.37	-21.74	-20.08
Ayous	65	90	82	65	constant	-85.15	-44.15	-38.94	-76.01	-39.43	-34.8
Azobe	75	85	63	35	constant	-49.44	-21.08	-19.6	-45.45	-19.4	-18.04
Douka	85	85	25	80	constant	-33.55	-13.54	-13.54	-33.55	-13.54	-13.54
Doussié	70	70	90	35	constant	-8.75	-2.45	-2.39	-8.75	-2.45	-2.39
Igaganga	60	60	52	35	constant	28.72	16.27	16.27	28.72	16.27	16.27
Iroko	80	85	79	20	constant	33.15	6.18	5.86	39.21	7.36	6.99
Izombe	80	80	74	20	constant	-28.42	-18.36	-18.36	-28.42	-18.36	-18.36
Kosipo	80	90	86	65	constant	-73.83	-32.92	-30.82	-68.05	-30.36	-28.43
Limba	60	75	67	20	constant	-59.2	-34.47	-31.41	-49.58	-28.9	-26.36
Okan	65	85	53	20	constant	-64.09	-21.12	-18.42	-59.96	-19.76	-17.25
Okoume	70	70	90	25	constant	-17.91	-11.8	-11.8	-17.91	-11.8	-11.8
Padouk	70	75	69	35	constant	-29.93	-16.59	-15.34	-22.51	-12.53	-11.61
Pao_rosa	65	65	66	20	1%	-41.26	-12.65	-11.7	-41.26	-12.65	-11.7
Sapelli	85	85	86	35	constant	-39.49	-17.7	-16.21	-39.49	-17.7	-16.21
Sipo	80	90	83	20	constant	-8.76	-3	-2.89	-5.24	-1.9	-1.86
Tali_ivo	55	75	40	35	constant	-62.19	-49.36	-40.91	-56.97	-45.21	-37.49
Tali_sua	65	75	60	35	constant	-45.85	-15.76	-14.57	-41.86	-12.50	-11.40
Wenge	60	65	62	35	constant	-60.42	-26.77	-26.77	-52.85	-23.44	-23.44

6 Rédaction des fiches et Statut de conservation de l'UICN

Les valeurs de RPP calculées ont été intégrées dans des fiches d'évaluations des statuts de vulnérabilité en suivant les lignes directrices de l'UICN. Bien que les statuts de conservation proposés se basent essentiellement sur le critère A3, les autres critères ont également été commentés en considérant l'ensemble des informations disponibles dans les synthèses bibliographiques.

Ces fiches ont été analysées et amendées lors d'un atelier de validation qui s'est tenu à Libreville (Gabon) du 5 au 9 décembre 2022 (Tableau 8). Cet atelier a réuni les membres de l'administration forestière, les responsables nationaux de la CITES, les botanistes nationaux, les gestionnaires forestiers ainsi que les autorités UICN de la liste rouge des pays d'Afrique centrale. A l'issue de l'atelier, les recommandations ci-après ont été adoptées.

Trois **espèces sont classées dans la catégorie vulnérable**, il s'agit de : *Entandrophragma candollei* (Kosipo), *Erythrophleum ivorense* (Tali des forêts côtières), *Triplochiton scleroxylon* (Ayous). Ces espèces devraient faire l'objet de mesures de gestion particulière, par exemple des méthodes d'appui à la régénération.

Neuf espèces sont classées dans la catégorie « Presque Menacée » (NT). Ce sont : *Bobgunnia fistuloides* (Pao rosa), *Cylicodiscus gabunensis* (Okan), *Entandrophragma cylindricum* (Sapelli), *Erythrophleum suaveolens* (Tali des forêts continentales), *Lophira alata* (Azobé), *Millettia laurentii* (Wengué), *Prioria balsamifera* (Agba / Tola), *Terminalia superba* (Limba / Fraké), *Tieghemella africana* (Douka). L'évolution de leurs populations devrait faire l'objet d'un monitoring régulier.

Enfin, les espèces suivantes sont classées en « Préoccupation Mineure » (LC) : *Afzelia bipindensis* (Doussié), *Aucoumea klaineana* (Okoumé), *Dacryodes igaganga* (Igaganga), *Entandrophragma utile* (Sipo), *Milicia excelsa* (Iroko), *Pterocarpus soyauxii* (Padouk), *Testulea gabonensis* (Izombé).

Les remarques et recommandations faites par les experts réunis lors de l'atelier de Libreville ont été intégrées dans les dernières versions des fiches espèces (voir annexe). Les évaluations seront soumises au Missouri Botanical Garden - Scientist, Africa & Madagascar Department, qui est l'Autorité de la Liste Rouge pour l'Afrique centrale des plantes (CARLA/UICN) de la Commission de la sauvegarde des espèces de l'UICN (Species Survival Commission, SSC), en vue de leur publication sur le site internet de Liste Rouge des espèces de l'UICN (www.iucnredlist.org).

Tableau 8 - Synthèse des évaluations réalisées pour 21 espèces dans le cadre du projet Vulnérabilité, Libreville 2022. DMEp = Diamètre minimum d'exploitation pondéré en centimètre, DMAp = Diamètre minimum d'aménagement pondéré en centimètre, DFR = Diamètre de fructification régulière en centimètre, DMEr = Diamètre minimum d'exploitation recommandé (Dynafac)* en centimètre, Rég. = Régénération, T.mob = Taux de mobilisation en pourcent (FRMi, 2018), DM = Diamètre de maturité en centimètre (sensus UICN)**, PE = Population estimée (dhp > 20 cm) dans UFA analysées en million d'arbres, Mod100 = Modification prévue dans l'aire de répartition dans 100 ans en pourcent, SA = Statut UICN actuel, SP = Statut proposé dans le cadre du projet, Evo = Evolution du statut, / = Non déterminé.

Essence	Nom scientifique	DMEp	DMAp	DFR	DMEr	Rég.	T.mob	DM	PE	Mod100	SA	SP	Evo
Agba / tola	*Prioria balsamifera*	80	80	60	90	++	10	55	3,4	-20	EN	NT	↘
Ayous	*Triplochyton scleroxylon*	65	90	90	100	-	60	65	8,9	-35	LC	VU	↗
Azobé	*Lophira alata*	75	85	50	70	++	74	35	6,0	-18	VU	NT	↘
Douka	*Tieghmella africana*	85	85	70	90	+	15	80	0,5	-14	EN	NT (protégé au Gabon)	↘
Doussié	*Afzelia bipindensis*	70	70	50	70	++	73	35	2,2	-2	VU	LC	↘
Igaganga	*Dacryodes igaganga*	60	60	35	/	++	/	35	6,2	16	/	LC	**NEW!**
Iroko	*Milicia excelsa*	80	85	50	70	+	64	20	2,7	7	NT	LC	↘
Izombé	*Testulea gabonensis*	80	80	50	/	++	/	20	1,3	-18	EN	LC	↘
Kosipo	*Entandrophragma candollei*	80	90	90	100	+	51	65	7,5	31	VU	VU	↔
Limba / fraké	*Terminalia superba*	60	75	40	60	-	9	20	12,3	-26	/	NT	**NEW!**
Okan	*Cylicodiscus gabunensis*	65	85	60	80	-	91	20	3,0	-17	LC	NT	↗
Okoumé	*Aucoumea klaineana*	70	70	50	70	+	93	25	55,8	-12	VU	LC	↘
Padouk	*Pterocarpus soyauxii*	70	75	40	60	++	30	35	18,9	-12	/	LC	**NEW!**
Pao rosa	*Bobgunnia fistuloides*	65	65	70	70	+	18	20	1,5	-12	LC	NT	↗
Sapelli	*Entandrophragma cylindricum*	85	85	70	90	+	80	35	11,6	-16	VU	NT	↘
Sipo	*Entandrophragma utile*	80	90	80	100	+	50	20	1,7	-2	VU	LC	↘
Tali	*Erythrophleum ivorense*	55	75	60	80	-	62	35	3,1	-37	LC	VU	↗

Essence	Nom scientifique	DMEp	DMAp	DFR	DMEr	Rég.	T.mob	DM	PE	Mod100	SA	SP	Evo
Tali	*Erythrophleum suaveolens*	65	75	60	80	+/-	62	35	8,5	-11	LC	NT	↗
Wengué	*Millettia laurentii*	60	65	40	60	+	20	35	1,1	-23	EN	NT	↘
Zingana	*Microberlinia bisculata*					Non révisé					EN	EN	↔
Zingana	*Microberlinia brazzavilensis*					Non révisé					/	VU	/

**diamètre permettant de maintenir des flux de gènes (pollen et graines) optimaux, il correspond au diamètre de fructification régulière (50 % de probabilité de fructification) + 15 ou 20 cm*

***diamètre à partir duquel la probabilité de fleurir est de 50 %*

7 Diffusion des résultats

Plusieurs activités de communication ont été réalisées. Il s'agit principalement de la participation aux ateliers redlisting organisés par le MBG, aux séminaires du laboratoire de foresterie tropicale, aux réunions de suivies du projet et l'organisation d'un atelier à Libreville. Toutes les présentations et autres communications produites dans le cadre du projet sont téléchargeables via ce lien : https://dox.uliege.be/index.php/s/Y4cy55duQBDRJGR?path=%2FPr%C3%A9sentations

7.1 Mise en annexe II de la CITES des espèces africaines des genres *Afzelia* (Doussié), *Khaya* (Acajou) et *Pterocarpus* (Padouk)

Le projet a été approché par plusieurs pays producteurs de bois en Afrique centrale, notamment le Cameroun et le Gabon, au sujet la volonté de l'UE d'inclure en annexe 2[2] de la CITES les espèces africaines des genres *Pterocarpus* (Padouk), *Khaya* (Acajou) et *Afzelia* (Doussié) (https://cites.org/eng/cop/19/amendment-proposals/provisional). Selon cette annexe « le commerce international des spécimens des espèces inscrites à l'Annexe II peut être autorisé et doit dans ce cas être couvert par un permis d'exportation ou un certificat de réexportation ». Au regard des faibles menaces qui pèsent sur ces espèces, en particulier le Padouk et le Doussié analysés dans le cadre du présent projet, des rencontres ont été organisées avec les points focaux CITES (Belgique et France) et les référents UE en charge du suivi de ces questions en marge de la COP19 CITES au Panama. Ces rencontres avaient pour objectif le partage des résultats obtenus dans le cadre du présent projet, qui montrent que le Padouk et le Doussié ne sont pas menacées. Ces résultats ont également été présentés lors de la COP 19 par G. Loubota.

Des newsletters ont été publiées sur les sites partenaires, dont la principale est celle mettant en avant la contribution du projet pour la production des données scientifiques de terrain pour la prochaine conférence CITES (https://www.atibt.org/fr/news/13186/des-donnees-scientifiques-de-terrain-pour-la-prochaine-conference-cites). Malgré ces efforts de communication, les genres *Pterocarpus* et *Afzelia* ont été inclus en annexe II de la CITES, et GxABT (Université de Liège) a publié un article pour tirer la sonnette d'alarme (https://www.gembloux.uliege.be/cms/c_10325279/fr/l-uliege-tire-la-sonnette-d-alarme-sur-les-restrictions-d-exploitation-de-plusieurs-especes-de-bois-en-afrique).

[2] L'Annexe II est la liste des espèces qui, bien que n'étant pas nécessairement menacées actuellement d'extinction, pourraient le devenir si le commerce de leurs spécimens n'était pas étroitement contrôlé. Elle comprend aussi ce qu'on appelle les "espèces semblables", c'est-à-dire celles dont les spécimens commercialisés ressemblent à ceux d'espèces inscrites pour des raisons de conservation (voir Article II, paragraphe 2, de la Convention). Le commerce international des spécimens des espèces inscrites à l'Annexe II peut être autorisé et doit dans ce cas être couvert par un permis d'exportation ou un certificat de réexportation. La CITES n'impose pas de permis d'importation pour ces espèces (bien qu'un permis soit nécessaire dans certains pays ayant pris des mesures plus strictes que celles prévues par la Convention). Les autorités chargées de délivrer les permis et les certificats ne devraient le faire que si certaines conditions sont remplies mais surtout si elles ont l'assurance que le commerce ne nuira pas à la survie de l'espèce dans la nature (voir Article IV de la Convention).

7.2 Atelier d'actualisation des statuts de conservation UICN de 19 espèces de bois d'œuvre en Afrique centrale examinées par un comité d'experts

L'atelier de validation des statuts UICN de dix-neuf espèces d'arbres exploitées en Afrique centrale s'est tenue du 05 au 09 décembre 2022 à Libreville (Gabon). Cet atelier a largement été relayé sur les médias nationaux, (i) dans la presse écrite :

- https://www.gabonreview.com/exploitation-du-bois-les-statuts-de-conservation-de-21-especes-en-revision-a-libreville/ ;
- https://www.agenceafrique.com/39229-gabon-libreville-accueille-un-atelier-de-revision-des-statuts-de-conservation-dune-vingtaine-despeces-ligneuses-dafrique-centrale.html ;
- https://www.lenouveaugabon.com/fr/agro-bois/0612-19254-gabon-vers-la-mise-en-place-d-un-mecanisme-de-controle-de-la-gestion-des-especes-exploitees-des-forets et dans presse parlé, l'extrait disponible à l'adresse suivante https://www.facebook.com/tvgabon24/videos/452739127056230/ a été diffusé sur Gabon24.

Figure 3 - Participants à l'atelier d'actualisation de la liste rouge de l'UICN : 19 espèces de bois d'œuvre d'Afrique centrale à Libreville au Gabon.

8 Conclusion et recommandation

Ce projet a permis une analyse du statut de vulnérabilité de 19 espèces exploitées pour leur bois d'œuvre. Les analyses ont mobilisé des données d'inventaires forestiers sur près de 22 millions d'hectares et sur des données démographiques issues de plus de 20 ans de recherche sur la dynamique forestière en Afrique centrale menées par le collectif Dynafac.

Le critère A3 de l'UICN a majoritairement été utilisé, en estimant la réduction de la population projetée, inférée ou suspectée sur maximum 100 ans. Sur les 19 espèces étudiées, trois présentent une diminution de plus de 30% et ont été classées vulnérables. Il s'agit du Kosipo (*Entandrophragma candollei*), du Tali (*Erythrophleum ivorense*) et de l'Ayous (*Triplochiton scleroxylon*).

En comparaison avec les statuts de vulnérabilité précédents, les résultats de cette étude proposent de modifier les statuts de vulnérabilité :

- Pour 5 espèces, le nouveau statut constitue une augmentation de la vulnérabilité (*Triplochyton scleroxylon, Cylicodiscus gabunensis, Bobgunnia fistuloides, Erythrophleum ivorense, Erythrophleum suaveolens*)
- Pour 10 espèces, le nouveau statut constitue une diminution de la vulnerabilité (*Prioria balsamifera, Lophira alata, Tieghmella africana, Afzelia bipindensis, Milicia excelsa, Testulea gabonensis, Aucoumea klaineana, Entandrophragma cylindricum, Entandrophragma utile, Millettia laurentii*)
- Pour une espèce, le statut n'a pas été modifié (*Entandrophragma candollei*)
- 3 nouvelles espèces qui n'étaient pas catégorisées ont été analysées (*Dacryodes igaganga, Terminalia superba, Pterocarpus soyauxii*).

Bien que cette étude ait classé le Padouk (*Pterocarpus soyauxii)* et le Doussié (*Afzelia bipindensis)* dans la catégorie LC, donc non vulnérables, elles ont été récemment inclues en annexe II de la CITES. Ce fait démontre la nécessité de considérer des évaluations récentes et robustes des statuts de vulnérabilité avant toute nouvelle volonté de classement d'espèces commerciales en annexe II de la CITES.

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10 Annexes

10.1 Annexe 1. *Afzelia bipindensis* - Harms

Draft

Afzelia bipindensis **- Harms**

PLANTAE - TRACHEOPHYTA - MAGNOLIOPSIDA - FABALES - FABACEAE - Afzelia - bipindensis

Common Names: Aja, Ayan-olutoko, Doussie, Doussié, Odo Niyan, Red Doussié
Synonyms: *Pahudia bequaertii* (De Wild.) Dewit
Afzelia bequaertii De Wild. (1925)
Afzelia caudata Hoyle (1933) p.p

Taxonomic Notes

Afzelia bipindensis is morphologically very close to three other species of the genus (*A. africana*, *A. bella*, and *A. pachyloba*), but very distinct genetically (Donkpegan, 2017). All the species are traded internationally under the name of doussié (Donkpegan et al., 2014) and its sometimes difficult to provide separate trade and population information for each species. However, distinct chemical fingerprints of the wood of *Afzelia pachyloba* and A. *bipindensis* demonstrated an effective method for identifying these two commercially important species (Kitin et al., 2021).Recent genetic work has demonstrated that *A. bipindensis* is a likely complex of two sister (sub-) species and criteria for their separation have been proposed but the new (sub-)species must still be described (Allaer, 2017; Donkpegan et al., 2017). In the absence of a published description of a new species, the present evaluation will consider *A. bipindensis* as a unique taxa.

Red List Status
LC - Least Concern, A3 (IUCN version 3.1)

● Red List Assessment

● Assessment Information

Date of Assessment: 2022-09-01
Assessor(s): Monthe, F., Loubota, G., Ligot, G., Texier, N., Stévart, T. & Doucet, JL.
Reviewer(s):
Institution(s):
Acknowledgements: This evaluation was performed by the project «Actualisation du statut de vulnérabilité des espèces ligneuses exploitées en Afrique centrale » grant number C224, funded by PPECF (Programme de Promotion de l'Exploitation Certifiée des Forêts) and the Gembloux Agro-Bio Tech faculty of the University of Liège through the AFRITIMB project subsidised by the FRFS-WISD (grant number PDR-WISD-07). We thank the forestry companies active in Central Africa and the consultancy firms (FRMi, Sylvafrica, and TEREA) for providing the management inventory data, the non-profit organisation Nature+ asbl, and the DYNAFAC collective for providing demographic data (mortality and growth). We express our gratitude to ATIBT (Association Technique Internationale des Bois Tropicaux) and ANPN (Agence Nationale des Parcs Nationaux du Gabon) for supporting this project «Actualisation du statut de vulnérabilité des espèces ligneuses exploitées en Afrique centrale ». We are also grateful to DYNAFAC collective through the P3FAC project funded by FFEM (Fonds Français pour l'Environnement Mondial) (grant number CZZ 2101.01R) and to the Fondation Franklinia for supporting this evaluation.
Regions: Global

● Identification Description

Afzelia bipindensis is a large tree reaching 40 m in height and 1.4 m in diameter, with a cylindrical bole and slight upright buttresses. The bark of young trees is finely fissured, with irregular scales and/or sinuous ridges with age and lenticels. The slice is yellowish and granular, without exudate but with a strong odour of banana skin. The leaves are composed of 5-6 pairs of medium-sized opposite leaflets (6-13 x 3-6). The petioles are remarkably twisted. The leaf blade is shiny on the upper side and much lighter on the lower side. The lateral veins (5-8 pairs) meet well before the edge of the leaf blade. Its flowers are large-petalled and pink to purplish, making it easy to distinguish from *A. bella*. The fruits are large, black, woody, kidney-shaped pods (11-20 x 5-8 cm) with more or less bumpy surface. They contain shiny black compressed oval seeds 3-4 cm long, covered at the base by a bright red deeply two-lobed aril, with one lobe larger than the other.
Misidentifications are possible with related species of the genus: *A. bella* and *A. pachyloba* Harms. *A. bipindensis* is distinguished by small leaflets (less than 6 cm long) and seeds with lemon-yellow arils. It is restricted to evergreen coastal forests.

- **Assessment Rationale**

Afzelia bipindensis is a widespread tall tree in African dense moist evergreen and semi-deciduous Guineo-Congolian forest, long-lived, non-pioneer light demanding and usually non-gregarious species, which forms root associations with ectomycorrhizal fungi and arbuscular mycorrhizae. It is distributed from Ivory Coast to Angola. Based on a 2 x 2 km cell size, the AOO of this species is estimated as 560 km^2 with a minimum of 76 locations (number of forest management units of different logging companies in Central Africa). This species is not "Vulnerable" status under criterion B2. The EOO is calculated as 5 733 937 km^2, above the upper threshold for "Vulnerable" status under criterion B1.
Commonly known as doussié or Afzelia, with three other species of the genus (*A. africana*, *A. bella*, and *A. pachyloba*), *A. bipindensis* it is among the most exploited forest species in tropical Africa sought after for the quality of its wood (excellent dimensional stability) and social importance. The minimum cutting diameter (MCD) in Central Africa varies between 60 and 80 cm is globally higher than the regular fruiting diameter (RFD) estimated at 50 cm DBH, ensuring optimal regeneration of the species. Its wood is nowadays less demanded on the international markets. The population structure of this species showed decreasing suggesting a good regeneration with a density of 0.13 stems.ha^{-1} (dbh ≥ 20 cm) in Central Africa (see Supplementary Material). Given its stem density and the mean annual increment of 0. 21 ± 0. 22 cm/year in Central Africa (see Supplementary Material), we estimate the number of mature individuals over 10 000 across the distribution range, well above the threatened category under criteria C and D.
The most serious long-term threat is the conversion of the forest to agriculture and grazing, and illegal logging. However, the species is not considered severely fragmented as the 220 known occurrences represent more than 50 localities (sensu Comité des normes et des pétitions de l'UICN, 2019). Considering the species' generation length (195 years), an inference of population reduction for three generations in the past is impossible following A1 and A2 criteria. Based on simulations of the expected population reduction on its distribution range including protected areas, non - permanent forest areas and production forest (logging concessions), we estimated population reduction of 2% in the next 100 years below the threshold to be considered threatened under criterion A3. An assessment of the population reduction according to criterion A4 considering one to two generations back and one to two generations forward would likely introduce high levels of uncertainty due to the lack of data to efficiently model the reduction of population size in the past. No quantitative analysis of the probability of extinction in the wild was conducted, and therefore criterion E does not apply.
Considering (i) the population density, (ii) the good matching between MCD and RFD and (iii) the reduction of population in the future across the distribution range below the upper threshold for Vulnerable, the species is assessed as Least Concern (LC), A3cd.

Reasons for change

Reason(s) for Change in Red List Category from the Previous Assessment:

Afzelia bipindensis was previously assessed as "Vulnerable" by the IUCN (https://www.iucnredlist.org/species/33033/9751784) at the African Regional Workshop (Conservation & Sustainable Management of Trees, Zimbabwe, July 1996), 1998, following the A1cd criterion. During the last few years, important data have been produced on the self-ecology, population dynamics (growth, recruitment, mortality) of the species. Moreover, a new version of the IUCN guidelines is available (from version 2.3 to 3.1). Given all these information, it was necessary to produce a new assessment of the species.

Distribution

Geographic Range

Afzelia bipindensis, is found in Guineo–Congolian rainforest species, widely distributed mainly from Ivory Coast to the DRC and Angola (Donkpegan, 2017; Donkpegan et al., 2014). In the Congo basin, the species share its range with *A. africana*, *A. bella*, and *A. pachyloba.* The extent of occurrence (EOO) in native area is estimated at 5 733 937 km^2 across its distribution range.

Area of Occupancy (AOO)

Estimated area of occupancy (AOO) - in km2	Justification
560	The AOO has been estimated using ConR based on the 2 × 2 km cell size of 220 occurrences from CJB (Conservatoire et Jardin botaniques de Genève) and RAINBIO

Continuing decline in area of occupancy (AOO)	Qualifier	Justification
Yes	Inferred	The species has suffered from reduction in area of occupancy, due to habitat degradation and deforestation in West Africa forest (Vancutsem et al., 2021).

Extent of Occurrence (EOO)

Estimated extent of occurrence (EOO)- in km2	EOO estimate calculated from Minimum Convex Polygon	Justification
5 733 937	true	Calculated using ConR based on 217 known occurrences from CJB (Conservatoire et Jardin botaniques de Genève) and RAINBIO

Continuing decline in extent of occurrence (EOO)	Qualifier	Justification
Yes	Inferred	The species has certainly undergone an extent of occurrence reduction in West Africa, linked to the reduction in forest area (Vancutsem et al., 2021).

Locations Information

Number of Locations	Justification
70-200	More than 76 localities. Based on the most serious plausible threat (conversion of its habitat) and illegal logging across the distribution range.

Continuing decline in number of locations	Qualifier	Justification
Yes	Inferred	The main threat remains the reduction of the forest area in West Africa.

Extreme fluctuations in the number of locations	Justification
No	Habitat degradation is the main threat.

- **Very restricted AOO or number of locations (triggers VU D2)**

Very restricted in area of occupancy (AOO) and/or # of locations	Justification
No	-

- **Elevation / Depth / Depth Zones**

Elevation Lower Limit (in metres above sea level): 0
Elevation Upper Limit (in metres above sea level): 900

- **Map Status**

Map Status	Use map from previous assessment	How the map was created, including data sources/methods used:	Please state reason for map not available:	Data Sensitive?	Justification	Geographic range this applies to:	Date restriction imposed:
Done	-	Qgis. The dataset was created from a compilation of Rainbio and CJB	-	-	-	-	-

- **Biogeographic Realms**

Biogeographic Realm: Afrotropical

Occurrence

- **Countries of Occurrence**

Country	Presence	Origin	Formerly Bred	Seasonality
Angola	Extant	Native	-	Resident
Cameroon	Extant	Native	-	Resident
Central African Republic	Extant	Native	-	Resident
Republic of the Congo	Extant	Native	-	Resident
Democratic Republic of the Congo	Extant	Native	-	Resident
Côte d'Ivoire	Extant	Native	-	Resident
Equatorial Guinea	Extant	Native	-	Resident
Gabon	Extant	Native	-	Resident
Ghana	Extant	Native	-	Resident
Nigeria	Extant	Native	-	Resident
Uganda	Extant	Native	-	Resident

Population

Afzelia bipindensis is morphologically very similar to three others *Afzelia* species (*A. africana*, *A. bella*, and *A. pachyloba*) and share the same trade name in international market “doussié” or “afzelia” (Gérard and Louppe, 2011). It is therefore difficult to obtain information on the trade and populations of each of these species. *A. africana* and *A. bella* are mainly exported from West Africa. However, recent work demonstrated distinct chemical fingerprints of the wood of *A. pachyloba* and *A. bipindensis* using direct analysis in real-time (DART) time-of-flight mass spectrometry (TOFMS) (Kitin et al., 2021). Widespread in the wild, population densities of *A. bipindensis* are relatively low in Central Africa (0.13 stems.ha^{-1}, for stems of diameter ≥ 20 cm), with an average wood volume of 0.3-1.8 m³.ha^{-1} in some populations in Cameroon (Fétéké and Philippart, 2008).

The average diameter growth is 0.21 ± 0.22 in Central Africa (see Supplementary Material), but can vary between 0.14 ± 0.02 cm/year and 0.30 ± 0.05 cm/year respectively in Northern Republic of the Congo (Loundoungou) and Southern Cameroon (Mindourou) (Ligot et al., 2022). The species is not well adapted to artificial plantations (Doucet et al., 2016), young stands of *A. bipindensis* are often invaded by faster-growing trees and vines, resulting in slow growth or even death of *A. bipindensis*. Continuous weeding is necessary to ensure good growth in plantations (Gérard and Louppe, 2011). Plantations in Gabon show that survival and growth are greater on cleared land and open areas than in the forest understory (Gérard and Louppe, 2011). Natural mortality is unknown for this species, nevertheless, an average of 1% was observed for 42 timber species in central Africa (Ligot et al., 2022).

The legal minimum cutting diameter "MCD" varies across its distribution range (60 cm in Democratic Republic of Congo and Republic of Congo, 70 cm in Gabon, 80 cm in Cameroon and Central Africa Republic). The MCD is higher than the regular fruiting diameter (RFD) of 50 cm observed in Cameroon and Gabon. However, when the top is sufficiently exposed to light, it can fructify abundantly from 25 cm, the minimum fertility diameter was set at 20 cm in Central Africa (Doucet, 2003; Meunier et al., 2015).

Using the Red List criterion A3, the projected population reduction (PPR) to be met in the future (100 years because the generation length of the species is 195 years) of the *A. bipindensis* population was assessed across its distribution range. Because *A. bipindensis* is a widespread species in West, East and Central Africa, the PPR was estimated for each region.

In Central Africa, three different PPR were thus estimated: PPRpa in protected areas, PPRpf in production forests and PPRnp in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas. First, protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). The population of the species in protected areas covering its range was kept stable in the future over 100 years, suggesting that the PPR in protected areas was 0%. Second, the evolution of the *A. bipindensis* population was simulated using an Usher matrix model to estimate the PPR of production forests (logging concessions, PPRpf). The simulations were initialised using the density (number of trees.ha-1) per diameter class (from 20 cm diameter, mature individuals) from forest management inventories of logging companies. The evolution of this initial population depended on several demographics (recruitment, mortality, and growth rate) and logging parameters (minimum cutting diameter, cutting and damage rate) that were adjusted using data of permanent tree plot monitoring. Thus, the density of *A. bipindensis* in 100 years was predicted with a logging event every 25 years, which corresponds to the average cutting cycle in Central Africa. PPRpf was then calculated as the difference between initial and final number of trees. Third, the major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Illegal logging and the habitat lost from deforestation rate have been both activities that allowed estimating the PPRnp in non-permanent domains.

In West and East Africa, the forest areas were subject to a constant annual deforestation rate of 1.20% year-1 and 1.53% year-1, respectively (Vancutsem et al., 2021). Taking this rate of deforestation as constant over the next 100 years, when it is expected to decline, is a reasonable precautionary measure.

We thus had three different PPR: PPR in Central Africa, PPR in West Africa and PPR in East Africa. The global PPR was then computed after weighting the three values by their relative forest areas. The global PPR result was found to be 2%, lower than 30%.

For further information about this methodology, see the attached Supplementary Material document.

- **Population Information**

Current Population Trend: Decreasing

Extreme fluctuations? (in # of mature individuals)	Justification
No	-

Severely fragmented?	Justification

No	-

Continuing decline in mature individuals?	Qualifier	Justification

Continuing decline % in mature individuals within 3 generations or 10 years, whichever is longer (up to max. of 100 years in the future)	Qualifier	Justification

Extreme fluctuations in the number of subpopulations	Justification
No	-

Continuing decline in number of subpopulations	Qualifier	Justification
No	-	-

All individuals in one subpopulation: No

Number of Subpopulations	Justification	Subpopulation Details	Subpopulation description	Number of mature individuals	Subpopulation trend	Qualifier	Location type	Number of Subpopulations	Location bounding box	Location coordinates	Notes
2	Genetic analyses using 10 nuclear microsatellites for 200 individuals sampled across the distribution range of the species (Donkpegan, 2017)	-	-	-	-	-	-	-	-	-	-

- **Population Reduction - Past**

Percent Change in past	Reduction or Increase	Qualifier	Justification

Basis?

Reversible?
Yes

Understood?
Yes

Ceased?
No

- **Population Reduction - Future**

Percent Change in future	Reduction or Increase	Qualifier	Justification
2%	Reduction	Projected	Using the Red List criterion A3, the projected population reduction (PPR) to be met in the future (100 years because the generation length of the species is 195 years) of the *A. bipindensis* population was assessed across its distribution range. Because *A. bipindensis* is a widespread species in West, East and Central Africa, the PPR was estimated for each region. In Central Africa, three different PPR were thus estimated: PPRpa in protected areas, PPRpf in production forests and PPRnp in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas. First, protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). The population of the species in protected areas covering its range was kept stable in the future over 100 years, suggesting that the PPR in protected areas was 0%. Second, the evolution of the *A. bipindensis* population was simulated using an Usher matrix model to estimate the PPR of production forests (logging concessions, PPRpf). The simulations were initialised using the density (number of trees.ha^{-1}) per diameter class (from 20 cm diameter, mature individuals) from forest management inventories of logging companies. The evolution of this initial population depended on several demographics (recruitment, mortality, and growth rate) and logging parameters (minimum cutting diameter, cutting and damage rate) that were adjusted using data of permanent tree plot monitoring. Thus, the density of *A. bipindensis* in 100 years was predicted with a logging event every 25 years, which corresponds to the average cutting cycle in Central Africa. PPRpf was then calculated as the difference between initial and final number of trees. Third, the major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Illegal logging and the habitat lost from deforestation rate have been both activities that allowed estimating the PPRnp in non-permanent domains. In West and East Africa, the forest areas were subject to a constant annual deforestation rate of 1.20% year-1 and 1.53% year-1, respectively (Vancutsem et al., 2021). Taking this rate of deforestation as constant over the next 100 years, when it is expected to decline, is a reasonable precautionary measure. We thus had three different PPR: PPR in Central Africa, PPR in West Africa and PPR in East Africa. The global PPR was then computed after weighting the three values by their relative forest areas. The global PPR result was found to be 2% lower than 30%. For further information about this methodology, see the attached Supplementary Material document.

Basis?
b) an index of abundance appropriate for the taxon, d) actual or potential levels of exploitation

- **Population Reduction - Ongoing**

Both: Percent Change over any 10 year or 3 generation period, whichever is longer, and must include both past and future, future can't go beyond 100 years	Reduction or Increase	Number of years for this period	Qualifier	Justification

Basis?

Reversible?
Yes

Understood?
Yes

Ceased?
No

• Habitats and Ecology

Afzelia bipindensis is a large tree reaching 40 m in height and 1.4 m in diameter. It is a non-pioneer light-demanding species that occurs in moist evergreen and semi-deciduous forest up to 900 m altitude, normally on well-drained soils, in primary and secondary forest (Donkpegan et al., 2017, 2014; Doucet et al., 2016; Gérard and Louppe, 2011). It forms root associations with ectomycorrhizal fungi and arbuscular mycorrhizae (Gérard and Louppe, 2011).

A. bipindensis bears hermaphrodite flowers. Flowering occurs from 20 cm in diameter in Central Africa (see Supplementary Material). Pollination is mainly by beetles *Prosephus sp*. (Coleoptera - Elateridae) and *Anomala sp*. (Coleoptera - Rutelinae), but also some Sphingidae, Noctuidae and Syrphidae (P3FAC, 2020). It is a sarcochorous species whose seeds are dispersed after opening the pod (autochory) and then by animals (zoochory) especially small rodents such as *Cricetomys emini*, *Funisciurus isabella* and an undetermined species of Muridae (Evrard et al., 2019). They removed more than 90% of the seeds, after detaching the aril, which increased the germination rate, they also played as main predator (Evrard et al., 2019). In Cameroon, Central Africa Republic and Republic of the Congo fruits are observed between June-October, September-November, and (April-June)-July-August respectively. While in Democratic Republic of the Congo and Gabon, fruits are observed from October-December and February-March (June-July), respectively. Young stems (10-20 cm) are usually well represented and the global structure is balanced (see Supplementary Material).

• IUCN Habitats Classification Scheme

Habitat	Season	Suitability	Major Importance?
1.6. Forest -> Forest - Subtropical/Tropical Moist Lowland	Resident	Suitable	Yes

• Continuing Decline in Habitat

Continuing decline in area, extent and/or quality of habitat?	Qualifier	Justification
Yes	Observed	Annual deforestation rate of 0.35%, 1.20% and 1.53%, in Central, West and East Africa respectively (Vancutsem et al., 2021).

- **Life History**

Generation Length	Justification	Data Quality
195	Minimum estimate of generation length for the species from the average growth rate, and the mean diameter of mature individuals (see supplementary Material)	good

Age at maturity: female or unspecified
94 Years

Age at Maturity: Male
94 Years

Size at Maturity (in cms): Female
20

Size at Maturity (in cms): Male
20

Reproductive Periodicity
Annual

Annual Rate of Population Increase

Natural Mortality
1% (Ligot et al. 2022)

- **Systems**

System: Terrestrial

- **Plant / Fungi Specific**

Wild relative of a crop? No

Plant and Fungal Growth Forms
Tree - large

Use and Trade

- **General Use and Trade Information**

Afzelia bipindensis is a heavy, hard, reddish-brown wood that is highly prized on the international market (Eba'a Atyi et al., 2022).

At industrial level, *A. bipindensis* is sought after for its resistance to termites, fungi and dry wood insects. It is therefore a wood that does not require preservative treatment. Its characteristics make it a material recommended for uses that require solid, stable and resistant wood: shipbuilding, exterior and exterior joinery, exterior cladding, bridge construction, heavy or industrial flooring, heavy timber construction and shingles, cooperage and winery. *A. bipindensis* has often been used preferentially for the construction of velodrome tracks (Donkpegan et al., 2014).

In many logged forests, large, well-shaped *A. bipindensis* have become very rare. From 2000-2005 Gabon exported 8,600 m³/year. In 2006, Cameroon exported 6,100 m³ of sawn timber. In the Central African Republic, *A. bipindensis* also has the reputation of being an excellent timber species, in 2004, the country exported around 6 500 m³. In 2010, Cameroon, and the Republic of Congo exported 5,128 and 2 868 m³ respectively (ATIBT, 2010). In 2016, Central Africa produced 17 853 m³ (FRMi, 2018) and 26 698 m³(all the three doussie species) in 2018 (Eba'a Atyi et al., 2022).

At a local level, *A. bipindensis* is used as firewood and for the production of charcoal. In Cameroon, the exudate from the bark is used for stomach complaints. The arils of the seeds are applied to chapped lips (Donkpegan et al., 2014).

Subsistence:	Rationale:	Local Commercial:	Further detail including information on economic value if available:
Yes	-	Yes	-

National Commercial Value: Yes
International Commercial Value: Yes
Is there harvest from captive/cultivated sources of this species? Yes
Trend in level of total offtake from wild sources: Stable
Trend in level of total offtake from domesticated sources: Unknown

- **Non- Consumptive Use**

Non-consumptive use of the species? true

• Threats

The main threats in the non-permanent domain across distribution range, are mainly related to habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging and the abusive harvesting of plant parts requested as non-wood forest products (Bradshaw et al., 2009). In Central Africa, illegal logging accounts for nearly 46% of total log production (FRMi, 2018). This production generally comes from unallocated forest areas (non-permanent forest domain).
Afzelia bipindensis is exploited in Central Africa. In West and East Africa, forests are generally not managed in concessions, and the large part of the rainforest has been transformed into cultivated areas (Nix, 2019).

- **Threats Classification Scheme**

No past, ongoing, or future threats exist to this species. false

Threat	Timing	Scope	Severity	Impact Score
1.1. Residential & commercial development -> Housing & urban areas	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4
2.1.1. Agriculture & aquaculture -> Annual & perennial non-timber crops -> Shifting agriculture	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
2.2.2. Agriculture & aquaculture -> Wood & pulp plantations -> Agro-industry plantations	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
2.3.2. Agriculture & aquaculture -> Livestock farming & ranching -> Small-holder grazing, ranching or farming	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4

3.2. Energy production & mining -> Mining & quarrying	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
4.1. Transportation & service corridors -> Roads & railroads	Past, Likely to Return	Minority (<50%)	Slow, Significant Declines	Low Impact: 4
5.3.1. Biological resource use -> Logging & wood harvesting -> Intentional use: (subsistence/small scale) [harvest]	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 4
5.3.2. Biological resource use -> Logging & wood harvesting -> Intentional use: (large scale) [harvest]	Ongoing	Minority (<50%)	Slow, Significant Declines	Medium Impact: 6
7.1.3. Natural system modifications -> Fire & fire suppression -> Trend Unknown/Unrecorded	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4

● Conservation

Afzelia bipindensis is known to occur in protected areas and in at least 4 *ex situ* collections (BGCI, 2022). In certified forest concessions where the species is exploited, or permanent forest plots are usually installed. These plots provide important data for (i) quantifying population dynamics processes at the stand level: mortality, growth and recruitment; (ii) phenological studies to determine the regular fruiting diameter (RFD). These plots are managed in collaboration with forest concessions grouped within the DYNAFAC collective (see here for more information https://www.dynafac.org/fr/p/130/installation-de-dispositifs-de-suivi-de-la-dynamique-forestiere). Compilation of these data will provide important additional information for targeted silvicultural measures for the sustainable management of this species. (DYNAFAC, 2022; Ligot et al., 2022).

A. bipindensis is also monitored in nurseries and planted in forest concessions (Doucet et al., 2016 ; Dainou et al., 2021).

Genetic studies have revealed a well-differentiated genetic cluster endemic to Gabon, suggesting the presence of a cryptic species (Donkpegan, 2017). It would be important to finalise the botanical characterisation of this species.

Logging in Central Africa is subject to strict legislation, species can only be harvested above a certain diameter and measures must be taken to ensure the renewal of the resource (Fargeot et al., 2004). Indeed, management plans for tropical rainforests require the determination of a minimum cutting diameter (MCD) to ensure a minimum renewal rate at the end of a rotation period (duration between two cuts on the same cutting base), the minimum reconstitution rate (usually 40-50% depending on the country) as well as the rotation duration, being imposed by forestry legislation (Durrieu de Madron and Forni, 1997).

In addition, it will also be necessary to :

- Ensure the implementation of the recommendations of the Dynafac collective, including the establishment of a system for monitoring the populations of commercial species in the different forest types defined in a consensual manner;
- Set up monitoring and support systems for the regeneration of commercial species, prioritising species with regeneration deficits;
- Set up programmes to guarantee the phenotypic quality of commercial species populations: seed banks, seed stands, plus trees, seed orchards, conservation plantations;

- Consider threatened species in the delimitation of conservation series and in the identification of High Conservation Values;
- Update conservation statuses on a five-yearly basis, in particular by setting up a system of "green statuses";
- Define red lists adapted to regional or national contexts;
- Evaluate the status of cryptic species or species close to commercial species evaluated during this workshop.

- **Conservation Actions In- Place**

Action Recovery Plan	Note
Yes	Plantings within FSC-forest concessions

Systematic monitoring scheme	Note
Yes	The species is monitored in permanent plots installed within forestry companies in Central Africa (see here for more information https://www.dynafac.org/fr)

Occur in at least one PA	Note
Yes	The species may appear in at least 50 protected areas considering it distribution range

Percentage of population protected by PAs (0-100)	Note
1-10	Considering protected area across species distribution range

Area based regional management plan	Note
Unknown	-

Invasive species control or prevention	Note
No	-

Harvest management plan	Note
Yes	In legal forest concessions, the species is exploited according to a management plan.

Subject to ex-situ conservation	Note
Yes	-

Included in international legislation	Note
No	-

Subject to any international	Note

management/trade controls	
No	The species is the subject of the proposal CoP19 Prop. 46, "Inclusion of all African populations of *Afzelia africana*, *A. bipindensis*, *A. pachyloba* and *A. quanzensis* in Appendix II, , in accordance with Article II, Paragraph 2 (a) of the Convention and satisfying Criterion B of Annex 2 a of Resolution Conf. 9.24 (Rev. CoP17) and, because of their similarity, all other African populations of the genus *Afzelia* in Appendix II, in accordance with Article II, Paragraph 2 (b) of the Convention and satisfying Criterion A of Annex 2 b of Resolution Conf. 9.24 (Rev. CoP17)". https://cites.org/sites/default/files/documents/E-CoP19-Prop-46.pdf

- **Important Conservation Actions Needed**

Conservation Actions	Note
3.1.1. Species management -> Species management -> Harvest management	-
3.1.2. Species management -> Species management -> Trade management	-
3.4.2. Species management -> Ex-situ conservation -> Genome resource bank	-

- **Research Needed**

Research	Note
1.1. Research -> Taxonomy	-
1.2. Research -> Population size, distribution & trends	-
3.1. Monitoring -> Population trends	-
3.2. Monitoring -> Harvest level trends	-
3.3. Monitoring -> Trade trends	-

• Ecosystem Services

- **Ecosystem Services Provided by the Species**

	Importance:	Geographic range of benefit:
1. Water Quality	2 - Important	Global
3. Flood Control	2 - Important	Global
4. Climate Regulation	2 - Important	Global
5. Landscape	2 - Important	Global
6. Air Quality	2 - Important	Global
7. Nutrient Cycling	2 - Important	Global
8. Habitat Maintenance	2 - Important	Global
9. Provision of Critical Habitat	2 - Important	Global

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● SUPPLEMENTARY MATERIAL

Afzelia bipindensis – Harms

● IUCN status using criterion A3

We adopted the criterion A3 to assess the projected population reduction (PPR) to be met in the future (up to a maximum of 100 years) of *Afzelia bipindensis*. To quantify the projected population reduction, simulations must be performed on mature individuals and three generations with a maximum of 100 years according to **criterion A3**. We estimated mature individuals and generation length, as recommended by the IUCN guidelines.

A **mature individual** is an individual that can reproduce, able to bear flowers or seeds (fertile in plant kingdom). To quantify the mature individuals for each species, we used phenological data of DYNAFAC network[3] from a combined dataset of 95 trees belonging to four sites in three countries (Cameroun, Central African Republic, and Gabon). The minimum and maximum sampled diameters ranged from 14 to 123 cm (median 55 cm). The monitoring period ranged from 2004 to 2020. We assumed that the monitoring period was long enough to capture at least one reproductive event per tree such that trees without observed flowering/fruiting events were considered non-reproductive (only 9 percent of all monitored trees were non-reproductive). We used the methodology for the size at reproduction of canopy tree species in Central Africa (Ouédraogo et al., 2018): the **diameter of a mature individual** was obtained after fitting logistic regressions and the level of 50% of the probability to produce the flower or fruit was adopted for this species. Using this approach, the diameter of a mature individual was obtained after setting the 50% probability to produce flowers or fruits. Thus, the minimum diameter of mature individuals for this species was **35 cm**.

The **generation length** was the report between the mean diameter of mature individuals considering population structure and the mean increment. Given that the minimum diameter of mature individuals was 35 cm, we weighted the total number of trees by their diameter from 35 cm to 125 cm (Figure 1) to compute the number of mature individuals. The mean of mature individuals was **42 cm**. The **mean increment** of the species was **0.213 cm**, obtained from 475 observations from logged and unlogged forests of published data (Ligot et al., 2022)and unpublished data in three countries (Cameroon, Gabon, and Republic of Congo). Thus, the **generation length** was 42 cm / 0.213 cm = **197 years**. The age at maturity (**164 years**) has been estimated as the report between the **minimum diameter of mature individuals** (**35 cm**) and the **mean annual increment** (**0.213 cm)**.

● Estimation of the projected population reduction (PPR)

We adopted the criterion A3 to assess the projected population reduction (PPR) to be met in the future (up to a maximum of 100 years) of *Afzelia bipindensis*. *Afzelia bipindensis*, is found in Guineo–Congolian rainforest species,

[3] https://www.dynafac.org/en

widely distributed mainly from Ivory Coast to the DRC and Angola (Donkpegan et al., 2014). The geographic range of species was in three regions (Central Africa, West Africa, and East Africa) characteristic of three biogeographical regions across the tropical African forests (Fayolle et al., 2014). According to each region, different data (deforestation annual rate, growth, mortality, recruitment, forest inventory, etc.) have been used with logging data in Central Africa. Thus, the PPR was estimated for each region and the global PPR was then computed after weighting the three values by their relative forest areas.

- **PPR in Central Africa**

In this region, forest management follows three different modalities: protected areas, production forests (logging concessions), and non-permanent forest domain. Based on occurrences, the natural range of this species includes all countries in Central Africa (Figure 1). The total natural area is estimated at 200 414 869.3 ha. Within this area, there are 56 483 244.95 ha (28.2%) for production forests, 25 714 214.5 ha (12.8%) for protected areas, and 118 217 409.9 ha (59.0%) for the non-permanent domain.
Three different PPR were thus estimated: PPR_{pa} in protected areas, PPR_{pf} in production forests, and PPR_{np} in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas and then added to estimate the PPR_{C} in Central Africa.

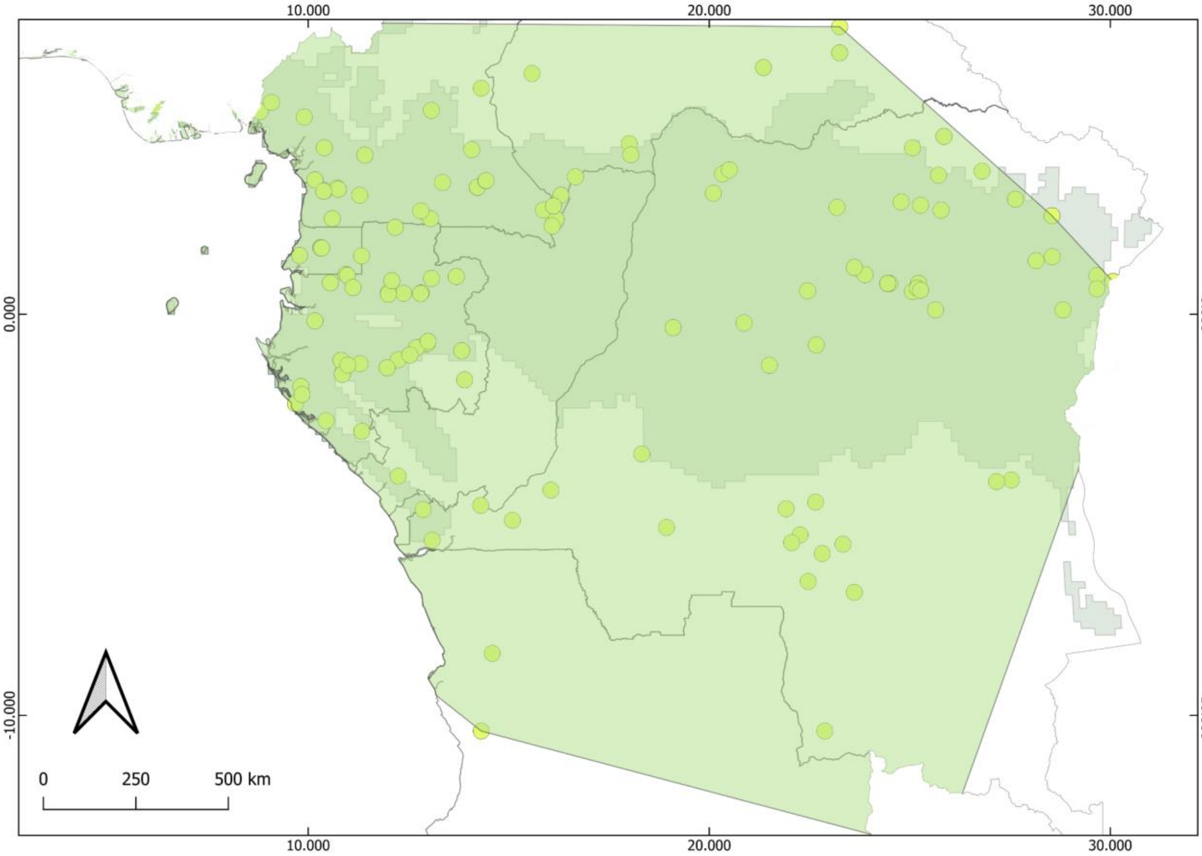

Figure 1. The range of *Afzelia bipindensis* in Central Africa estimated from RAINBIO and CJB data, validated in December 2022 during a workshop with a group of experts in Gabon.

- **PPR in protected areas**

Central Africa countries have allocated a higher proportion of their land to conservation than any other tropical regions, with relatively higher conservation success (Laurance et al., 2012). Indeed, most protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). They are currently representing a large part of forest and tree species conservation in Central Africa. Thus, the population of each species in protected areas according to FRMI (2018) covering its range was kept stable in the future over 100 years. **In these conditions, it was hypothesized that the PPR in protected areas for each species is 0%, suggesting no population reduction in the present and future.**

- **PPR in production forests**

To quantify the evolution of the population of each timber species, matrix population models are widely used to study population dynamics (Picard & Liang, 2014). The population of this species was described at time t by a vector N_t corresponding to the density (number of trees ha^{-1}) in each diameter class (from 20 cm diameter to more than 120 cm). The density per diameter class was estimated using data from forest inventories that were carried out in 76 forest management units (FMU) of different logging companies in five countries (Cameroon, Central African Republic, Democratic Republic of the Congo, Gabon, and Republic of the Congo). Most logging companies followed a standardized inventory protocol (Réjou-Méchain et al., 2011). These forest inventory data covered about 18 million ha (Table 1), that are representative of 31% of Central Africa's production forests of this species. The number of trees sampled in Central Africa was 2 262 326 with a density of 0.131 tree ha^{-1}. Large-scale commercial inventories have already been found useful in the identification of large-scale patterns in Central Africa (Réjou-Méchain et al., 2011). Using large-scale data from commercial forest inventories, Réjou-Méchain et al. (2021) jointly model the distribution in the abundance of the most dominant tree species and produce continuous maps of the floristic and functional composition of central African forests.

Table 1. Forest management units (FMU) sampled in Central Africa (Cameroon, CAR: Central African Republic, DRC: Democratic Republic of the Congo, EG: Equatorial Guinea, Gabon, and RCongo: Republic of the Congo).

	Sampling	
Country	FMU	Area (ha)
Cameroon	21	2 088 175
CAR	4	1 705 598
DRC	13	3 768 777
EG	-	-
Gabon	31	5 973 638
RCongo	7	3 692 333
Total	76	17 228 521

The Usher matrix model was used to simulate the evolution of the recovery rate of all population and the exploitable stock of each species after logging in Central Africa. According to the Usher assumption, between t and t+1, an individual can either stay alive in the same class, stay alive and move up to the next class, or die; it cannot move up by more than one class or move backwards, i.e., the individual is free from diameter shrinkage (Picard et al., 2012). The Usher matrix model (U) considers three parameters (mortality, recruitment, and growth rate that are constant in time) to estimate the transition probabilities:

$$U = \begin{pmatrix} q_1 + g_1 & g_2 & \cdots & \cdots & g_I \\ p_1 & q_2 & 0 & \cdots & 0 \\ 0 & \ddots & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & p_{I-1} & q_I \end{pmatrix}$$

where q_i is the probability for an individual to stay alive in class i between two consecutive time steps, p_i is the upgrowth transition rate (the probability for an individual to grow up from class i to class i +1), and g_i is the recruitment rate (Picard & Liang, 2014).

Tree mortality, recruitment, and growth are three central processes for predicting the dynamics of tropical rainforests and estimating these three processes requires long-term monitoring in difficult field conditions (Picard & Gourlet-Fleury, 2008). These processes determine the evolution of the species population in the forest stand. The natural mortality is defined as the number of standing dead trees, and few studies have reported estimates of mortality rates in Central Africa. Data about tree mortality are still scarce and it does not allow to precisely moddel the mortality rate for each species and size class. Given the current state of knowledge, it appears reasonable to use a fixed mortality rate of 1% for all species and size classes, in agreement with the results of Ligot et al. (2022) on 21,180 trees belonging to 42 timber species of Central Africa annually monitored from one to seven years.

The recruitment integrates fruiting and seed dispersal from mother trees, and the survival of plant juveniles until they reach a size threshold where they are included in the stand. The recruitment term in the model is the average annual input of new individuals into the first size class from 20 cm. The recruitment events, like mortality events, are infrequent and thus difficult to model (Karsenty & Gourlet-Fleury, 2006). The population structure showed a curve in "decreasing exponential" suggesting a good regeneration (Figure 2). To model the recruitment, we used the hypothesis defined as the recruitment rate that would maintain a constant number of trees in the first diameter class. Claeys et al. (2019) projected the future forest dynamics up to the end of the century and they showed that projected mortality and recruitment rates in 2099 could not differ from the ones observed today. Thus, the hypothesis on the recruitment and the mortality rate is used in the future (up to 100 years) as they do today.

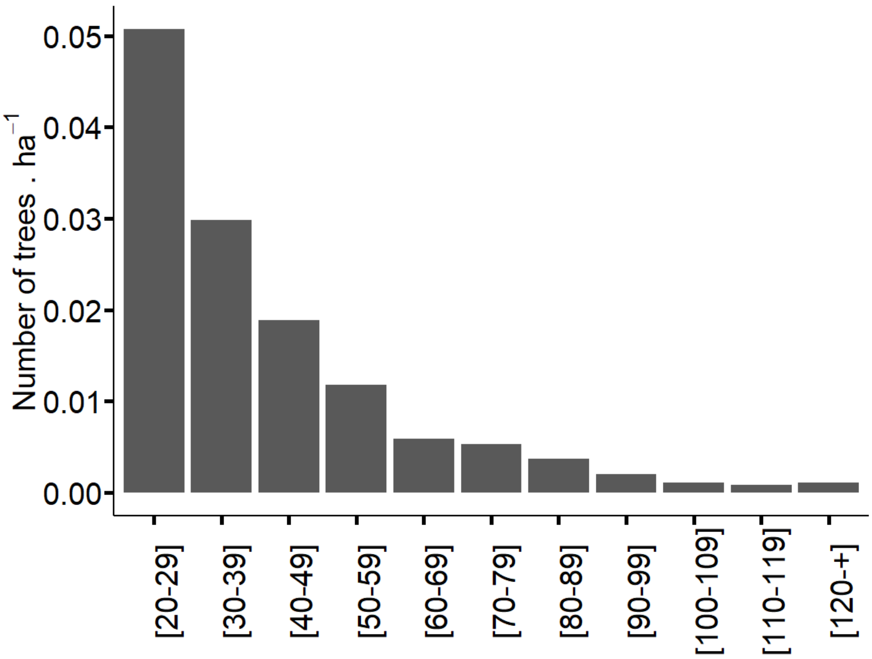

Figure 2. Population structure of *Afzelia. bipindensis* defined using the number of trees per ha and per diameter class (from 20 cm, from 76 logging concessions in Central Africa covering an area of 17 228 521 ha).

Since the mid-1900s, periodic tree monitoring and tree ring analyses have been carried out to study variability in tree growth across species in Central Africa (Durrieu de Madron, Nasi, et al., 2000; Ligot et al., 2019, 2022). We fitted growth models for each species using data from logged and unlogged areas of permanent tree plot monitoring from the DYNAFAC[4] network covering the five Central African countries. From the combined dataset, we identified 477 trees belonging to 7 sites in three countries (Cameroun, Gabon, and Republic of Congo). Minimum and maximum sampled diameters ranged from 10 to 124 cm. The monitoring period ranged from 2005 to 2017. The mixed second-degree polynomial models (with a random site effect) were fitted for species monitored in several sites. Because of two estimated coefficients of the mixed model were not significant, the mean of the increment (**0.213 cm**) has been used to estimate the diameter growth (Table 2).

Table 2. Estimated coefficients (a, b, and c) of growth models between the increment (ac in cm $year^{-1}$) and the initial diameter (D in cm). The sample including the number of trees (n) and the number of sites (site) are also given. * significant (p-value < 0.05) and ^{ns} non-significant (p-value > 0.050)

species	n	site	model	a	b	c
Doussie	477	7	$ac \sim D + D^2 + (1\|site)$	0.218*	0.001^{ns}	-0.000001^{ns}

The transition probabilities of three parameters (mortality, growth, and recruitment rate) allowed making the harvested matrix. The logging operations have been modeled using the logging parameters (minimum cutting diameter, cutting, and damage rate). The minimum cutting diameters were obtained from decrees of application of

[4] https://www.dynafac.org/en

the forestry administrations (MCD_A) at the country level and the one used in the management plan (MCD_M, with $MCD_M \geq MCD_A$) at the logging company level. At the Central Africa level, we weighted the MCD_A and MCD_M values to the occupied area and **$MCD_A = MCD_M = 70$ cm**. The cutting rate (CA), which defines the proportion of harvested trees (trees with a diameter greater than MCD_A or MCD_M), was given by logging companies, and it was also weighted at the Central Africa level with a value of 68%. Given the current state of knowledge, it appears reasonable to use a fixed damage rate caused by logging of 7% of the initial population that disappears (Durrieu de Madron, Fontez, et al., 2000). The average cutting cycle (i.e. the period between two successive logging operations) is 28 years (FRMI, 2018), but we used 25 years to simplify computation of four simulations reaching 100 years (25, 50, 75 and 100 years), as requested by IUCN criterion A.
The Figure 3 shows the PPR in production forests for the *Afzelia bipindensis*. The reduction in the population of each species was then calculated as the difference between the initial numbers of mature individuals and the predicted numbers of mature individuals predicted after 100 years. **The PPR in production forest was – 8.75 % over 100 years.**

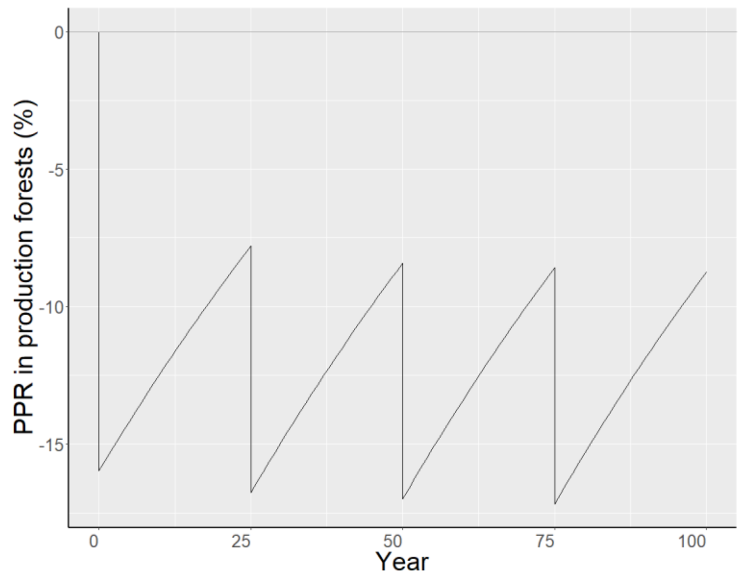

Figure 3. Simulations showing the projected population reduction (PPR) from the diameter of mature individuals (35 cm) in production forests for the *Afzelia bipindensis* over 100 years for constant recruitment.

- **PPR in the non-permanent forest domain**

The major threats in the non-permanent domain are habitat loss due to the destruction of natural environments because of population growth and urbanization, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Based on the large range of this species in Central Africa, the harvested volume from illegal logging and legal logging are 46% and 54%, respectively (FRMI 2018). In this condition, it was hypothesized that there is 54% of PPR from production forests and 46% of PPR from illegal logging in 100% PPR due to forest logging. Given that the PPR of production forests associated with its forest area was known, we deduced the PPR and forest area of illegal logging from those of the production forests. As a result, 48 115 356.8 ha were affected for the illegal logging for this species. The non-permanent domain area (118 217 409.9 ha) was considered as the area which was related to today's deforestation rate of 0.35% $year^{-1}$ in Central

Africa (Vancutsem et al., 2021). This is a conservative value since it will probably decrease in the future (Swamy et al., 2018).

The PPR in Central Africa by considering the PPR in production forest, protected area and non-permanent domain was – 2.45% over 100 years.

- PPR in West and East Africa

In these two regions, forests are generally not managed in concessions, and the large part of the rainforest has been transformed in cultivated areas (Nix, 2019). Given the high degree of anthropization in this area, the main threats are the habitat loss due to the destruction of natural environments and illegal logging, and the trees are frequently felled in fields. Applying the deforestation rate related to agricultural production can be considered as a proxy for tree removal. Thus, the forest areas in West Africa (15 600 000 ha) and East Africa (6 400 000 ha) were subject to a constant annual deforestation rate of 1.20% $year^{-1}$ and 1.53% $year^{-1}$ respectively (Vancutsem et al., 2021). Taking this rate of deforestation as constant over the next 100 years, when it is expected to decline, is a reasonable precautionary measure incorporating illegal logging.

- PPR global

We thus had three different PPR: PPR_C in Central Africa, PPR_W in West Africa, and PPR_E in East Africa. The global PPR was then computed after weighting the three values by their relative forest areas:

$$PPR = \frac{(S_C \times PPR_C) + (S_W \times PPR_W) + (S_E \times PPR_E)}{S_C + S_W + S_E}$$

where S_C, S_W, and S_E are forest areas in Central, West and East Africa, respectively.

The criterion A3 based on (c) a decline in area of occupancy (AOO), extent of occurrence (EOO) and/or habitat quality; and (d) potential levels of exploitation, has been computed as follow: (i) 30%≤PPR<50%, the species is considered as Vulnerable (VU); (ii) 50%≤PPR <80%, the species is considered as Endangered (EN), and PPR ≥ 80%, the species is considered as Critically endangered (CR).

The PPR global in distribution range of the *Afzelia bipindensis* was – 2.39%. This PPR is < 30%, suggesting that this species is not threatened in its geographic area.

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10.2 Annexe 2. *Aucoumea klaineana* - Pierre

Draft

Aucoumea klaineana - Pierre

PLANTAE - TRACHEOPHYTA - MAGNOLIOPSIDA - SAPINDALES - BURSERACEAE - Aucoumea - klaineana

Common Names: Angouma, Gaboon, Moukoumi, N'koumi, Okoume, Okoumé, Okumé

Synonyms: No Synonyms

Red List Status
LC – Least Concern, A3cd (IUCN version 3.1)

- **Red List Assessment**

- **Assessment Information**

Date of Assessment: 2022-09-01

Assessor(s): Monthe, F., Loubota, G., Ligot, G., Texier, N., Stévart, T. & Doucet, JL.

Reviewer(s):

Institution(s):

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Regions: Global

- **Identification Description**

Aucoumea klaineana is a large tree, 35-50 m high (up to 60 m) and 2 m in diameter, with light, grey-green foliage and a pasted or buttressed base. Its trunk is brown and smooth when young, then reddish-brown with scales that break off in patches in older trees. Its fibrous, pinkish-red slice gives off a transparent liquid and a strong incense smell. Clusters of resin, whitish when fresh and then blackish, may form. Its leaves are compound, reddish when young. The leaflets are opposite, shiny at the top and with long petioles. Its flowers are whitish and its spinning top-shaped fruits open into 5 leathery parts that resemble spoons like its small winged seeds.

- **Assessment Rationale**

Aucoumea klaineana is a widespread tall tree endemic to the moist evergreen Atlantic rainforests, long-lived, usually gregarious pioneer species that forms root anastomoses. It is distributed from southern Cameroon to southern Congo and can be found planted in other tropical countries. Based on a 2 x 2 km cell size, the AOO of this species is estimated as 436 km^2 with a minimum of 44 locations (number of forest management units of different logging companies in Central Africa). This species is not "Vulnerable" status under criterion B2. The EOO is calculated as 247 743 km^2, above the upper threshold for "Vulnerable" status under criterion B1.

Commonly known as Okoume, it is the most exploited forest species in tropical Africa, sought after for the quality of its wood. It accounts for almost 70% of log production in Gabon. The minimum cutting diameter (MCD) in Central Africa varies from 70 to 80 cm, it is higher than the regular fruiting diameter (RFD) of 55 cm. This MCD is consistent with the value recommended by DYNFAC to ensure optimal gene flow in populations (DYNAFAC, 2022). The population structure of this species showed a curve in "decreasing exponential" suggesting a good regeneration, with a density of 6.58 stems.ha^{-1} (dbh ≥ 20 cm) in Gabon (see Supplementary Material). Given its stem density and the mean annual increment of 0.69 ± 0.22 cm/year in Gabon (see Supplementary Material), we estimate the number of mature individuals over 10 000 across the distribution range, well above the threatened category under criteria C and D.

The most serious long-term threat is the conversion of the forest to agriculture and illegal logging. However, the species is not considered severely fragmented as 725 known occurrences represent more than 50 localities (sensu Comité des normes et des pétitions de l'UICN, 2019). Considering the species' generation length (79 years), an inference of three generations in the past goes back around 1800 before the period characterised by high regeneration of light-demanding trees species, resulting from gardening activities of local populations in the forest, creating scattered large openings (Biwolé et al., 2015; Morin-Rivat et al., 2017). So the species would certainly not be threatened according to the A2 and A1 criteria. Based on simulations of the expected population reduction on its distribution range including protected areas, non - permanent forest areas and production forest (logging concessions), we estimated population reduction of 11.8% in the next 100 years below the threshold to be considered threatened under criterion A3. An assessment of the population reduction according to criterion A4 considering one to two generations back and one to two generations forward would likely introduce high levels of uncertainty due to the lack of data to efficiently model the reduction of population size in the past. No quantitative analysis of the probability of extinction in the wild was conducted, and therefore criterion E does not apply.

Considering (i) the high population density, (ii) the rapid growth, (iii) the good regeneration in grasslands of its distribution area and high capacities to colonised news open habitats, (iv) in accordance with scientific recommendations, and (v) the reduction of population in the future across the distribution range below the lower limit for Vulnerable, the species is assessed as Least Concern (LC), A3cd.

Reasons for change

Reason(s) for Change in Red List Category from the Previous Assessment:

Aucoumea klaineana was previously assessed as "Vulnerable" by the IUCN (https://www.iucnredlist.org/species/33056/9745747) at the African Regional Workshop (Conservation & Sustainable Management of Trees, Zimbabwe, July 1996), 1998, following the A1cd criterion. During the last few years, important data have been produced on the self-ecology, population dynamics (growth, recruitment, mortality) of the species. Moreover, a new version of the IUCN guidelines is available (from version 2.3 to 3.1). Given all these information, it was necessary to produce a new assessment of the species.

• Distribution

• Geographic Range

Aucoumea klaineana, is found everywhere in Gabon except in the northeastern third, limited from a line passing through Okondja in the east and between Mitzic and Oyem in the north (Brunck et al., 1990), at all altitudes from sea level to near the summit of Mount Iboundji, one of the highest point in the country (980 m). It is also found in Equatorial Guinea (Río Muni), in south-western Congo and in the extreme south-west of Cameroon. The species is artificially planted in its native range but also in other regions of Cameroon, Ivory Coast, DRC, Ghana, Madagascar, Indonesia, Malaysia, Suriname and French Guyana. Nevertheless, the species shows poor performance plantations outside its natural range (Brunck et al., 1990). The extent of occurrence (EOO) in native area is estimated at 247 743 km^2 across its distribution range.

• Area of Occupancy (AOO)

Estimated area of occupancy (AOO) - in km2	Justification
436	The AOO has been estimated using ConR based on the 2 × 2 km cell size of 725 occurrences from CJB (Conservatoire et Jardin botaniques de Genève) and RAINBIO

Continuing decline in area of occupancy (AOO)	Qualifier	Justification
Yes	Inferred	Global Habitat reduction in area of occupancy (Vancutsem et al., 2021)

• Extent of Occurrence (EOO)

Estimated extent of occurrence (EOO)- in km2	EOO estimate calculated from Minimum Convex Polygon	Justification

247 743	true	Calculated using ConR based on 725 known occurrences from CJB (Conservatoire et Jardin botaniques de Genève)and RAINBIO

Continuing decline in extent of occurrence (EOO)	Qualifier	Justification
Yes	Inferred	Global Habitat reduction of extent of occurrence (Vancutsem et al., 2021). However, the species has the ability to colonise open areas, particularly savannahs in Gabon.

- **Locations Information**

Number of Locations	Justification
40-200	More than 44 localities. Based on the most serious plausible threat (conversion of its habitat) and illegal logging across the distribution range.

Continuing decline in number of locations	Qualifier	Justification
No	Inferred	The main threat remains the reduction of the forest due to habitat degradation and deforestation

Extreme fluctuations in the number of locations	Justification
No	

- **Very restricted AOO or number of locations (triggers VU D2)**

Very restricted in area of occupancy (AOO) and/or # of locations	Justification
No	-

- **Elevation / Depth / Depth Zones**

Elevation Lower Limit (in metres above sea level): 0

Elevation Upper Limit (in metres above sea level): 980

- **Map Status**

Map Status	Use map from previous assessment	How the map was created, including data sources/methods used:	Please state reason for map not available:	Data Sensitive?	Justification	Geographic range this applies to:	Date restriction imposed:
Done	-	Qgis. The dataset was created from a compilation of Rainbio and CJB	-	-	-	-	-

- **Biogeographic Realms**

Biogeographic Realm: Afrotropical

- **Occurrence**

- **Countries of Occurrence**

Country	Presence	Origin	Formerly Bred	Seasonality
Cameroon	Extant	Native	-	-
Congo	Extant	Native	-	-
Côte d'Ivoire	Possibly Extant	Introduced	-	Resident
Equatorial Guinea	Extant	Native	-	-
French Guiana	Possibly Extant	Introduced	-	Resident
Gabon	Extant	Native	-	-
Ghana	Possibly Extant	Introduced	-	Resident
Indonesia	Possibly Extant	Reintroduced	-	Resident
Madagascar	Possibly Extant	Introduced	-	Resident
Malaysia	Possibly Extant	Introduced	-	Resident

- **Population**

Aucoumea klaineana is a Lower-Guinean species, mainly distributed in Atlantic evergreen rainforests from southern Cameroon to southern Congo (Meunier et al., 2015). It is a very abundant species with an average density of 6.58 stems.ha^{-1} (dbh ≥ 20 cm) in Gabon (see Supplementary Material). . In old monodominant coastal savannah forests, densities between 300 and 500 stems.ha^{-1} are observed (Mapaga et al., 2002). In the Lopé Reserve (central Gabon), floristic surveys describe nearly 175 stems.ha^{-1}, while only 8 stems.ha^{-1} are observed in old Marantaceae forests (White et al., 2000). The average growth is 0.63 ± 0.44 cm/year in Gabon (see Supplementary Material). Thousands of increment measurements carried out on *A. klaineana* since the 1950s reveal an average growth rate ranging from 0.1 to 2.33 cm.yr^{-1} (Guidosse et al., 2022). In assisted natural regeneration experiments , the density of *A. klaineana* seedlings was 0.38 m^{-2} after six months The average annual growth in height of those seedlings was 86 cm, reaching 196 cm for the dominant ones (Doucet et al., 2004). Natural mortality rates of this species depend on the vegetation type.

The legal minimum cutting diameter "MCD" varies across its distribution range, (70 cm in Gabon and Republic of Congo (Decree No. 1993-11285, Law 1-82 [Gabon]; Decree n°2002-437 [Congo]) and 80 cm in Cameroon (ONADEF, 1992)). It is higher than the regular fruiting diameter (RFD) of 55cm observed in Gabon. The minimum diameter of fertility is estimated at 25 cm in Central Africa (see Supplementary Material). Based on almost 40 years of monitoring forest dynamics in Central Africa, the DYNAFAC collective recommends a MCD of 70 cm in Central Africa (including Cameroon) to maintain optimal gene flow and regeneration (DYNAFAC, 2022). Many planting trials were done on huge areas for *A. klaineana* in Gabon (Brunck et al., 1990 ; Guidosse et al., 2022) : in (i) monospecific plantations in open areas (ii) monospecific plantations in felling gaps, (iii) multi-species plantations. These experiments show the strong adaptive capacity of the species to restore degraded forest areas (Doucet et al., 2021). In addition, the assisted natural regeneration and vegetative multiplication can also be used in Gabon particularly.

Using the Red List criterion A3, the projected population reduction (PPR) to be met in the future (100 years because the generation length of the species is 79 years) of the *A. klaineana* population was assessed across its distribution range. Because *A. klaineana* is a widespread species in Central Africa, the PPR was estimated for the region.

In Central Africa, three different PPR were thus estimated: PPRpa in protected areas, PPRpf in production forests and PPRnp in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas. First, protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). The population of the species in protected areas covering its range was kept stable in the future over 100 years, suggesting that the PPR in protected areas was 0%. Second, the evolution of the *A. klaineana* population was simulated using an Usher matrix model to estimate the PPR of production forests (logging concessions, PPRpf). The simulations were initialised using the density (number of trees.ha^{-1}) per diameter class (from 25 cm diameter, mature individuals) from forest management inventories of logging companies. The evolution of this initial population depended on several demographics (recruitment, mortality, and growth rate) and logging parameters (minimum cutting diameter, cutting and damage rates) that were adjusted using data of permanent tree plot monitoring. Thus, the density of *A. klaineana* in 100 years was predicted with a logging event every 25 years, which corresponds to the average cutting cycle in Central Africa. PPRpf was then calculated as the difference between initial and final number of trees. Third, the major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Illegal logging and the habitat lost from deforestation rate have been both activities that allowed estimating the PPRnp in non-permanent domains.

The global PPR was then computed after weighting the three values (protected area, production forest and non-permanent domain) by their relative forest areas. The global PPR result was found to be 11.8 %, lower than 30%. For further information about this methodology, see the attached Supplementary Material document.

- **Population Information**

Current Population Trend: Decreasing

Extreme fluctuations? (in # of mature individuals)	Justification
No	-

Severely fragmented?	Justification
No	-

Continuing decline in mature individuals?	Qualifier	Justification

Continuing decline % in mature individuals within 3 generations or 10 years, whichever is longer (up to max. of 100 years in the future)	Qualifier	Justification

Extreme fluctuations in the number of subpopulations	Justification
No	-

Continuing decline in number of subpopulations	Qualifier	Justification
No	-	-

All individuals in one subpopulation: No

Number of Subpopulations	Justification	Subpopulation Details	Subpopulation description	Number of mature individuals	Subpopulation trend	Qualifier	Location type	Number of Subpopulations	Location bounding box	Location coordinates	Notes
0		-	-	-	-	-	-	-	-	-	-

- **Population Reduction - Past**

Percent Change in past	Reduction or Increase	Qualifier	Justification

Basis?
c) a decline in area of occupancy, extent of occurrence and/or quality of habitat

Reversible?
Yes

Understood?
Yes

Ceased?
No

- **Population Reduction - Future**

Percent Change in future	Reduction or Increase	Qualifier	Justification
11.8%	Reduction	Inferred	Using the Red List criterion A3, the projected population reduction (PPR) to be met in the future (100 years because the generation length of the species is 79 years) of the *A. klaineana* population was assessed across its distribution range. Because *A. klaineana* is a widespread species in Central Africa, the PPR was estimated for the region. In Central Africa, three different PPR were thus estimated: PPRpa in protected areas, PPRpf in production forests and PPRnp in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas. First, protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). The population of the species in protected areas covering its range was kept stable in the future over 100 years, suggesting that the PPR in protected areas was 0%. Second, the evolution of the *A. klaineana* population was simulated using an Usher matrix

	model to estimate the PPR of production forests (logging concessions, PPRpf). The simulations were initialised using the density (number of trees.ha^{-1}) per diameter class (from 25 cm diameter, mature individuals) from forest management inventories of logging companies. The evolution of this initial population depended on several demographics (recruitment, mortality, and growth rate) and logging parameters (minimum cutting diameter, cutting and damage rates) that were adjusted using data of permanent tree plot monitoring. Thus, the density of *A. klaineana* in 100 years was predicted with a logging event every 25 years, which corresponds to the average cutting cycle in Central Africa. PPRpf was then calculated as the difference between initial and final number of trees. Third, the major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Illegal logging and the habitat lost from deforestation rate have been both activities that allowed estimating the PPRnp in non-permanent domains. The global PPR was then computed after weighting the three values (protected area, production forest and non-permanent domain) by their relative forest areas. The global PPR result was found to be 11.8%, lower than 30%.

Basis?
b) an index of abundance appropriate for the taxon, d) actual or potential levels of exploitation

- **Population Reduction - Ongoing**

Both: Percent Change over any 10 year or 3 generation period, whichever is longer, and must include both past and future, future can't go beyond 100 years	Reduction or Increase	Number of years for this period	Qualifier	Justification

Basis?

Reversible?
Yes

Understood?
Yes

Ceased?
No

• Habitats and Ecology

Aucoumea klaineana is a large tree reaching 60 m in height and 2 m in diameter. It is a pioneer and strictly light-demanding species, which colonises open environments of natural (*e.g.* savanna or forest openings) or anthropic origin (*e.g.* fallow lands), often in dense patches. As such, *A. klaineana* is generally considered to be a gregarious species. It principally establishes in abandoned fields and savannahs. In mature forest its regeneration is rare and limited to large gaps. Selective logging allows only significant regeneration along roads. The species also colonises large light gaps, but does not regenerate in the forest understory. As the stand increases in age, *A. klaineana* is gradually replaced by more shade tolerant species, leaving only scattered individuals in mature forests. The abundance of young individuals is therefore inversely proportional to the age of the forest (Doucet et al., 2004). *A. klaineana* grows on all types of soil. From the sandy, poorly drained soils of the estuary of Gabon to the drier, more clay-rich continental soils. Soil type has a minor influence on the establishment of *A. klaineana* populations compared to climatic and biotic factors (Guidosse et al., 2022; Leroy Deval, 1974). During savanna colonisation, the soil is dry and poor in litter and the roots of *A. klaineana* go deep into the soil.

A. klaineana flowers at the beginning of the long rainy season (October) in Gabon. Although it can be fertile from 23 cm diameter, full flowering is observed from 55 cm diameter (Doucet, 2003; Guidosse et al., 2022). It is pollinated by social (Apidae: Apinae, Meliponinae) and solitary bees (Xylocopidae) and by flies (Diptera: Calliphoridae, Syrphidae) (Brunck et al., 1990). Female trees of *A. klaineana* start to bear fruit at the end of December, during the short dry season. A "good seed carrier" gives an average of 10 to 30 litres of seeds (there are 800 to 850 seeds per litre). Production depends on the diameter and height of the tree; some dominant trees could produce up to 100 litres (Leroy Deval, 1976). The seeds are wind dispersed and are usually found on trees of 50 to 60 cm in diameter, with a well-developed crown can be dispersed up to 100 m (Doucet, 2003). Dominant winds thus play a decisive role in the spatial distribution of seeds.

In *A. klaineana* stands, the phenomenon of root anastomosis facilitates the transmission of photoassimilates between individuals. Indeed, the phenomenon allows the dominant individual to accelerate its growth in order to win the race to the canopy and thus overtake the other competing species. The dominant tree could then feed the dominated in its biological cell (i.e. all the individuals physiologically connected to each other by their roots), which cover the ground and slow down the development of the herbaceous stratum (Doucet et al., 2021; Guidosse et al., 2022).

As most light-demanding species in dense, undisturbed forests, it can have a diametric bell-shaped structure with a regeneration deficit. However in Central Africa, the global structure is balanced (see Appendix 1).

- **IUCN Habitats Classification Scheme**

Habitat	Season	Suitability	Major Importance?
1.6. Forest -> Forest - Subtropical/Tropical Moist Lowland	Resident	Suitable	Yes

- **Continuing Decline in Habitat**

Continuing decline in area, extent and/or quality of habitat?	Qualifier	Justification
Yes	Observed	Despite the annual deforestation rate of 0.35% in Central Africa (Vancutsem et al., 2021), the species can also colonise savannah and other open habitats.

- **Life History**

Generation Length	Justification	Data Quality
79	Minimum estimate of generation length for the species from the average growth rate, and the mean diameter of mature individuals (see Supplementary Material)	good

Age at maturity: female or unspecified
36 Years

Age at Maturity: Male
36 Years

Size at Maturity (in cms): Female
25

Size at Maturity (in cms): Male
25

Reproductive Periodicity
Annual

Annual Rate of Population Increase

Natural Mortality
1% (Ligot et al. 2022)

- **Systems**

System: Terrestrial

- **Plant / Fungi Specific**

Wild relative of a crop? No

Plant and Fungal Growth Forms
Tree - large

- **Use and Trade**

- **General Use and Trade Information**

Aucoumea klaineana is the most exploited forest species in the tropical Central. The wood is described in Gérard et al., (2016). It is one of the best timbers for veneer and plywood production. The exploitation was once very selective and limited to the best shaped trees for the wood peeling industry. With the new market demands to process lower-quality logs by sawing, the proportion of the species actually exploited sharply increased in some concessions in Gabon, from 30-40% during the 1990s to 65-75% today (FRMi, 2018).

At industrial level, *A. klaineana* is processed into batten or chipboard panels and veneers, and is widely used in shipbuilding for interior decoration panels and for exterior applications. The wood is also suitable for light interior fittings, carpentry, furniture, sports equipment, cigar boxes and packing cases. The logs are traditionally used to make dugout canoes. The wood can be used as fuel and is suitable for the production of pulp (van Valkenburg, 2005).

In the international market, in 2018, *A. klaineana* accounted for 1 956 234m³ of wood, 60% of Gabon's total production (Eba'a Atyi et al., 2022). In 2010, the Gabonese government banned the export of logs. This strongly encouraged local wood processing and the export of veneers to the European market which reached 142 000 m³ in 2017 (Guidosse et al., 2022). Other producing countries (Congo and Equatorial Guinea) have taken advantage of this ban to export more logs to China. For example, Congo increased its exports of *A. klaineana* logs by 20% between 2016 and 2017 to reach 940 000 m³. Since July 2020, Congo has also banned the export of logs except "logs of heavy and hardwood species whose processing requires specific technology" (art. 97, Law No. 33-2020). In 2018, sawn timber was mainly directed to China (61%), Vietnam (15%) and Belgium (6%)(Guidosse et al., 2022). At a local level, *A. klaineana* resin from the bark is used to make torches and in oil lamps in Gabon and Equatorial Guinea, and also in cosmetics for the skin and in nail polish. It is also used to treat superficial wounds and abscesses, and to disinfect water (van Valkenburg, 2005).

Subsistence:	Rationale:	Local Commercial:	Further detail including information on economic value if available:
Yes	-	Yes	-

National Commercial Value: Yes

International Commercial Value: Yes

Is there harvest from captive/cultivated sources of this species? Yes

Trend in level of total offtake from wild sources: Stable

Trend in level of total offtake from domesticated sources: Unknown

- **Non- Consumptive Use**

Non-consumptive use of the species? true

- **Threats**

The main threats in the non-permanent domain across distribution range, are mainly related to habitat loss due to the destruction of natural environments as a result of population explosion and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging and the abusive harvesting of plant parts requested as non-wood forest products (Bradshaw et al., 2009).

Aucoumea klaineana is the most exploited tree in Central Africa. No study considers logging as a direct driver of deforestation because of the low logging intensity (1-2 stems per hectare).

- **Threats Classification Scheme**

No past, ongoing, or future threats exist to this species. false

Threat	Timing	Scope	Severity	Impact Score
1.1. Residential & commercial development -> Housing & urban areas	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4

2.1.1. Agriculture & aquaculture -> Annual & perennial non-timber crops -> Shifting agriculture	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
2.2.2. Agriculture & aquaculture -> Wood & pulp plantations -> Agro-industry plantations	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
2.3.2. Agriculture & aquaculture -> Livestock farming & ranching -> Small-holder grazing, ranching or farming	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4
3.2. Energy production & mining -> Mining & quarrying	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
4.1. Transportation & service corridors -> Roads & railroads	Past, Likely to Return	Minority (<50%)	Negligible declines	Past Impact
5.3.1. Biological resource use -> Logging & wood harvesting -> Intentional use: (subsistence/small scale) [harvest]	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 4
5.3.2. Biological resource use -> Logging & wood harvesting -> Intentional use: (large scale) [harvest]	Ongoing	Minority (<50%)	Slow, Significant Declines	Medium Impact: 6
7.1.3. Natural system modifications -> Fire & fire suppression -> Trend Unknown/Unrecorded	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4

• Conservation

Aucoumea klaineana is known to occur in protected areas and in at least one *ex situ* collections (BGCI, 2022). In certified forest concessions where the species is exploited, permanent forest plots are usually installed. These plots provide important data for (i) quantifying population dynamics processes at the stand level: mortality, growth and recruitment; (ii) phenological studies to determine the regular fruiting diameter (RFD).

These plots are managed in collaboration with forest concessions grouped within the DYNAFAC collective (see here for more information https://www.dynafac.org/fr/p/130/installation-de-dispositifs-de-suivi-de-la-dynamique-forestiere). Compilation of these data will provide important additional information for targeted silvicultural measures for the sustainable management of this species. First summaries have provided information on important parameters such as: mortality, growth etc (DYNAFAC, 2022; Ligot et al., 2022). *A. klaineana* is also monitored in nurseries and planted in some forest concessions. Several plantations and various methods are used to ensure the regeneration of the species. Its high growth rates, allowing for a relatively short cutting rotation. Literature shows that the extent of past human disturbance in the forests of the Congo Basin hds a positive impact on the abundance of pioneer species such as *A. klaineana* (Daïnou et al., 2016; Morin-Rivat et al., 2017; Van Gemerden et al., 2003). Keeping the environment open would ensure good regeneration of the species. To improve stand management it is important to understand the determinants of its growth. Guidosse et al. (2022) highlighted the lack of knowledge about the role of the rhizosphere in the dynamics of the species populations. To be effective, silviculture of *A. klaineana* should take these aspects into account to a greater extent. Logging induces a reduction in the quality of the logs due to decades of exploitation focused on the best shaped trees. Itcould thus have unfortunate consequences on the quality of the production. Optimising *A. klaineana* silviculture and thus maintaining its trade is essential for the development of Gabon and bordering regions. This species remains the leader in a niche market which is the production of veneer sheets by peeling.

In Central Africa, the sustainability of timber exploitation is primarily based on so-called sustainable forest management, guaranteed by management plans defining the rules of exploitation". However, as many other logged species, it suffers from illegal timber trade, therefore it is crucial to develop effective monitoring and prevention systems.

Aucoumea klaineana is a High Conservation Value species, parts of the tree are used by local communities for various traditional uses (HCV 6 for wood, bark and resin).

In addition, it will also be necessary to :

- Ensure the implementation of the recommendations of the Dynafac collective, including the establishment of a system for monitoring the populations of commercial species in the different forest types defined in a consensual manner;
- Set up monitoring and support systems for the regeneration of commercial species, prioritising species with regeneration deficits;
- Set up programmes to guarantee the phenotypic quality of commercial species populations: seed banks, seed stands, plus trees, seed orchards, conservation plantations;
- Consider threatened species in the delimitation of conservation series and in the identification of High Conservation Values;
- Update conservation statuses on a five-yearly basis, in particular by setting up a system of "green statuses";
- Define red lists adapted to regional or national contexts;
- Evaluate the status of cryptic species or species close to commercial species evaluated during this workshop.

- **Conservation Actions In- Place**

Action Recovery Plan	Note
No	Large plantations occurred in the past but today there are only some plantings at very local scale.

Systematic monitoring scheme	Note
Yes	The species is monitored in permanent plots installed within forestry companies in Central Africa (see here for more information https://www.dynafac.org/fr)

Occur in at least one PA	Note
Yes	The species may appear in at least 100 protected areas considering its distribution range.

Percentage of population protected by PAs (0-100)	Note
1-10	- Considering protected area across species distribution range

Area based regional management plan	Note
Unknown	-

Invasive species control or prevention	Note
No	-

Harvest management plan	Note
Yes	In legal forest concessions, the species is exploited according to a management plan.

Subject to ex-situ conservation	Note
Yes	-

Included in international legislation	Note
No	-

Subject to any international management/trade controls	Note
No	

- **Important Conservation Actions Needed**

Conservation Actions	Note
3.1.1. Species management -> Species management -> Harvest management	-
3.1.2. Species management -> Species management -> Trade management	-
3.4.2. Species management -> Ex-situ conservation -> Genome resource bank	-

- **Research Needed**

Research	Note
1.2. Research -> Population size, distribution & trends	-
3.1. Monitoring -> Population trends	-
3.2. Monitoring -> Harvest level trends	-
3.3. Monitoring -> Trade trends	-

• Ecosystem Services

• Ecosystem Services Provided by the Species

	Importance:	Geographic range of benefit:
1. Water Quality	2 - Important	Global
3. Flood Control	2 - Important	Global
4. Climate Regulation	2 - Important	Global
5. Landscape	2 - Important	Global
6. Air Quality	2 - Important	Global
7. Nutrient Cycling	2 - Important	Global
8. Habitat Maintenance	2 - Important	Global
9. Provision of Critical Habitat	2 - Important	Global

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SUPPLEMENTARY MATERIAL

Aucoumea klaineana - Pierre

IUCN status using criterion A3

We adopted the criterion A3 to assess the projected population reduction (PPR) to be met in the future (up to a maximum of 100 years) of *Aucoumea klaineana*. To quantify the projected population reduction, simulations must be performed on mature individuals and three generations with a maximum of 100 years according to **criterion A3**. We estimated mature individuals and generation length, as recommended by the IUCN guidelines (UICN, 2019).
A **mature individual** is an individual that can reproduce, able to bear flowers or seeds (fertile in plant kingdom). To quantify the mature individuals for each species, we used phenological data from a combined dataset of 105 trees in Gabon (Doucet, 2003). Using the relation between the percentage of fertile trees and tree diameter, the **diameter of a mature individual** was obtained by fitting 50% of fertile trees to produce the flower or fruit. The minimum diameter of mature individuals for this species was **25 cm** (Doucet, 2003; Guidosse et al., 2022).
The **generation length** was the report between the mean diameter of mature individuals considering population structure and the mean increment. Given that the minimum diameter of mature individuals was 25 cm, we weighted the total number of trees by their diameter from 25 cm to 125 cm (Figure 1) to compute the number of mature individuals. The mean of mature individuals was **54 cm**. The **mean increment** of the species was **0.687 cm**, obtained from 57 observations of unpublished data in Gabon. Thus, the **generation length** was 54 cm / 0.687 cm = **79 years**. The age at maturity (36 years) has been estimated as the report between the **minimum diameter of mature individuals (25 cm**) and the **mean increment (0.687 cm)**.

Estimation of the projected population reduction (PPR)

We adopted the criterion A3 to assess the projected population reduction (PPR) to be met in the future (up to a maximum of 100 years). Because *Aucoumea klaineana* is a widespread species in Central Africa, the PPR was estimated in central Africa (Guidosse et al., 2022).

PPR in Central Africa

In this region, forest management follows three different modalities: protected areas, production forests (logging concessions) and non-permanent forest domain. Based on occurrences, the natural range of this species includes countries in Central Africa (Figure 1). The total natural area is estimated at 24 386 497.8 ha. Within this area, there are 14 582 044.8 ha (60%) for production forests, 2 330 014.15 ha (10%) for protected areas, and 7 474 438.8 ha (30%) for the non-permanent domain.

Three different PPR were thus estimated: PPR_{pa} in protected areas, PPR_{pf} in production forests and PPR_{np} in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas and then added to estimate the PPR_C in Central Africa.

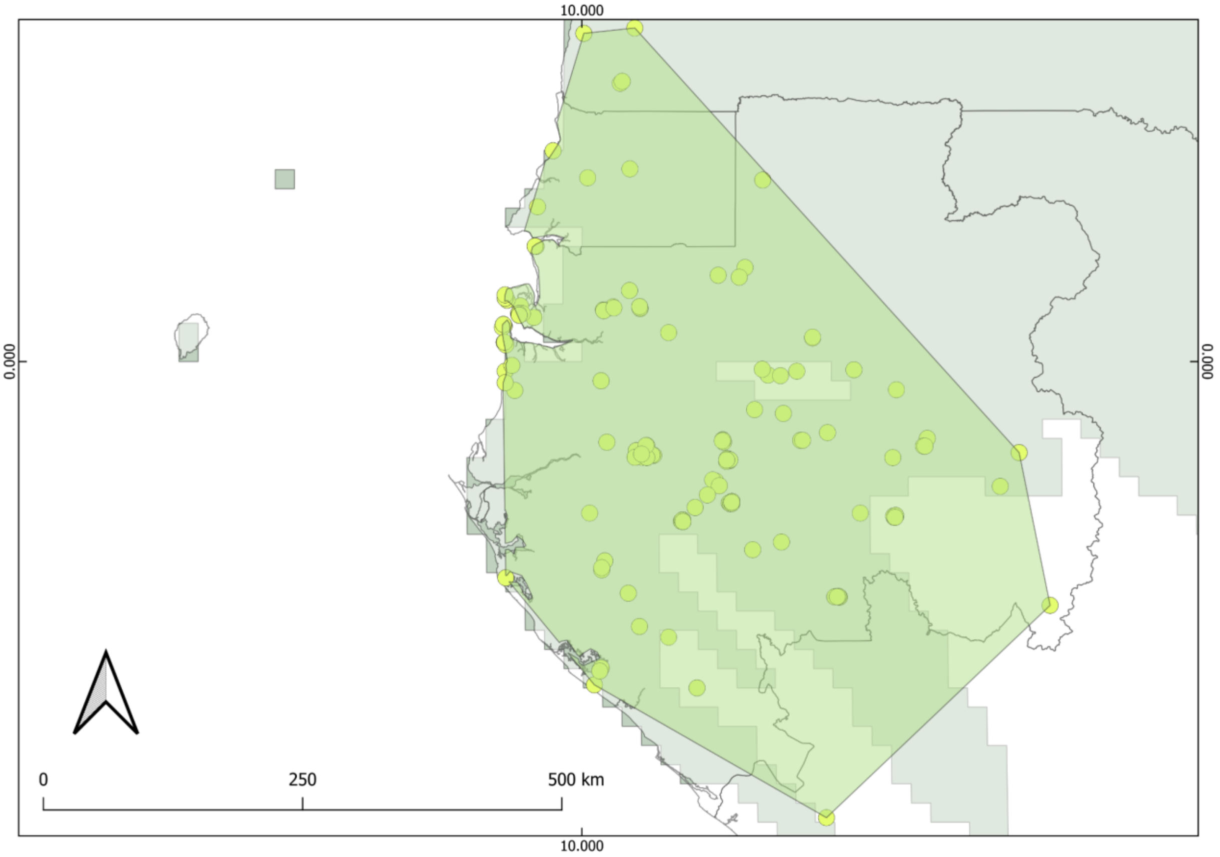

Figure 1. The range of *Aucoumea klaineana* in Central Africa estimated from RAINBIO and CJB data, validated in December 2022 during a workshop with a group of experts in Gabon.

- **PPR in protected areas**

Central Africa countries have allocated a higher proportion of their land to conservation than any other tropical regions, with relatively higher conservation success (Laurance et al., 2012). Indeed, most protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). They are currently representing a large part of forest and tree species conservation in Central Africa. Thus, the population of each species in protected areas (according to FRMI, 2018) covering its range was kept stable in the future over 100 years. **In these conditions, it was hypothesized that the PPR in protected areas for each species is 0%, suggesting no population reduction in the present and future.**

- **PPR in production forests**

To quantify the evolution of the population of each timber species, matrix population models are widely used to study population dynamics (Picard & Liang, 2014). The population of this species was described at time t by a vector N_t corresponding to the density (number of trees ha^{-1}) in each diameter class (from 20 cm diameter to more than

120 cm). The density per diameter class were estimated using data of forest inventories that were carried out in 44 forest management units (FMU) of different logging companies in Gabon. Most logging companies followed a standardized inventory protocol (Réjou-Méchain et al., 2011). These forest inventory data covered about 8 million ha (Table 1), that are representative of 58% of Central Africa's production forests of this species. The number of trees sampled in Gabon was 55 865 136 with a density of 6.58 tree ha^{-1}. Large-scale commercial inventories have already been found useful in the identification of large-scale patterns in Central Africa (Réjou-Méchain et al., 2011). Using large-scale data from commercial forest inventories, Réjou-Méchain et al. (2021) jointly model the distribution in the abundance of the most dominant tree species and produce continuous maps of the floristic and functional composition of central African forests.

Table 1. Forest management units (FMU) sampled in Central Africa (Cameroon, CAR: Central African Republic, DRC: Democratic Republic of the Congo, EG: Equatorial Guinea, Gabon and RCongo: Republic of the Congo).

	Sampling	
Country	FMU	Area (ha)
Cameroon	-	-
CAR	-	-
DRC	-	-
EG	-	-
Gabon	44	8 492 018
RCongo	-	-
Total	44	8 492 018

The Usher matrix model was used to simulate the evolution of the recovery rate of all population and the exploitable stock of each species after logging in Central Africa. According to the Usher assumption, between t and t+1, an individual can either stay alive in the same class, stay alive and move up to the next class, or die; it cannot move up by more than one class or move backwards, i.e., the individual is free from diameter shrinkage (Picard et al., 2012). The Usher matrix model (U) considers three parameters (mortality, recruitment and growth rate that are constant in time) to estimate the transition probabilities:

$$U = \begin{pmatrix} q_1 + g_1 & g_2 & \cdots & \cdots & g_I \\ p_1 & q_2 & 0 & \cdots & 0 \\ 0 & \ddots & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & p_{I-1} & q_I \end{pmatrix}$$

where q_i is the probability for an individual to stay alive in class i between two consecutive time steps, p_i is the upgrowth transition rate (the probability for an individual to grow up from class i to class i +1), and g_i is the recruitment rate (Picard & Liang, 2014).

Tree mortality, recruitment, and growth are three central processes for predicting the dynamics of tropical rainforests, and estimating these three processes requires long-term monitoring in difficult field conditions (Picard & Gourlet-Fleury, 2008). These processes determine the evolution of the species population in the forest stand. The

natural mortality is defined as the number of standing dead trees, and few studies have reported estimates of mortality rates in Central Africa. Data about tree mortality are still scarce and it does not allow to precisely model the mortality rate for each species and size class. Given the current state of knowledge, it appears reasonable to use a fixed mortality rate of 1% for all species and size classes, in agreement with the results of Ligot et al. (2022) on 21,180 trees belonging to 42 timber species of Central Africa annually monitored from one to seven years.
The recruitment integrates fruiting and seed dispersal from mother trees, and the survival of plant juveniles until they reach a size threshold where they are included in the stand. The recruitment term in the model is the average annual input of new individuals into the first size class from 20 cm. The recruitment events, like mortality events, are infrequent and thus difficult to model (Karsenty & Gourlet-Fleury, 2006). The population structure showed a curve in "decreasing exponential" suggesting a good regeneration (Figure 2). To model the recruitment, we used the hypothesis defined as the recruitment rate that would maintain a constant number of trees in the first diameter class. Claeys et al. (2019) projected the future forest dynamics up to the end of the century and they showed that projected mortality and recruitment rates in 2099 could not differ from the ones observed today. Thus, the hypothesis on the recruitment and the mortality rate is used in the future (up to 100 years) as they do today.

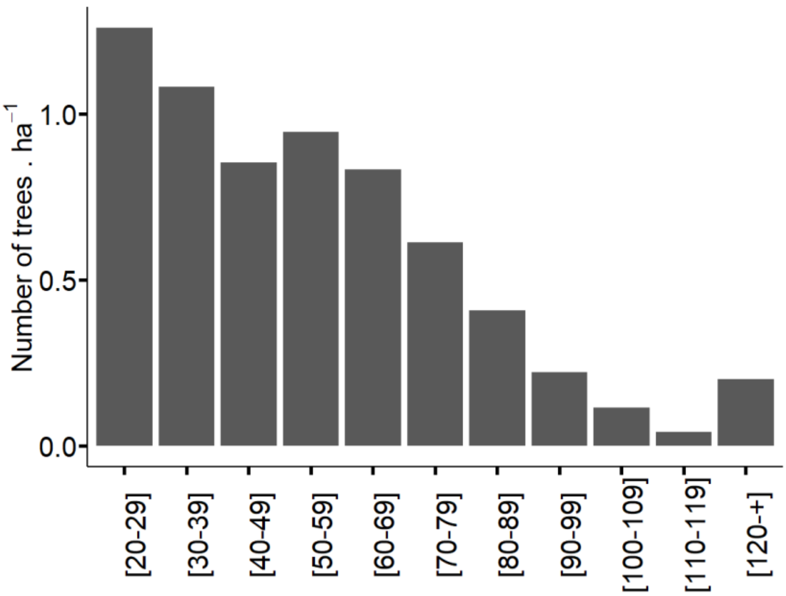

Figure 2. Population structure of *Aucoumea klaineana* (Okoumé) defined using the number of trees per ha and per diameter class (from 20 cm of 44 logging concessions in Gabon covering an area of 8 492 018 ha).

Since the mid-1900s, periodic tree monitoring and tree ring analyses have been carried out to study variability in tree growth across species in Central Africa (Durrieu de Madron, Nasi, et al., 2000; Ligot et al., 2019, 2022). We fitted growth models for each species using data from logged and unlogged areas of permanent tree plot monitoring from the DYNAFAC[5] network covering the five Central African countries. From the combined dataset, we identified 57 trees belonging to one site in Gabon. Minimum and maximum sampled diameters ranged from 10 to 75 cm. The

[5] https://www.dynafac.org/en

monitoring period ranged from 2000 to 2008. The second-degree polynomial model was fitted for this species. Because of three estimated coefficients of the second-degree polynomial model were not significant, the mean of the increment (**0.687 cm**) has been used to estimate the diameter growth (Table 2).

Table 2. Estimated coefficients (a, b and c) of growth models between the increment (ac in cm year^{-1}) and the initial diameter (D in cm). The sample including the number of trees (n) and the number of sites (site) is also given. ^{ns} non-significant (p-value > 0.050)

species	n	site	model	a	b	c
Okoumé	57	1	$ac \sim D + D^2$	-0.247^{ns}	0.033^{ns}	-0.0003^{ns}

The transition probabilities of three parameters (mortality, growth, and recruitment rate) allowed making the harvested matrix. The logging operations have been modeled using the logging parameters (minimum cutting diameter, cutting and damage rate). The minimum cutting diameters were obtained from decrees of application of the forestry administrations (MCD_A) at the country level and the one used in the management plan (MCD_M, with $MCD_M \geq MCD_A$) at the logging company level. At the Central Africa level, we weighted the MCD_A and MCD_M values to the occupied area and **$MCD_A = MCD_M = 70$ cm**. The cutting rate (CA), which defines the proportion of harvested trees (trees with a diameter greater than MCD_A or MCD_M), was given by logging companies, and it was also weighted at the Central Africa level with a value of 70%. Given the current state of knowledge, it appears reasonable to use a fixed damage rate caused by logging of 7% of the initial population that disappears (Durrieu de Madron, Fontez, et al., 2000). The average cutting cycle (i.e. the period between two successive logging operations) is 28 years (FRMI, 2018), but we used 25 years to simplify computation of four simulations reaching 100 years (25, 50, 75, and 100 years), as requested by IUCN criterion A.

The Figure 3 shows the PPR in production forests for the *Aucoumea klaineana*. The reduction in the population of each species was then calculated as the difference between the initial numbers of mature individuals and the predicted numbers of mature individuals predicted after 100 years. **The PPR in production forest was – 17.91% over 100 years**.

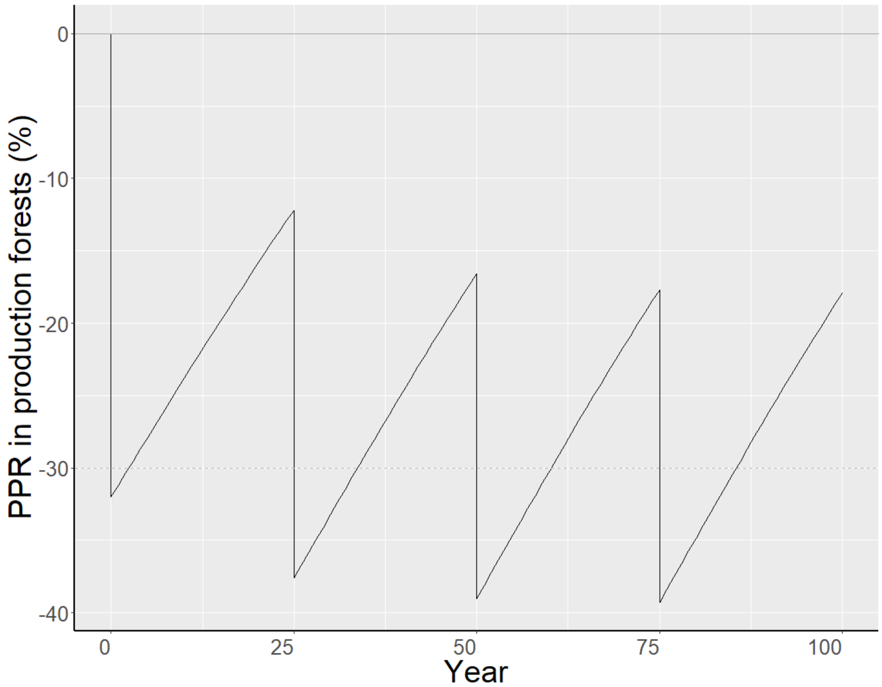

Figure 3. Simulations showing the projected population reduction (PPR) from diameter of mature individuals (25 cm) in production forests for the *Aucoumea klaineana* for constant recruitment over 100 years.

- **PPR in the non-permanent forest domain**

The major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanization, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Based on the large range of this species in Central Africa (Figure 1), the harvested volume from illegal logging and legal logging are 24% and 76%, respectively (FRMI 2018). In this condition, it was hypothesized that there is 76% of PPR from production forests and 24% of PPR from illegal logging in 100% PPR due to forest logging. Given that the PPR of production forests associated with its forest area was known, we deduced the PPR and forest area of illegal logging from those of the production forests. As a result, 4 604 856.25 ha were affected by the illegal logging for this species. The non-permanent domain area (7 474 438.8 ha) was considered as the area which was related to today's deforestation rate of 0.05% year^{-1} in the geographic range of this species (Eba'a et al., 2022). This is a conservative value since it will probably decrease in the future (Swamy et al., 2018).

- **PPR global = PPR in Central Africa**

We thus had three different PPR: PPR_{pa} in protected area, PPR_{pf} in production forests, and PPR_{np} in non-permanent domain. The global PPR was then computed after weighting the three values by their relative forest areas:

$$PPR = \frac{(S_{pa} \times PPR_{pa}) + (S_{pf} \times PPR_{pf}) + (S_{np} \times PPR_{np})}{S_{pa} + S_{pf} + S_{np}}$$

where S_{pa}, S_{pf}, and S_{np} are forest areas in protected area, production forests and non-permanent domain, respectively.

The criterion A3 based on (c) a decline in area of occupancy (AOO), the extent of occurrence (EOO), and/or habitat quality; and (d) potential levels of exploitation, has been computed as follows: (i) 30%≤PPR<50%, the species is considered as Vulnerable (VU); (ii) 50%≤PPR <80%, the species is considered as Endangered (EN), and PPR ≥ 80%, the species is considered as Critically Endangered (CR).

The PPR global in the distribution range of the *Aucoumea klaineana* was -**11.8%.** This PPR is < 30%, suggesting that this species is not threatened in its geographic area.

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10.3 Annexe 3. *Bobgunnia fistuloides* - (Harms) J.H.Kirkbr. & Wiersema

Draft

Bobgunnia fistuloides **- (Harms) J.H.Kirkbr. & Wiersema**

PLANTAE - TRACHEOPHYTA - MAGNOLIOPSIDA - FABALES - FABACEAE - Bobgunnia - fistuloides

Common Names: Akite, Asomanini, Awong, Dina, Kiela Kusu, Ndina, Oken, Pao Rosa, Pau Rosa

Synonyms: *Swartzia fistuloides* Harms

Bobgunnia comprises 2 species and is confined to mainland tropical Africa. It has been separated from *Swartzia*, a genus of over 100 species in tropical America, mainly on the basis of seed characteristics.

Red List Status
NT - Near Threatened, A3cd (IUCN version 3.1)

- **Red List Assessment**

- **Assessment Information**

Date of Assessment: 2022-09-01

Assessor(s): Monthe, F., Loubota, G., Ligot, G., Texier, N., Stévart, T. & Doucet, JL.

Reviewer(s):

Institution(s):

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Regions: Global

- **Identification Description**

Bobgunnia fistuloides is a medium-sized tree not exceeding 25 m in height and 80 cm in diameter, with a trunk that is often twisted, greyish turning yellowish and breaking off into long scales, and with a cylindrical or almost cylindrical base. Its thin, fibrous slice is yellowish and has a strong banana-like smell. Its leaves are compound, alternate, with 6 to 13 alternate leaflets that are larger towards the top. These leaflets are quite symmetrical and thin, quickly decaying on the ground, rounded to subcordate at the base and acuminate at the top, with a marginal vein. Its long inflorescences (16-30 cm) are pendulous with single-petalled white flowers. Its fruits are long, cylindrical, fleshy indehiscent pods (10-30 cm), shiny and blackish when ripe, rounded at the ends and slightly narrowed between the numerous seeds, which are surrounded by a sticky, fragrant substance. The seed is rounded (± 1 cm diameter), slightly domed, with a shiny brown seed coat.

- **Assessment Rationale**

Bobgunnia fistuloides is a medium-sized tree, long-lived, non-gregarious crypto-pioneer of African moist evergreen and semi-deciduous forests. It is distributed from Guinea to Democratic Republic of Congo. Based on a 2 x 2 km cell size, the AOO of this species is estimated as 704 km2 with a minimum of 66 locations (number of forest management units of different logging companies in Central Africa). This species is not "Vulnerable" status under criterion B2. The EOO is calculated as 4 113 431 km2, above the upper threshold for "Vulnerable" status under criterion B1.

Commonly known as Pao rosa, it is a timber species in tropical Africa, sought after for the quality of its wood. The minimum cutting diameter (MCD) in Central Africa varies between 50 and 70 cm and is globally close to the regular fruiting diameter (RFD) estimated at 50 cm diameter at breast height (dbh), ensuring optimal regeneration of the species. The population structure of this species decreasing exponential, suggesting a good regeneration with a density of 0.10 stems.ha^{-1} (dbh ≥ 20 cm) in Central Africa (see Supplementary Material). Given its stem density and the mean annual increment of 0.32 ± 0.28 cm/year in Central Africa (see Supplementary Material), we estimate the number of mature individuals over 10 000 across the distribution range, well above the threatened category under criteria C and D.

Considering the species' generation length of 186 years (see Supplementary Material), an inference of population reduction for three generations in the past is impossible following A1 and A2 criteria. *B. fistuloides* seeds are mainly dispersed by African forest elephants (*Loxodonta cyclotis*) (Scalbert et al., 2022), assessed as Critically Endangered A2abd (Gobush et al., 2021). Indeed, estimates from 161 localities across the African forest elephants range indicate an irreversible reduction of more than 80% of the continental population in the past three generations (93 years) and the taxon lost 30% of its geographical range between 2002–2011 (Gobush et al., 2021; Maisels et al., 2013). Based on simulations of the expected population reduction of *B. fistuloides* in its distribution range including protected areas, non-permanent domain, and production forests (logging concessions), we estimated population reduction of 11.7 %. An assessment of the population reduction according to criterion A4 considering one to two generations back and one to two generations forward would likely introduce high levels of uncertainty due to the lack of data to efficiently model the reduction of population size in the past. No quantitative analysis of the probability of extinction in the wild was conducted, and therefore criterion E does not apply.

Considering (i) the population density and the natural regeneration, (ii) taking into account the impact of the reduction of populations of main dispersers, the reduction of population in the future across the distribution range, the species is assessed as near threatened NT, A3cd, and it can be threatened (VU) in future on the criterion A3 with a decline in area of occupancy or habitat quality.

Reasons for change

Reason(s) for Change in Red List Category from the Previous Assessment:

Bobgunnia fistuloides was previously assessed as "Least Concern" by the IUCN (*https://www.iucnredlist.org/species/33061/20029309*) (Groom, 2012). During the last few years, important data have been produced on the self-ecology, population dynamics (growth, recruitment, mortality) of the species. Moreover, a new version of the IUCN guidelines is available (from version 2.3 to 3.1). Given all this information, it was necessary to produce a new assessment of the species.

● Distribution

● Geographic Range

B. fistuloides is widely distributed across West and Central Africa from Guinea to Democratic Republic of the Congo. The extent of occurrence (EOO) in native area is estimated to 4 113 431 km^2 across its distribution range.

● Area of Occupancy (AOO)

Estimated area of occupancy (AOO) - in km2	Justification
704	AOO has been estimated using ConR based on the 2 × 2 km cell size of 259 occurrences from CJB (Conservatoire et Jardin botaniques de Genève) and RAINBIO

Continuing decline in area of occupancy (AOO)	Qualifier	Justification
Yes	Inferred	The species has suffered from reduction in area of occupancy, due to habitat degradation and deforestation in West and Central Africa forest (Vancutsem et al., 2021)

● Extent of Occurrence (EOO)

Estimated extent of occurrence (EOO)- in km2	EOO estimate calculated from Minimum Convex Polygon	Justification
4 113 431	true	Calculated using ConR based on 262 known occurrences from CJB (Conservatoire et Jardin botaniques de Genève) and RAINBIO

Continuing decline in extent of occurrence (EOO)	Qualifier	Justification
Yes	Observed	The species has certainly undergone Extent of Occurrence reduction in West and Central Africa, linked to the reduction in forest area (Vancutsem et al., 2021)

- **Locations Information**

Number of Locations	Justification
60-200	More than 66 localities. Based on the most serious plausible threat (conversion of its habitat) and illegal logging across the distribution range.

Continuing decline in number of locations	Qualifier	Justification
Yes	Inferred	The main threat remains the reduction of the forest area in West Africa.

Extreme fluctuations in the number of locations	Justification

- **Very restricted AOO or number of locations (triggers VU D2)**

Very restricted in area of occupancy (AOO) and/or # of locations	Justification
No	-

- **Elevation / Depth / Depth Zones**

Elevation Lower Limit (in metres above sea level): 0

Elevation Upper Limit (in metres above sea level): 500

- **Map Status**

Map Status	Use map from previous assessment	How the map was created, including data sources/methods used:	Please state reason for map not available:	Data Sensitive?	Justification	Geographic range this applies to:	Date restriction imposed:
Done	-	Qgis. The dataset was created from a compilation of Rainbio and CJB	-	-	-	-	-

- **Biogeographic Realms**

Biogeographic Realm: Afrotropical

- **Occurrence**

- **Countries of Occurrence**

Country	Presence	Origin	Formerly Bred	Seasonality
Angola	Extant	Native	-	Resident
Cameroon	Extant	Native	-	Resident
Central African Republic	Extant	Native	-	Resident
Chad	Extant	Native	-	Resident
Congo	Extant	Native	-	Resident
Democratic Republic of the Congo	Extant	Native	-	Resident
Equatorial Guinea	Extant	Native	-	Resident
Gabon	Extant	Native	-	Resident
Ghana	Extant	Native	-	Resident
Guinea	Extant	Native		Resident
Ivory Coast				
Liberia	Extant	Native	-	Resident
Nigeria	Extant	Native	-	Resident

Senegal	Extant	Native	-	Resident

- **Population**

Bobgunnia fistuloides is a guineo-congolian species, widely distributed in moist evergreen and semi-deciduous forests from Guinea to Democratic Republic of Congo. Its average density is 0.10 stems.ha^{-1} from 20 cm diameter in Central Africa (see Supplementary Material). This density can locally vary from 0.01 stems.ha-^{1} in Cameroon (Oyen, 2012) to 1 stems.ha-^{1} in Gabon (Doucet, 2003).

The average growth is 0.32 ± 0.28 cm/year in evergreen stands and in semi-deciduous riverine forest in Central Africa (see Supplementary Material). Seeds are mainly dispersed by elephants (*Loxodonta cyclotis*) but duikers (*Cephalophus callipygus*) could also disperse seeds (D'Aspremont Lynden, 2020). In nurseries, the average germination rate is 70% (50-80%), seeds can be stored for several years, but the conditions are not well known (Daïnou et al., 2021). In some concessions B*. fistuloides* is planted with a diameter growth rate of 0.777 ± 0.096 cm/year in Cameroon (Doucet et al., 2016).

The minimum fertility diameter estimated at 20 cm in Central Africa (see Supplementary Material), well below the legal minimum cutting diameter "MCD" (50 cm in Cameroon, 60 cm in Gabon, Democratic Republic of Congo, and Republic of Congo, and 70 cm in RCA). Those MCD are generally higher than the regular fruiting diameter (RFD), estimated at 55 cm (DYNAFAC, 2022). In the legal logging concession of central Africa, the MCD must be adapted to ensure sufficient recovery rates after each cutting cycle. At the Central Africa level, we weighted the MCD values to the occupied area with MCD = 65 cm (see Supplementary Material).

Using the Red List criterion A3, the projected population reduction (PPR) to be met in the future (100 years because the generation length of the species is 186 years) of the *B. fistuloides* population was assessed across its distribution range. Because *B. fistuloides* is a widespread species in West and Central Africa, the PPR was estimated for each region. In Central Africa, three different PPR were thus estimated: PPRpa in protected areas, PPRpf in production forests and PPRnp in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas. First, protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). The population of the species in protected areas covering its range was kept stable in the future over 100 years, suggesting that the PPR in protected areas was 0%. Second, the evolution of the *B. fistuloides* population was simulated using an Usher matrix model to estimate the PPR of production forests (logging concessions, PPRpf). The simulations were initialised using the density (number of trees.ha-1) per diameter class (from 20 cm diameter, mature individuals) from forest management inventories of logging companies. The evolution of this initial population depended on several demographics (recruitment, mortality, and growth rate) and logging parameters (minimum cutting diameter, cutting and damage rate) that were adjusted using data of permanent tree plot monitoring. Thus, the density of *B. fistuloides* in 100 years was predicted with a logging event every 25 years, which corresponds to the average cutting cycle in Central Africa. PPRpf was then calculated as the difference between initial and final number of trees. Third, the major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Illegal logging and the habitat lost from deforestation rate have been both activities that allowed estimating the PPRnp in non-permanent domains. In West Africa, the forest areas were subject to a constant annual deforestation rate of 1.20% year-1 (Vancutsem et al., 2021). Taking this rate of deforestation as constant over the next 100 years, when it is expected to decline, is a reasonable precautionary measure. We thus had two different PPR: PPRC in Central Africa and PPRW in West Africa. The global PPR was then computed after weighting the three values by their relative forest areas. The global PPR result was found to be 11.7 % (for further information about this methodology, see Supplementary Material).

- **Population Information**

Current Population Trend: Decreasing

Extreme fluctuations? (in # of mature individuals)	Justification
No	-

Severely fragmented?	Justification
No	-

Continuing decline in mature individuals?	Qualifier	Justification

Continuing decline % in mature individuals within 3 generations or 10 years, whichever is longer (up to max. of 100 years in the future)	Qualifier	Justification

Extreme fluctuations in the number of subpopulations	Justification
	-

Continuing decline in number of subpopulations	Qualifier	Justification
	-	-

All individuals in one subpopulation: No

Number of Subpopulations	Justification	Subpopulation Details	Subpopulation description	Number of mature	Subpopulation trend	Qualifier	Location type	Number of Subpopulations	Location bounding box	Location coordinates	Notes

	-	-	-	-	-	-	-	-	-

- **Population Reduction - Past**

Percent Change in past	Reduction or Increase	Qualifier	Justification

Basis?

Reversible?
Yes

Understood?
Yes

Ceased?
No

- **Population Reduction - Future**

Percent Change in future	Reduction or Increase	Qualifier	Justification
11.7%	Reduction	Projected	Using the Red List criterion A3, the projected population reduction (PPR) to be met in the future (100 years because the generation length of the species is 186 years) of the *B. fistuloides* population was assessed across its distribution range. Because *B. fistuloides* is a widespread species in West and Central Africa, the PPR was estimated for each region. In Central Africa, three different PPR were thus estimated: PPRpa in protected areas, PPRpf in production forests and PPRnp in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas. First, protected areas have resisted the attribution of extractive industry permits, land

	conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). The population of the species in protected areas covering its range was kept stable in the future over 100 years, suggesting that the PPR in protected areas was 0%. Second, the evolution of the *B. fistuloides* population was simulated using an Usher matrix model to estimate the PPR of production forests (logging concessions, PPRpf). The simulations were initialized using the density (number of trees.ha-1) per diameter class (from 20 cm diameter, mature individuals) from forest management inventories of logging companies. The evolution of this initial population depended on several demographics (recruitment, mortality, and growth rate) and logging parameters (minimum cutting diameter, cutting and damage rate) that were adjusted using data of permanent tree plot monitoring. Thus, the density of *B. fistuloides* in 100 years was predicted with a logging event every 25 years, which corresponds to the average cutting cycle in Central Africa. PPRpf was then calculated as the difference between initial and final number of trees. Third, the major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Illegal logging and the habitat lost from deforestation rate have been both activities that allowed estimating the PPRnp in non-permanent domains. In West Africa, the forest areas were subject to a constant annual deforestation rate of 1.20% year-1 (Vancutsem et al., 2021). Taking this rate of deforestation as constant over the next 100 years, when it is expected to decline, is a reasonable precautionary measure. We thus had two different PPR: PPRC in Central Africa and PPRW in West Africa. The global PPR was then computed after weighting the three values by their relative forest areas. The global PPR result was found to be 11.7 %. For further information about this methodology, see Supplementary Material

Basis?
b) an index of abundance appropriate for the taxon, d) actual or potential levels of exploitation

- **Population Reduction - Ongoing**

Both: Percent Change over any 10 year or 3 generation period, whichever is longer, and must include both past and future, future can't go beyond 100 years	Reduction or Increase	Number of years for this period	Qualifier	Justification

Basis?

Reversible?

Understood?

Ceased?

Habitats and Ecology

Bobgunnia fistuloides is a medium size tree reaching 25 m in height and 80 cm in diameter, long-lived, non-gregarious cryptopioneer of moist evergreen and semi-deciduous forests up to 500 m altitude. It can be observed in Marantacae forest and in forest-savannah mosaic (White & Abernethy, 1996). It requires canopy openings to develop and will subsequently be overgrown by neighbouring trees (Maus, 2018).

Bobgunnia fistuloides bear hermaphrodite flowers. Flowering is reported in May in Ivory Coast and in July in Ghana, but in Gabon flowering and fruiting are asynchronous throughout the year. Small trees of 20 cm diameter can already bear flowers, but the regular fruiting diameter is 55 cm (Cameroon and Gabon). In Gabon mature fruits can be observed from January to May (Doucet, 2003). The fruits have a strong yeasty odour and are eaten by elephants and seedlings are frequently found in their dung (Oyen, 2012). The seeds are thus mainly dispersed by elephants (zoochory) but also, to a lesser extent, by duikers (D'Aspremont Lynden, 2020). Good natural regeneration is then observed in logged forest in Gabon, along roads and trails used by elephants. The seeds start germinating 5–10(–20) days after sowing, and the germination rate is high.

- **IUCN Habitats Classification Scheme**

Habitat	Season	Suitability	Major Importance?
1.6. Forest -> Forest - Subtropical/Tropical Moist Lowland	Resident	Suitable	Yes

- **Continuing Decline in Habitat**

Continuing decline in area, extent and/or quality of habitat?	Qualifier	Justification
Yes	Observed	The annual deforestation rate of 0.35% in Central Africa (Vancutsem et al., 2021).

- **Life History**

Generation Length	Justification	Data Quality
186	Minimum estimate of generation length for the species from the average growth rate, and the mean diameter of mature individuals (see Supplementary Material)	Good

Age at maturity: female or unspecified
63 Years

Age at Maturity: Male
63 Years

Size at Maturity (in cms): Female
20

Size at Maturity (in cms): Male
20

Reproductive Periodicity
Annual

Annual Rate of Population Increase

Natural Mortality
1% (Ligot et al. 2022)

- **Systems**

System: Terrestrial

- **Plant / Fungi Specific**

Wild relative of a crop? No

Plant and Fungal Growth Forms
Tree - large

- **Use and Trade**

- **General Use and Trade Information**

Bobgunnia fistuloides is among logged species in tropical Africa. At industrial level, *B. fistuloides* is an exotic pinkish white to light red wood that has been traded internationally, sometimes as a substitute of rosewood (*Dalbergia* spp.). It is a very heavy and hard wood with good stability. It is also resistant to termites, fungi and dry wood insects. The wood is mainly used for (i) sliced veneers, due to its good slicing ability, (ii) cabinet making, including luxury furniture, (iii) percussion instruments, and (iv) carving and turning. From 2000 to 2003 Gabon exported on average 3 150 m^3 of logs per year. In 2018, 3,795 m^3 were produced in central Africa Central Africa (FRMi, 2018).

At a local level, the bark is used as fish poison. In traditional medicine in Gabon and Congo, young children were bathed in a warm decoction of the bark to treat fever. In the Republic of Congo a bark macerate is used as a bath to treat skin diseases and filariasis of the eye. A decoction of the bark mixed with sweet peppers can be taken by nursing mothers to stimulate milk production. The bark extract is taken by men against gonorrhoea and by women against various menstrual problems. In Gabon bark decoctions are drunk against diarrhoea (Oyen, 2012).

Subsistence:	Rationale:	Local Commercial:	Further detail including information on economic value if available:
Yes	-	Yes	-

National Commercial Value: Yes

International Commercial Value: Yes

Is there harvest from captive/cultivated sources of this species? Yes

Trend in level of total offtake from wild sources: Stable

Trend in level of total offtake from domesticated sources: Unknown

- **Non- Consumptive Use**

Non-consumptive use of the species? true

- **Threats**

The main threats in the non-permanent domain across distribution range, are: habitat loss due to the destruction of natural environments as a result of population explosion and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging and the abusive harvesting of plant parts requested as non-wood forest products (Bradshaw et al., 2009). In Central Africa, illegal logging accounts for nearly 46% of total log production (FRMi, 2018). This production generally comes from unallocated forest areas (non-permanent forest domain).

Bobgunnia fistuloides is exploited in Central Africa. No study considers logging as a direct driver of deforestation because of the low logging densities (1-2 stems per hectare). However, studies on the impact of logging on the species and habitats are needed. Poaching is an indirect threat for that species which is mainly dispersed by elephants whose population are dramatically declining.

- **Threats Classification Scheme**

No past, ongoing, or future threats exist to this species. false

Threat	Timing	Scope	Severity	Impact Score
1.1. Residential & commercial development -> Housing & urban areas	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4
2.1.1. Agriculture & aquaculture -> Annual & perennial non-timber crops -> Shifting agriculture	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
2.2.2. Agriculture & aquaculture -> Wood & pulp plantations -> Agro-industry plantations	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
2.3.2. Agriculture & aquaculture -> Livestock farming & ranching -> Small-holder grazing, ranching or farming	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4

3.2. Energy production & mining -> Mining & quarrying	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
4.1. Transportation & service corridors -> Roads & railroads	Past, Likely to Return	Minority (<50%)	Negligible declines	Past Impact
5.3.1. Biological resource use -> Logging & wood harvesting -> Intentional use: (subsistence/small scale) [harvest]	Ongoing	Minority (<50%)	Rapid Declines	Medium Impact: 6
5.3.2. Biological resource use -> Logging & wood harvesting -> Intentional use: (large scale) [harvest]	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4
7.1.3. Natural system modifications -> Fire & fire suppression -> Trend Unknown/Unrecorded	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4

• Conservation

Bobgunnia fistuloides is known to occur in protected areas and in at least 3 *ex situ* collections (BGCI, 2022). In certified forest concessions where the species is exploited, trails and or permanent forest plots are usually installed. These plots provide important data for (i) quantifying population dynamics processes at the stand level: mortality, growth and recruitment; (ii) phenological studies to determine the regular fruiting diameter (RFD). These tails and plots are managed in collaboration with forest concessions grouped within the DYNAFAC collective (see here for more information https://www.dynafac.org/fr/p/130/installation-de-dispositifs-de-suivi-de-la-dynamique-forestiere). Compilation of these data provide important additional information for targeted silvicultural measures for the sustainable management of this species. First summaries have provided information on important parameters such as: mortality, growth etc. (DYNAFAC, 2022; Ligot et al., 2022).

Logging in Central Africa is subject to strict legislation, species can only be harvested above a certain diameter and measures must be taken to ensure the renewal of the resource (Fargeot et al., 2004). Indeed, management plans for tropical rainforests require the determination of a minimum cutting diameter (MCD) to ensure a minimum renewal rate at the end of a cutting cycle (duration between two cuts on the same cutting base), the minimum reconstitution rate depending on the country, as well as the rotation duration (Durrieu de Madron and Forni, 1997).

In addition, it will also be necessary to :

- Ensure the implementation of the recommendations of the Dynafac collective, including the establishment of a system for monitoring the populations of commercial species in the different forest types defined in a consensual manner;
- Set up monitoring and support systems for the regeneration of commercial species, prioritising species with regeneration deficits;
- Set up programmes to guarantee the phenotypic quality of commercial species populations: seed banks, seed stands, plus trees, seed orchards, conservation plantations;

- Consider threatened species in the delimitation of conservation series and in the identification of High Conservation Values;
- Update conservation statuses on a five-yearly basis, in particular by setting up a system of "green statuses";
- Define red lists adapted to regional or national contexts;
- Evaluate the status of cryptic species or species close to commercial species evaluated during this workshop.

- **Conservation Actions In- Place**

Action Recovery Plan	Note
Yes	Reforestation within SFM certified forest concessions and others.

Systematic monitoring scheme	Note
Yes	The species is monitored in permanent plots installed within forestry companies in Central Africa (see here for more information https://www.dynafac.org/fr)

Occur in at least one PA	Note
Yes	Appear in at least 10 protected areas.

Percentage of population protected by PAs (0-100)	Note
1-10	-

Area based regional management plan	Note
Unknown	-

Invasive species control or prevention	Note
No	-

Harvest management plan	Note
Yes	In legal forest concessions, the species is exploited according to a management plan.

Subject to ex-situ conservation	Note

Yes	-

Included in international legislation	Note
No	-

Subject to any international management/trade controls	Note

- **Important Conservation Actions Needed**

Conservation Actions	Note
3.1.1. Species management -> Species management -> Harvest management	-
3.1.2. Species management -> Species management -> Trade management	-
3.4.2. Species management -> Ex-situ conservation -> Genome resource bank	-

- **Research Needed**

Research	Note
1.2. Research -> Population size, distribution & trends	-
1.3. Life history and ecology	
3.1. Monitoring -> Population trends	-
3.2. Monitoring -> Harvest level trends	-
3.3. Monitoring -> Trade trends	-

- **Ecosystem Services**

- **Ecosystem Services Provided by the Species**

	Importance:	Geographic range of benefit:
1. Water Quality	2 - Important	Global
3. Flood Control	2 - Important	Global
4. Climate Regulation	2 - Important	Global

5. Landscape	2 - Important	Global
6. Air Quality	2 - Important	Global
7. Nutrient Cycling	2 - Important	Global
8. Habitat Maintenance	2 - Important	Global
9. Provision of Critical Habitat	2 - Important	Global

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SUPPLEMENTARY MATERIAL

Bobgunnia fistuloides - (Harms) J.H.Kirkbr. & Wiersema

IUCN status using criterion A3

We adopted the criterion A3 to assess the projected population reduction (PPR) to be met in the future (up to a maximum of 100 years) of *Bobgunnia fistuloides*. To quantify the projected population reduction, simulations must be performed on mature individuals and three generations with maximum 100 years according to **criterion A3**. We estimated mature individuals and generation length, as recommended by the IUCN guidelines (UICN, 2019).
A **mature individual** is an individual that can reproduce, able to bear flowers or seeds (fertile in plant kingdom). To quantify the mature individuals for each species, we used phenological data from a combined dataset of 9 trees in Gabon (Doucet, 2003). Using the relation between the percentage of fertile trees and tree diameter, the **diameter of a mature individual** was obtained by fitting 50% of fertile trees to produce the flower or fruit. The minimum diameter of mature individuals for this species was **20 cm** (Doucet, 2003).
The **generation length** was the report between the mean diameter of mature individuals considering population structure and the mean increment. Given that the minimum diameter of mature individuals was 20 cm, we weighted the total number of trees by their diameter from 20 cm to 125 cm (Figure 1) to compute the number of mature individuals. The mean of mature individuals was **59.4 cm**. The **mean increment** of the species was **0.32 cm**, obtained from 111 observations from logged and unlogged forests of published data (Ligot et al., 2022) and unpublished data in three countries (Cameroon, Gabon, and Republic of Congo). Thus, the **generation length** was 59.4 cm / 0.32 cm = **186 years**. The age at maturity (**63 years**) has been estimated as the report between the **minimum diameter of mature individuals** (**20 cm**) and the **mean increment** (**0.32 cm**).

Estimation of the projected population reduction (PPR)

We adopted the criterion A3 to assess the projected population reduction (PPR) to be met in the future (up to a maximum of 100 years). *Bobgunnia fistuloides* (Pao rosa), is found in Guineo–Congolian rainforest species, widely from distributed mainly from Guinea to Democratic Republic of Congo. The geographic range of species was in two regions (Central Africa and West Africa) characteristic of two biogeographical regions across the tropical African forests (Fayolle et al., 2014). According to each region, different data (deforestation annual rate, growth, mortality, recruitment, forest inventory, etc.) have been used with logging data in Central Africa. Thus, the PPR was estimated for each region and the global PPR was then computed after weighting the two values by their relative forest areas.

PPR in Central Africa

In this region, forest management follows three different modalities: protected areas, production forests (logging concessions) and non-permanent forest domain. Based on occurrences, the natural range of this species includes all countries in Central Africa (Figure 1). The total natural area is estimated at 173 994 810.7 ha. Within this area, there are 47 808 286.9 ha (27.5%) for production forests, 12 617 501.3 ha (7.3%) for protected areas, and 113 569 022.5 ha (65.2%) for the non-permanent domain.

Three different PPR were thus estimated: PPR_{pa} in protected areas, PPR_{pf} in production forests and PPR_{np} in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas and then added to estimate the PPR_{C} in Ce ntral Africa.

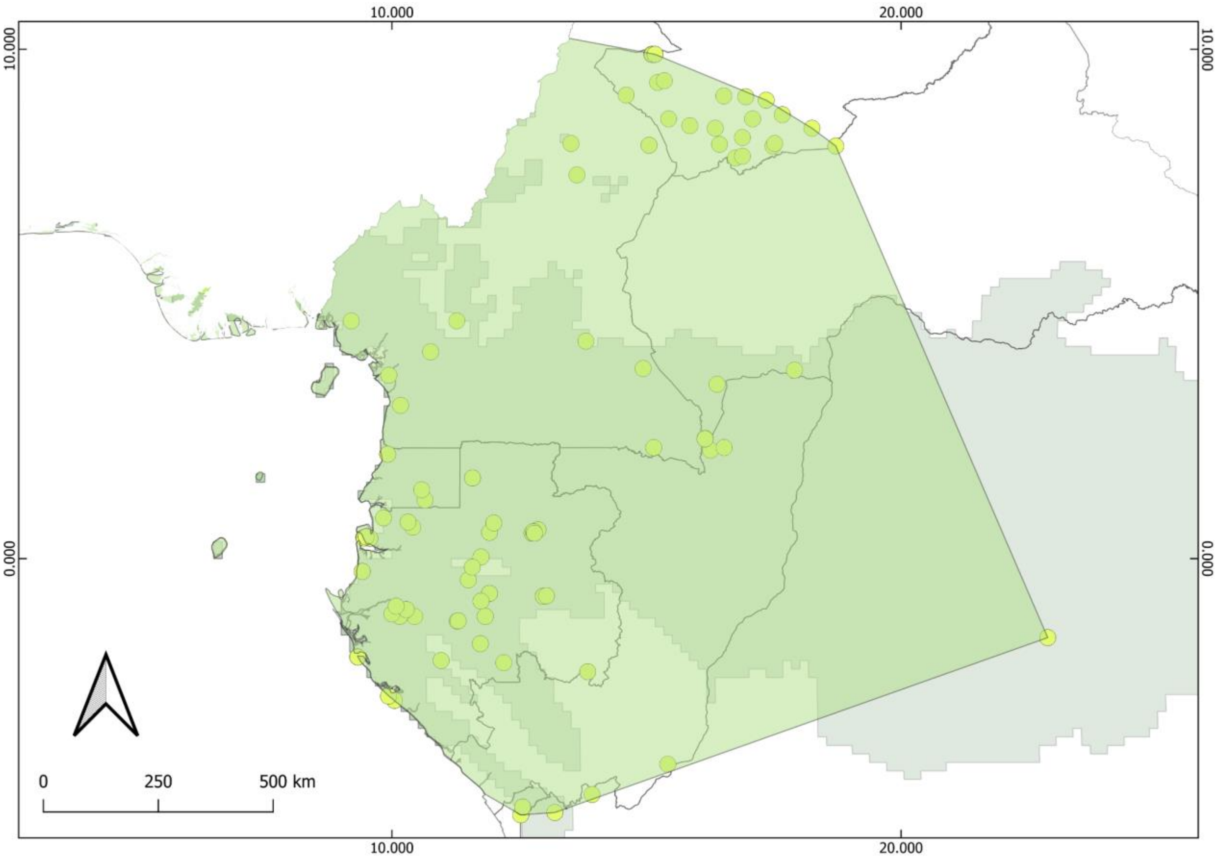

Figure 1. The range of *Bobgunnia fistuloides* in Central Africa estimated from RAINBIO and CJB data, validated in December 2022 during a workshop with a group of experts in Gabon.

PPR in protected areas

Central Africa countries have allocated a higher proportion of their land to conservation than any other tropical regions, with relatively higher conservation success (Laurance et al., 2012). Indeed, most protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). They are currently representing a large part of forest and tree species conservation in Central Africa. Thus, the population of each species in protected areas (according to FRMI, 2018) covering its range was kept stable in the future over 100 years.

In these conditions, it was hypothesized that the PPR in protected areas for each species is 0%, suggesting no population reduction in the present and future.

PPR in production forests

To quantify the evolution of the population of each timber species, matrix population models are widely used to study population dynamics (Picard & Liang, 2014). The population of this species was described at time t by a vector N_t corresponding to the density (number of trees ha^{-1}) in each diameter class (from 20 cm diameter to more than 120 cm). The density per diameter class were estimated using data of forest inventories that were carried out in 66 forest management units (FMU) of different logging companies in four countries (Cameroon, Central African Republic, Gabon, and Republic of Congo). Most logging companies followed a standardized inventory protocol (Réjou-Méchain et al., 2011). These forest inventory data covered about 15 million ha (Table 1), that are representative of 32% of Central Africa's production forests of this species. The number of trees sampled in Central Africa was 1 532 458 with a density of 0.102 tree ha^{-1}. Large-scale commercial inventories have already been found useful in the identification of large-scale patterns in Central Africa (Réjou-Méchain et al., 2011). Using a large-scale data of commercial forest inventories, Réjou-Méchain et al. (2021) jointly model the distribution in abundance of the most dominant tree species and produce continuous maps of the floristic and functional composition of central African forests.

Table 1. Forest management units (FMU) sampled in Central Africa (Cameroon, CAR: Central African Republic, DRC: Democratic Republic of the Congo, EG: Equatorial Guinea, Gabon and RCongo: Republic of the Congo).

	Sampling	
Country	FMU	Area (ha)
Cameroon	10	1 060 530.01
CAR	5	1 930 919
DRC	-	-
EG	-	-
Gabon	44	8 365 085
RCongo	7	3 726 122
Total	66	15 082 656.01

The Usher matrix model was used to simulate the evolution of the recovery rate of all population and the exploitable stock of each species after logging in Central Africa. According to the Usher assumption, between t and t+1, an individual can either stay alive in the same class, stay alive and move up to the next class, or die; it cannot move up by more than one class or move backwards, i.e., the individual is free from diameter shrinkage (Picard et al., 2012). The Usher matrix model (U) considers three parameters (mortality, recruitment and growth rate that are constant in time) to estimate the transition probabilities:

$$U = \begin{pmatrix} q_1 + g_1 & g_2 & \cdots & \cdots & g_I \\ p_1 & q_2 & 0 & \cdots & 0 \\ 0 & \ddots & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & p_{I-1} & q_I \end{pmatrix}$$

where q_i is the probability for an individual to stay alive in class i between two consecutive time steps, p_i is the upgrowth transition rate (the probability for an individual to grow up from class i to class i +1), and g_i is the recruitment rate (Picard & Liang, 2014).

Tree mortality, recruitment and growth are three central processes for predicting the dynamics of tropical rainforests and estimating these three processes requires long-term monitoring in difficult field conditions (Picard & Gourlet-Fleury, 2008). These processes determine the evolution of the species population in the forest stand. The natural mortality is defined as the number of standing dead trees, and few studies have reported estimates of mortality rates in Central Africa. Data about tree mortality are still scarce and it does not allow for precisely modeling the mortality rate for each species and size class. Given the current state of knowledge, it appears reasonable to use a fixed mortality rate of 1% for all species and size classes, in agreement with the results of Ligot et al. (2022) on 21,180 trees belonging to 42 timber species of Central Africa annually monitored from one to seven years.

The recruitment integrates fruiting and seed dispersal from mother trees, and the survival of plant juveniles until they reach a size threshold where they are included in the stand. The recruitment term in the model is the average annual input of new individuals into the first size class from 20 cm. The recruitment events, like mortality events, are infrequent and thus difficult to model (Karsenty & Gourlet-Fleury, 2006). The population structure showed a curve in "decreasing exponential" suggesting a good regeneration (Figure 2). However, seeds of this species are mainly dispersed by elephants (*Loxodonta cyclotis*), and the loss of 80% of elephants leads to a low rate of tree recruitment. We assumed that the recruitment rate was 1%, i.e., the same value as the mortality rate. It is the most pessimistic hypothesis as only the trees that die naturally are replaced by newly recruited trees. The harvested trees are not replaced between two successive logging operations. Thus, the population of this species decreased in size between two successive logging operations. Claeys et al. (2019) projected the future forest dynamics up to the end of the century and they showed that projected mortality and recruitment rates in 2099 could not differ from the ones observed today. Thus, the hypothesis on the recruitment and the mortality rate is used in the future (up to 100 years) as they do today.

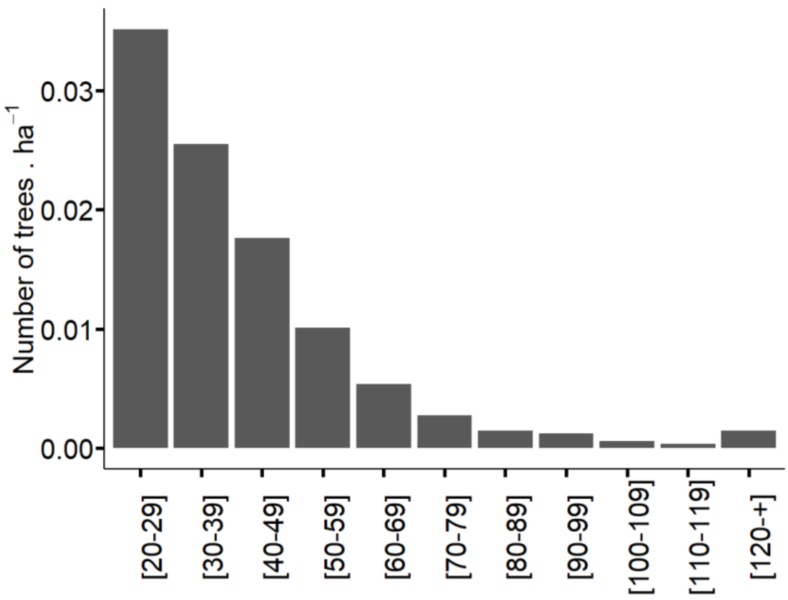

Figure 2. Population structure of *Bobgunnia fistuloides* (Pao rosa) defined using the number of trees per ha and per diameter class (from 20 cm of 66 logging concessions in Central Africa covering an area of 15 082 656.01 ha).

Since the mid-1900s, periodic tree monitoring and tree ring analyses have been carried out to study variability in tree growth across species in Central Africa (Durrieu de Madron, Nasi, et al., 2000; Ligot et al., 2019, 2022). We fitted growth models for each species using data from logged and unlogged areas of permanent tree plot monitoring from the DYNAFAC[6] network covering the five Central African countries. From the combined dataset, we identified 965 trees belonging to 3 sites in three countries (Cameroun, Gabon, and Republic of Congo). Minimum and maximum sampled diameters ranged from 10 to 90 cm. The monitoring period ranged from 2000 to 2018. The mixed second-degree polynomial models (with a random site effect) were fitted for species monitored in several sites. The estimated coefficient from mixed second-degree polynomial model has been used in the simulation in order to estimate the diameter growth (Table 2).

Table 2. Estimated coefficients (a, b and c) of growth models between the increment (ac in cm year^{-1}) and the initial diameter (D in cm). The sample including the number of trees (n) and the number of sites (site) are also given. * significant (p-value < 0.05)

species	n	site	model	a	b	c
Pao rosa	111	3	ac ~ D + D^2 + (1|site)	0.083*	0.014*	-0.0002*

The transition probabilities of three parameters (mortality, growth, and recruitment rate) allowed making the harvested matrix. The logging operations have been modeled using the logging parameters (minimum cutting diameter, cutting and damage rate). The minimum cutting diameters were obtained from decrees of application of the forestry administrations (MCD_A) at the country level and the one used in the management plan (MCD_M, with

[6] https://www.dynafac.org/en

$MCD_M \geq MCD_A$) at the logging company level. At the Central Africa level, we weighted the MCD_A and MCD_M values to the occupied area (**$MCD_A = MCD_M = 65$ cm**). The cutting rate (CA), which defines the proportion of harvested trees (trees with a diameter greater than MCD_A or MCD_M), was given by logging companies, and it was also weighted at the Central Africa level with a value of 66%. Given the current state of knowledge, it appears reasonable to use a fixed damage rate caused by logging of 7% of the initial population that disappears (Durrieu de Madron, Fontez, et al., 2000). The average cutting cycle (i.e. the period between two successive logging operations) is 28 years (FRMI, 2018), but we used 25 years to simplify computation of four simulations reaching 100 years (25, 50, 75 and 100 years), as requested by IUCN criterion A.
The Figure 2 shows the PPR in production forests for *Bobgunnia fistuloides*. The reduction in the population of each species was then calculated as the difference between the initial numbers of mature individuals and the predicted numbers of mature individuals predicted after 100 years. The PPR in production forest was **− 41.26%** for the recruitment at 1% over 100 years.

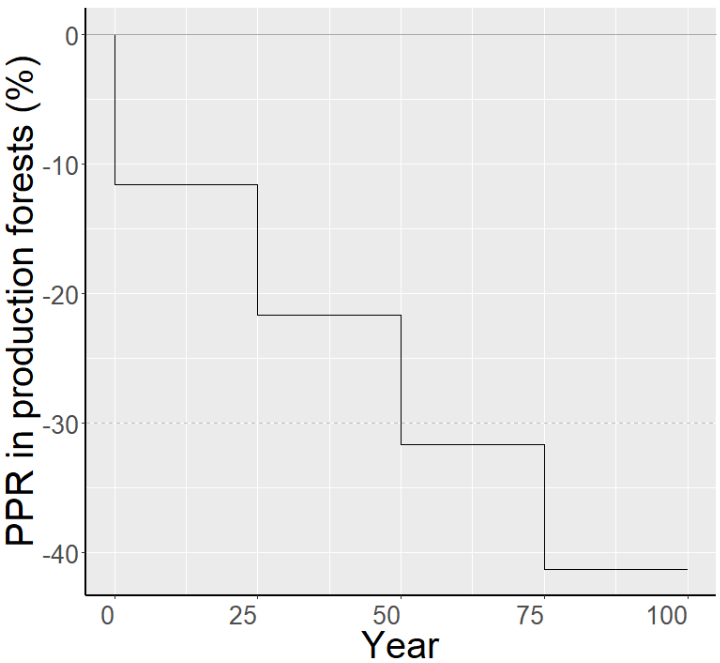

Figure 2. Simulations showing the projected population reduction (PPR) from the diameter of mature individuals (20 cm) in production forests for *Bobgunnia fistuloides* over 100 years for the recruitment at 1%.

PPR in the non-permanent forest domain

The major threats in the non-permanent domain are habitat loss due to the destruction of natural environments because of population growth and urbanization, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Based on the large range of this species in Central Africa (Figure 1), the harvested volume from illegal logging and legal logging are 24% and 76%, respectively (FRMI 2018). In this condition, it was hypothesized that there is 76% of PPR from production forests and 24% of PPR from illegal logging in 100% PPR due to forest logging. Given that the PPR of production forests associated with its forest area was known, we deduced the PPR and forest area of illegal logging from those of the production forests. As a result, 15 097 353.8 ha were affected by the illegal logging for this species. The non-permanent domain area (113 569 022.5 ha) was considered as the area which was related to today's deforestation rate of 0.27% year^{-1} in the geographic range of this species (Eba'a et al., 2022). This is a conservative value since it will probably decrease in the future (Swamy et al., 2018).

The PPR in Central Africa by considering the PPR in production forests, protected area and non-permanent domain was **− 12.65%** for the recruitment at 1% over 100 years.

PPR in West Africa

In this region, forests are generally not managed in concessions, and the large part of the rainforest has been transformed in cultivated areas (Nix, 2019). Given the high degree of anthropization in this area, the main threats are habitat loss due to the destruction of natural environments and illegal logging, and the trees are frequently felled in fields. Applying the deforestation rate related to agricultural production can be considered as a proxy for tree removal. Thus, the forest areas in West Africa (15 600 000 ha) were subject to a constant annual deforestation rate of 1.20% year^{-1} (Vancutsem et al., 2021). Taking this rate of deforestation as constant over the next 100 years, when it is expected to decline, is a reasonable precautionary measure incorporating illegal logging.

PPR global

We thus had two different PPR: PPR_C in Central Africa and PPR_W in West Africa. The global PPR was then computed after weighting the two values by their relative forest areas:

$$PPR = \frac{(S_C \times PPR_C) + (S_W \times PPR_W)}{S_C + S_W}$$

where S_C and S_W are forest areas in Central and West Africa, respectively.

The criterion A3 based on (c) a decline in area of occupancy (AOO), the extent of occurrence (EOO), and/or habitat quality; and (d) potential levels of exploitation, has been computed as follows: (i) 30%≤PPR<50%, the species is considered as Vulnerable (VU); (ii) 50%≤PPR <80%, the species is considered as Endangered (EN), and PPR ≥ 80%, the species is considered as Critically Endangered (CR).

The PPR global in the distribution range of *Bobgunnia fistuloides* was **− 11.7%** for recruitment at 1% over 100 years. This PPR is < 30%, suggesting that this species is not threatened in its geographic area.

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10.4 Annexe 4. *Cylicodiscus gabunensis* Harms

Draft

Cylicodiscus gabunensis **Harms.**

PLANTAE - TRACHEOPHYTA - MAGNOLIOPSIDA - FABALES - FABACEAE – *Cylicodiscus - gabunensis*

Common Names: Okan (french)

Synonyms:

Red List Status
NT – Near Threatened, A3cd (IUCN version 3.1)

- **Red List Assessment**
- **Assessment Information**

Date of Assessment: 2022-09-01

Assessor(s): Monthe, F., Loubota, G., Ligot, G., Texier, N., Stévart, T. & Doucet, JL.

Reviewer(s):

Institution(s):

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Regions: Global

- **Identification Description**

Cylicodiscus gabunensis is a very large tree reaching 60 m in height and exceeding 2 m in diameter, and often being deformed by elephants. Its trunk is dark blackish to brownish, marked with brown spines in young trees, and then a scaly bark. Its yellowish, very fibrous (cottony) bark gives off an unpleasant smell of rotten onion and a slight yellowish transparent exudate. Its leaves are bipinnate, with one to two pairs of pinnae. The 5 to 10 leaflets per pinnae are alternate. The leaf blade is glabrous, papery, asymmetrical at the base, and distinctly acuminate-mucronate at the top (5-10 x 2-5 cm). Its inflorescences are yellowish white. Its fruits are very long, leathery pods of 40-100 cm, narrow and flat, brown when ripe. The seeds are about 7 cm long, surrounded by a large wing, and attached at the top by a thread.

- **Assessment Rationale**

Cylicodiscus gabunensis is a widespread tall tree in African evergreen and semi-deciduous guineo-congolian forest (exclusively to the upper and lower Guinean sub-centres), long-living and light-demanding, usually non-gregarious, species (Ndonda Makemba et al., 2019). It is distributed from Ivory Coast to the Republic of the Congo. Based on a 2 x 2 km cell size, the AOO of this species is estimated as 344 km^2 with a minimum of 65 locations (number of forest management units of different logging companies in Central Africa). This species is not "Vulnerable" status under criterion B2. The EOO is calculated as 1 947 910 km^2, above the upper threshold for "Vulnerable" status under criterion B1.
Commonly known as Okan, it is a timber species in tropical Africa, sought after for the quality of its wood. The minimum cutting diameter (MCD) in Central Africa varies between 60 and 80 cm and is globally higher than the regular fruiting diameter (RFD) estimated at 60 cm (DYNAFAC, 2022), ensuring optimal regeneration of the species. The population structure showed a single-mode curve with a good representation of the small stems suggesting a good regeneration with a density of 0.27 stems.ha-1 (diameter at breast height ≥ 20 cm) in Central Africa (see Supplementary Material). Given its stem density and the mean annual increment of 0.674 ± 0.49 cm/year in Central Africa (see Supplementary Material), we estimate the number of mature individuals (diameter at breast height ≥ 20 cm, see Supplementary Material) over 10 000 across the distribution range, well above the threatened category under criteria C and D.
Considering the species' generation length of 117 years (see Supplementary Material), an inference of three generations in the past goes back to a period characterised by numerous activities in Central Africa, favouring the regeneration of light-demanding tropical species (Morin-Rivat et al., 2017; Ndonda Makemba et al., 2022). So, the species would certainly not be threatened according to the A2 and A1 criteria.
According to Ndonda Makemba et al. (2019), population structures of *Cylicodiscus gabunensis* seem to differ according to forest type, with a pattern characterised by a deficit of small-diameter trees in evergreen forests and a better regeneration in semi deciduous forests (decreasing exponential), suggesting the different succession stage across forest types. However, different forest concessions have broadly the same logging histories and *Cylicodiscus gabunensis* was not yet being logged in the past. Considering that the seeds are winged, the species is wind dispersed (Doucet, 2003; Meunier et al., 2015). To model the recruitment, we used the hypothesis defined as the recruitment rate that would maintain a constant number of trees in the first diameter class. Based on simulations of the expected population reduction of *Cylicodiscus gabunensis* in its distribution with constant recruitment, we estimated population reduction from 17-18 % in the next 100 years below the threshold to be considered threatened under criterion A3 (for further information about this methodology, see Supplementary Material). An assessment of the population reduction according to criterion A4 considering one to two generations back and one to two generations forward would likely introduce high levels of uncertainty due to the lack of data to efficiently model the reduction

of population size in the past. No quantitative analysis of the probability of extinction in the wild was conducted, and therefore criterion E does not apply.

Considering (i) the population density, (ii) the correspondence between MCD and RFD, and (iii) the reduction of population in the future across the distribution range below the upper threshold for Vulnerable, the species is assessed as near threatened NT, A3cd, and it can be threatened (VU) in future on the criterion A3 with a decline in area of occupancy or habitat quality.

Reasons for change

Reason(s) for Change in Red List Category from the Previous Assessment:

Cylicodiscus gabunensis was previously assessed as "Vulnerable" (https://www.iucnredlist.org/species/62021855/149016953) (BGCI and IUCN, 2019). During the last few years, important data have been produced on the self-ecology, population dynamics (growth, recruitment, mortality) of the species. Moreover, a new version of the IUCN guidelines is available (from version 2.3 to 3.1). Given all these information, it was necessary to produce a new assessment of the species.

- **Distribution**
- **Geographic Range**

Cylicodiscus gabunensis is widely distributed from Ivory Coast to the Republic of the Congo (Ndonda Makemba et al., 2019). It is very common in old secondary forests, it is found in tropical wet and monsoonal climates. The extent of occurrence (EOO) in native area is estimated 1 947 910 km^2 across its distribution range. Some databases mention the presence of the species up to Kenya, Angola or Sierra Leone, http://www.gbif.org/, most of these records, dating back more than fifty years, would result from misidentification, especially as no herbarium samples are available (Ndonda Makemba et al., 2019).

- **Area of Occupancy (AOO)**

Estimated area of occupancy (AOO) - in km2	Justification
344	The AOO has been estimated using ConR based on the 2 × 2 km cell size of 153 occurrences from CJB (Conservatoire et Jardin botaniques de Genève) and RAINBIO

Continuing decline in area of occupancy (AOO)	Qualifier	Justification
Yes	Inferred	The species has suffered from reduction in area of occupancy, due to habitat degradation and deforestation in West Africa forest (Vancutsem et al., 2021)

- Extent of Occurrence (EOO)

Estimated extent of occurrence (EOO)- in km2	EOO estimate calculated from Minimum Convex Polygon	Justification
1 947 910	true	Calculated using ConR based on 153 known occurrences from CJB (Conservatoire et Jardin botaniques de Genève) and RAINBIO

Continuing decline in extent of occurrence (EOO)	Qualifier	Justification
Yes	Inferred	The species has certainly undergone extent of occurrence reduction in West Africa, linked to the reduction in forest area (Vancutsem et al., 2021)

- Locations Information

Number of Locations	Justification
60-200	More than 65 localities. Based on the most serious plausible threat (conversion of its habitat) and illegal logging across the distribution range.

Continuing decline in number of locations	Qualifier	Justification
Yes	Inferred	The main threat remains the reduction of the forest area in West Africa.

Extreme fluctuations in the number of locations	Justification
No	

- Very restricted AOO or number of locations (triggers VU D2)

Very restricted in area of occupancy (AOO) and/or # of locations	Justification
No	-

- Elevation / Depth / Depth Zones

Elevation Lower Limit (in metres above sea level): 50

Elevation Upper Limit (in metres above sea level): 630

- **Map Status**

Map Status	Use map from previous assessment	How the map was created, including data sources/methods used:	Please state reason for map not available:	Data Sensitive?	Justification	Geographic range this applies to:	Date restriction imposed:
Done	-	Qgis. The dataset was created from a compilation of Rainbio and CJB	-	-	-	-	-

- **Biogeographic Realms**

Biogeographic Realm: Afrotropical

- **Occurrence**

- **Countries of Occurrence**

Country	Presence	Origin	Formerly Bred	Seasonality
Angola	Extant	Native	-	Resident
Cameroon	Extant	Native	-	Resident
Republic of the Congo	Extant	Native	-	Resident
Ivory Coast	Extant	Native	-	Resident
Equatorial Guinea	Extant	Native	-	Resident
Gabon	Extant	Native	-	Resident
Ghana	Extant	Native	-	Resident
Nigeria	Extant	Native	-	Resident

- **Population**

Cylicodiscus gabunensis is a guineo-Congolian species, widely distributed from Ivory Coast to the Republic of Congo. Its average density is 0.27 stems.ha^{-1} (diameter at breast height ≥ 20 cm) in Central Africa (see Supplementary Material). This density can locally reach 0.87 to 0.98 stems.ha-^{1} in some populations in Eastern Cameroon (Ndonda Makemba et al., 2019). Indeed, as for the vast majority of light-demanding species, population densities of *C. gabunensis* vary according to forest type. They are generally lower in moist evergreen forests (where the species has a "bell-shaped" population curve with a regeneration deficit, appendix I) and higher in semi-deciduous forests (where regeneration is better with a population following a "decreasing exponential" curve).

However, bark is consumed by elephants and considerable damage can be observed on the trunks of *C. gabunensis* in Gabon (Scalbert et al., 2022).

The average growth is 0.674 ± 0.49 cm/year in Central Africa (see Supplementary Material). In the nursery, the germination rate of *C. gabunensis* is high and reaches 70%, germination is very fast and starts five days after sowing and the seedlings reach a height of 40 cm in eight months (Ndonda Makemba et al., 2019). In some concessions *C. gabunensis* is planted with a diameter growth rate of 0.51 cm/year in Cameroon (Doucet et al., 2016).

The minimum fertility diameter is estimated at 20 cm in Central Africa (see Supplementary Material), well below the legal minimum cutting diameter "MCD" (60 cm in Cameroon, Central African Republic, and Republic of Congo, and 70 cm in Gabon). Those MCD are generally higher than the regular fruiting diameter (RFD), estimated at 60 cm in Cameroon (DYNAFAC, 2022). In the legal logging concession of central Africa, the MCD must be adapted to ensure sufficient recovery rates after each cutting cycle (MCD_M). At the Central Africa level, we weighted the MCD and MCD_M values to the occupied area with MCD = 65 cm and MCD_M = 85 cm (see Supplementary Material).

Using the Red List criterion A3, the projected population reduction (PPR) to be met in the future (100 years because the generation length of the species is 117 years) of the *C. gabunensis* population was assessed across its distribution range. Because *C. gabunensis* is a widespread species in West and Central Africa, the PPR was estimated for each region.

In Central Africa, three different PPR were thus estimated: PPRpa in protected areas, PPRpf in production forests and PPRnp in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas. First, protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). The population of the species in protected areas covering its range was kept stable in the future over 100 years, suggesting that the PPR in protected areas was 0%. Second, the evolution of the *C. gabunensis* population was simulated using an Usher matrix model to estimate the PPR of production forests (logging concessions, PPRpf). The simulations were initialised using the density (number of trees.ha-1) per diameter class (from 20 cm diameter, mature individuals) from forest management inventories of logging companies. The evolution of this initial population depended on several demographics (recruitment, mortality, and growth rate) and logging parameters (minimum cutting diameter, cutting and damage rate) that were adjusted using data of permanent tree plot monitoring. Thus, the density of *C. gabunensis* in 100 years was predicted with a logging event every 25 years, which corresponds to the average cutting cycle in Central Africa. PPRpf was then calculated as the difference between initial and final number of trees. Third, the major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Illegal logging and the habitat lost from deforestation rate have been both activities that allowed estimating the PPRnp in non-permanent domains.

In West Africa, the forest areas were subject to a constant annual deforestation rate of 1.20% year-1 (Vancutsem et al., 2021). Taking this rate of deforestation as constant over the next 100 years, when it is expected to decline, is a reasonable precautionary measure.

We thus had two different PPR: PPRC in Central Africa and PPRW in West Africa. The global PPR was then computed after weighting the two values by their relative forest areas. The global PPR result was found to be 17-18% (for further information about this methodology, see Supplementary Material).

- **Population Information**

Current Population Trend: Decreasing

Extreme fluctuations? (in # of mature individuals)	Justification
No	-

Severely fragmented?	Justification
No	-

Continuing decline in mature individuals?	Qualifier	Justification

Continuing decline % in mature individuals within 3 generations or 10 years, whichever is longer (up to max. of 100 years in the future)	Qualifier	Justification

Extreme fluctuations in the number of subpopulations	Justification
No	-

Continuing decline in number of subpopulations	Qualifier	Justification
No	-	-

All individuals in one subpopulation: No

Number of Subpopulations	Justification	Subpopulation Details	Subpopulation description	Number of mature individuals	Subpopulation trend	Qualifier	Location type	Number of Subpopulations	Location bounding box	Location coordinates	Notes

- **Population Reduction - Past**

Percent Change in past	Reduction or Increase	Qualifier	Justification

Basis?

Reversible?

Understood?

Ceased?

- **Population Reduction - Future**

Percent Change in future	Reduction or Increase	Qualifier	Justification
17-18%	Reduction	Projected	Using the Red List criterion A3, the projected population reduction (PPR) to be met in the future (100 years because the generation length of the species is 117 years) of the *C. gabunensis* population was assessed across its distribution range. Because *C. gabunensis* is a widespread species in West and Central Africa, the PPR was estimated for each region. In Central Africa, three different PPR were thus estimated: PPRpa in protected areas, PPRpf in production forests and PPRnp in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas. First, protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). The population of the species in protected areas covering its range was kept stable in the future over 100 years, suggesting that the PPR in protected areas was 0%. Second, the evolution of the *C. gabunensis* population was simulated using an Usher matrix model to estimate the PPR of production forests (logging concessions, PPRpf). The simulations were initialised using the density (number of trees.ha^{-1}) per diameter class (from 20 cm diameter, mature individuals) from forest management inventories

	of logging companies. The evolution of this initial population depended on several demographics (recruitment, mortality, and growth rate) and logging parameters (minimum cutting diameter, cutting and damage rate) that were adjusted using data of permanent tree plot monitoring. Thus, the density of *C. gabunensis* in 100 years was predicted with a logging event every 25 years, which corresponds to the average cutting cycle in Central Africa. PPRpf was then calculated as the difference between initial and final number of trees. Third, the major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Illegal logging and the habitat lost from deforestation rate have been both activities that allowed estimating the PPRnp in non-permanent domains. In West Africa, the forest areas were subject to a constant annual deforestation rate of 1.20% year-1 (Vancutsem et al., 2021). Taking this rate of deforestation as constant over the next 100 years, when it is expected to decline, is a reasonable precautionary measure. We thus had two different PPR: PPRC in Central Africa and PPRW in West Africa. The global PPR was then computed after weighting the two values by their relative forest areas. The global PPR result was found to be 17-18% (for further information about this methodology, see Supplementary Material).

Basis?
b) an index of abundance appropriate for the taxon, d) actual or potential levels of exploitation

- **Population Reduction - Ongoing**

Both: Percent Change over any 10 year or 3 generation period, whichever is longer, and must include both past and future, future can't go beyond 100 years	Reduction or Increase	Number of years for this period	Qualifier	Justification

Basis?

Reversible?

Understood?

Ceased?

- **Habitats and Ecology**

Cylicodiscus gabunensis is a large tree reaching 60 m in height and 2 m in diameter. It is a light-demanding and long-living species (Doucet, 2003; Kouadio, 2009; Meunier et al., 2015), only seedlings can tolerate a certain level of shade (Ndonda Makemba et al., 2019). It forms root associations with arbuscular mycorrhizal fungi and regenerates in large openings at a distance from the mother tree, especially in post-cultivation slash-and-burn fallows (anthropophilic species) (Ndonda Makemba et al., 2019).

Cylicodiscus gabunensis bears hermaphrodite flowers. In northern Gabon, flowering is observed from November to April, partly covering the rainy seasons (September-December and March-May) and the short dry season. In Ivory Coast, *C. gabunensis* flowers in March at the end of the long dry season. It is a wind-dispersed species (Doucet, 2003; Meunier et al., 2015). In the Ivory Coast, trees bear mature fruit between November and January or even February-March of the following year for late individuals, and in Ghana trees bear fruits from October to March (Daïnou et al., 2021; Ndonda Makemba et al., 2019). In northern Gabon, mature fruits are only observed from October to March, while in Cameroon, Central Africa Republic and the Northern Republic of the Congo fruit are observed from December to February (Daïnou et al., 2021). Unfortunately, there is currently very little data to robustly define flowering and fruiting diameters. Phenological monitoring is underway in the DYNAFAC permanent plots. Considering the personal observations of (Gillet & Doucet, Ndonda Makemba, personal communication) and the preliminary data from permanent plots of the DYNAFAC collective, we considered mature individuals as those having at least 50% of yielding flowers and/or seeds at a given diameter (20 cm) (see Supplementary Material).

According to Vleminckx (2015), stems of *C. gabunensis* (dhp > 30 cm) are observed where charcoal is present in the soil, which suggests that the species has become established in areas where anthropogenic fires occurred decades or centuries ago. In Gabon, current populations were established during the last periods of human occupation between 590 and 80 BP, in fallows on soils relatively rich in some plant nutrients (N, P, K), confirming the major role of past human activities in the establishment of this species (Ndonda Makemba et al., 2022). As most light-demanding species in dense, undisturbed forests, it can have a diametric bell-shaped structure with a regeneration deficit. However in Central Africa, the global structure is balanced (see Supplementary Material).

- **IUCN Habitats Classification Scheme**

Habitat	Season	Suitability	Major Importance?
1.6. Forest -> Forest - Subtropical/Tropical Moist Lowland	Resident	Suitable	Yes

- **Continuing Decline in Habitat**

Continuing decline in area, extent and/or quality of habitat?	Qualifier	Justification
Yes	Observed	The annual deforestation rate is 0.35% and 1.2% in Central and West Africa respectively (Vancutsem et al., 2021). The species can regenerate in open habitats.

- **Life History**

Generation Length	Justification	Data Quality
117	Minimum estimate of generation length for the species from the average growth rate, and the mean diameter of mature individuals (see Supplementary Material)	good

Age at maturity: female or unspecified
30 Years

Age at Maturity: Male
30 Years

Size at Maturity (in cms): Female
20

Size at Maturity (in cms): Male
20

Reproductive Periodicity
Annual

Annual Rate of Population Increase

Natural Mortality
1% (Ligot et al. 2022)

- **Systems**

System: Terrestrial

- **Plant / Fungi Specific**

Wild relative of a crop? No

Plant and Fungal Growth Forms
Tree - large

- **Use and Trade**
- **General Use and Trade Information**

Cylicodiscus gabunensis is among the most exploited forest species in Central Africa (Eba'a Atyi et al., 2022).

At industrial level, the wood of *C. gabunensis* is considered as adapted to conditions of permanent humidity, immersed in soil, sea water, marine environments including the brackish waters of estuaries. It is appreciated for marine bridge construction, railway sleeper production, exterior joinery, hydraulic works, decking, floodgates, etc. hydraulic works, planking, lock gates, heavy parquetry, carpentry, mine props and sculpture (Ayarkwa and Owusu, 2008; Ndonda Makemba et al., 2019). In 2009, the total volume exported (logs and sawnwood) from Africa (Cameroon, Republic of Congo, Gabon, Ghana) amounted to 367 942 m^3 (Ndonda Makemba et al., 2019). Before the cessation of log exports in 2010, Gabon was the main exporter of *C. gabunensis* logs, with an average of 190 949 m^3 per year between 2007 and 2009, and the species was the second most exploited species after okoumé (*Aucoumea klaineana* Pierre). In Cameroon, okan logs were the second most exported in 2010 and 2011 (ATIBT, 2010; Ndonda Makemba et al., 2019). In 2016, the species was the 6^{th} most exploited species in Central Africa, with 261 929m^3/year (FRMi, 2018). China, Hong Kong and Taiwan are the largest importers, accounting for 90% of exports (roundwood equivalents). They are followed by: Belgium, France, the Netherlands, Vietnam, India, Ukraine, Italy and Portugal (Ndonda Makemba et al., 2019).

At a local level, it is considered as a fetish tree, particularly by some indigenous peoples, including the Bavungu and Eshiras of Gabon, for whom the tree occupies a central place in rites and traditions. The tree can be used as shade in the gardens or fallow land and the wood can be used to produce charcoal. Its bark is used as soap for cleaning and as a fishing poison. In the traditional medicine several properties are recognized: a decoction of the bark is used to treat stomach aches, prostatitis, rheumatism, internal abscesses, fever, venereal diseases, malaria, venereal diseases, psoriasis, rheumatism, analgesic, anti-vomiting, sterility and respiratory infections. A maceration of the leaves is used against chickenpox and measles. As an infusion, the bark is used to treat diabetes. Combined with the bark of other species, the fields of application in traditional medicine are even wider (Ndonda Makemba et al., 2019).

Phytochemical studies, particularly of the bark of *C. gabunensis*, have revealed the existence of several useful compounds, such as ethyl acetate, which is rich in saponins, complex molecules with surface-active properties that cause their solutions to foam and act as detergents, this would explain its use as a soap (Kouitcheu et al., 2006; Ndonda Makemba et al., 2019).

Subsistence:	Rationale:	Local Commercial:	Further detail including information on economic value if available:
Yes	-	Yes	-

National Commercial Value: Yes

International Commercial Value: Yes

Is there harvest from captive/cultivated sources of this species? Yes

Trend in level of total offtake from wild sources: Stable

Trend in level of total offtake from domesticated sources: Unknown

- Non- Consumptive Use

Non-consumptive use of the species? true

- Threats

The main threats in the non-permanent domain across the species' distribution range, are mainly the destruction of natural environments as a result of population explosion and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging and the abusive harvesting of plant parts requested as non-wood forest products (Bradshaw et al., 2009). In Central Africa, illegal logging accounts for nearly 46% of total log production (FRMi, 2018). This production generally comes from unallocated forest areas (non-permanent forest domain). However, there is no data on the share of *C. gabunensis* in such trade.

Cylicodiscus gabunensis is exploited in Central Africa. No study considers logging as a direct driver of deforestation because of the low logging densities (1-2 stems per hectare). In West Africa, forests are generally not managed in concessions, and large parts of rainforests have been transformed into cultivated areas (Nix, 2019).

- Threats Classification Scheme

No past, ongoing, or future threats exist to this species. false

Threat	Timing	Scope	Severity	Impact Score
1.1. Residential & commercial development -> Housing & urban areas	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4
2.1.1. Agriculture & aquaculture -> Annual & perennial non-timber crops -> Shifting agriculture	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
2.2.2. Agriculture & aquaculture -> Wood & pulp plantations -> Agro-industry plantations	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
2.3.2. Agriculture & aquaculture -> Livestock farming & ranching -> Small-holder grazing, ranching or farming	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4
3.2. Energy production & mining -> Mining & quarrying	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
4.1. Transportation & service corridors -> Roads & railroads	Ongoing	Minority (<50%)	Negligible declines	Past Impact
5.3.1. Biological resource use -> Logging & wood harvesting -> Intentional use: (subsistence/small scale) [harvest]	Ongoing	Minority (<50%)	Rapid Declines	Medium Impact: 6
5.3.2. Biological resource use -> Logging & wood harvesting -> Intentional use: (large scale) [harvest]	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 4
7.1.3. Natural system modifications -> Fire & fire suppression -> Trend Unknown/Unrecorded	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4

- **Conservation**

Cylicodiscus gabunensis does not appear in any ex situ collections (BGCI, 2022), but may occur in many protected areas considering its distribution range. In certified forest concessions where the species is exploited, permanent forest plots are usually installed (DYNAFAC, 2022; Ligot et al., 2022). These plots provide important data for (i) quantifying population dynamics processes at the stand level: mortality, growth and recruitment; (ii) phenological studies to determine the regular fruiting diameter (RFD).

These plots are managed in collaboration with forest concessions grouped within the DYNAFAC collective (see here for more information https://www.dynafac.org/fr/p/130/installation-de-dispositifs-de-suivi-de-la-dynamique-forestiere). Compilation of these data provide important additional information for targeted silvicultural measures for the sustainable management of this species. Based on almost 40 years of monitoring forest dynamics in Central

Africa, the DYNAFAC collective recommends a MCD of 80 cm in Central Africa to maintain optimal gene flow and optimal regeneration (DYNAFAC, 2022). *C. gabunensis* is also monitored in nurseries and planted in some SFM-certified forest concessions.

The light-demanding species that dominate the canopy of many African forests are thought to have regenerated mainly towards the end of the 19th century, when farmers were abandoning their fields (Daïnou et al., 2016; Morin-Rivat et al., 2017; Van Gemerden et al., 2003). Keeping the environment open would ensure good regeneration of the species.

Logging in Central Africa is subject to strict legislation, species can only be harvested above a certain diameter and measures must be taken to ensure the renewal of the resource (Fargeot et al., 2004). Indeed, management plans for tropical rainforests require the determination of a minimum cutting diameter (MCD) to ensure a minimum renewal rate at the end of a cutting cycle (duration between two cuts on the same cutting base). The minimum reconstitution as well as the cutting cycle duration are imposed by forestry legislation (Durrieu de Madron and Forni, 1997).

In addition, it will also be necessary to :

- Ensure the implementation of the recommendations of the Dynafac collective, including the establishment of a system for monitoring the populations of commercial species in the different forest types defined in a consensual manner;
- Set up monitoring and support systems for the regeneration of commercial species, prioritising species with regeneration deficits;
- Set up programmes to guarantee the phenotypic quality of commercial species populations: seed banks, seed stands, plus trees, seed orchards, conservation plantations;
- Consider threatened species in the delimitation of conservation series and in the identification of High Conservation Values;
- Update conservation statuses on a five-yearly basis, in particular by setting up a system of "green statuses";
- Define red lists adapted to regional or national contexts;
- Evaluate the status of cryptic species or species close to commercial species evaluated during this workshop.

- **Conservation Actions In- Place**

Action Recovery Plan	Note
Yes	Reforestation within forest concessions and others in forest gaps, old parks, quarries, and large logging roads

Systematic monitoring scheme	Note
Yes	The species is monitored in permanent plots installed within forestry companies in Central Africa (see here for more information https://www.dynafac.org/fr)

Occur in at least one PA	Note
Yes	The species may appear in at least 100 protected areas considering it distribution range

Percentage of population protected by PAs (0-100)	Note
1-10	Considering protected area across species distribution range

Area based regional management plan	Note
Unknown	-

Invasive species control or prevention	Note
No	-

Harvest management plan	Note
Yes	In certified forest concessions, the species is exploited according to a management plan.

Subject to ex-situ conservation	Note
NO	-

Included in international legislation	Note
No	-

Subject to any international management/trade controls	Note
No	

- **Important Conservation Actions Needed**

Conservation Actions	Note
3.1.1. Species management -> Species management -> Harvest management	-
3.1.2. Species management -> Species management -> Trade management	-
3.4.2. Species management -> Ex-situ conservation -> Genome resource bank	-

- **Research Needed**

Research	Note
	-
1.2. Research -> Population size, distribution & trends	-
3.1. Monitoring -> Population trends	-
3.2. Monitoring -> Harvest level trends	-
3.3. Monitoring -> Trade trends	-

- **Ecosystem Services**

- **Ecosystem Services Provided by the Species**

	Importance:	Geographic range of benefit:
1. Water Quality	2 - Important	Global
3. Flood Control	2 - Important	Global
4. Climate Regulation	2 - Important	Global
5. Landscape	2 - Important	Global
6. Air Quality	2 - Important	Global
7. Nutrient Cycling	2 - Important	Global
8. Habitat Maintenance	2 - Important	Global

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IUCN status using criterion A3

We adopted the criterion A3 to assess the projected population reduction (PPR) to be met in the future (up to a maximum of 100 years) of *Cylicodiscus gabunensis*. To quantify the projected population reduction, simulations must be performed on mature individuals and three generations with a maximum of 100 years according to **criterion A3**. We estimated mature individuals and generation length, as recommended by the IUCN guidelines.

A **mature individual** is an individual that can reproduce, able to bear flowers or seeds (fertile in plant kingdom). To quantify the mature individuals for each species, we used phenological data of DYNAFAC network[7] from a combined dataset of 182 trees belonging to three sites in two countries (Cameroun, and Gabon). Minimum and maximum sampled diameters ranged from 10 to 220 cm (median 77 cm). The monitoring period ranged from 2004 to 2018 (Ouédraogo et al., 2018). We assumed that the monitoring period was long enough to capture at least one reproductive event per tree such that trees without observed flowering/fruiting events were considered non-reproductive (38 percent of all monitored trees were non-reproductive). We used the methodology for the size at reproduction of canopy tree species in Central Africa (Ouédraogo et al., 2018): the **diameter of a mature individual** was obtained after fitting logistic regressions and the level of 50% of the probability to produce the flower or fruit was adopted for this species. Using this approach, the diameter of a mature individual was obtained after setting the 50% probability to produce flowers or fruits. Thus, the minimum diameter of mature individuals for this species was **20 cm**.

The **generation length** was the report between the mean diameter of mature individuals considering population structure and the mean increment. Given that the minimum diameter of mature individuals was 20 cm, we weighted the total number of trees by their diameter from 20 cm to 125 cm (Figure 1) to compute the number of mature individuals. The mean of mature individuals was **79 cm**. The **mean increment** of the species was **0.674 cm**, obtained from 965 observations from logged and unlogged forests in Cameroon, and Gabon (Ligot et al., 2022). Thus, the **generation length** was 79 cm / 0.674 cm = **117 years**. The age at maturity (**30 years**) has been estimated as the report between the **minimum diameter of mature individuals** (**20 cm**) and the **mean increment** (**0.674 cm)**.

[7] https://www.dynafac.org/en

Estimation of the projected population reduction (PPR)

We adopted the criterion A3 to assess the projected population reduction (PPR) to be met in the future (up to a maximum of 100 years). *Cylicodiscus gabunensis* (Okan), is found in Guineo–Congolian rainforest species, widely from distributed mainly from Ivory Cost to Republic of Congo (Ndonda Makemba et al., 2019). The geographic range of species was in two regions (Central Africa and West Africa) characteristic of two biogeographical regions across the tropical African forests (Fayolle et al., 2014). According to each region, different data (deforestation annual rate, growth, mortality, recruitment, forest inventory, etc.) have been used with logging data in Central Africa. Thus, the PPR was estimated for each region and the global PPR was then computed after weighting the two values by their relative forest areas.

PPR in Central Africa

In this region, forest management follows three different modalities: protected areas, production forests (logging concessions), and non-permanent forest domain. Based on occurrences, the natural range of this species includes all countries in Central Africa (Figure 1). The total natural area is estimated at 99 754 248.99 ha. Within this area, there are 30 834 250.6 ha (31.0%) for production forests, 6 628 665.56 ha (6.6%) for protected areas, and 62 291 332.78 ha (62.4%) for the non-permanent domain.

Three different PPR were thus estimated: PPR_{pa} in protected areas, PPR_{pf} in production forests, and PPR_{np} in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas and then added to estimate the PPR_{C} in Central Africa.

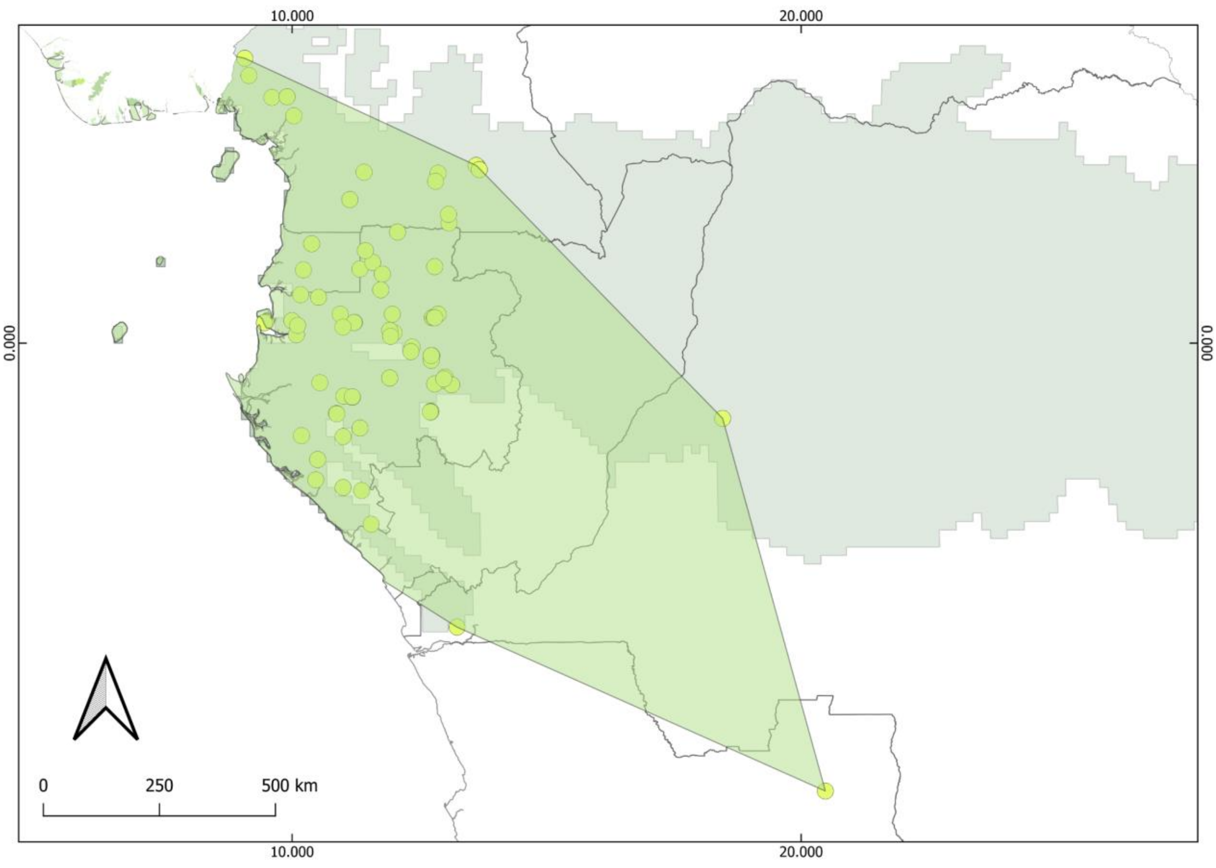

Figure 1. The range of *Cylicodiscus gabunensis* in Central Africa estimated from RAINBIO and CJB data, validated in December 2022 during a workshop with a group of experts in Gabon.

PPR in protected areas

Central Africa countries have allocated a higher proportion of their land to conservation than any other tropical regions, with relatively higher conservation success (Laurance et al., 2012). Indeed, most protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). They are currently representing a large part of forest and tree species conservation in Central Africa. Thus, the population of each species in protected areas (according to FRMI, 2018) covering its range was kept stable in the future over 100 years. **In these conditions, it was hypothesized that the PPR in protected areas for each species is 0%, suggesting no population reduction in the present and future.**

PPR in production forests

To quantify the evolution of the population of each timber species, matrix population models are widely used to study population dynamics (Picard & Liang, 2014). The population of this species was described at time t by a vector N_t corresponding to the density (number of trees ha^{-1}) in each diameter class (from 20 cm diameter to more than 120 cm). The density per diameter class was estimated using data from forest inventories that were carried out in 65 forest management units (FMU) of different logging companies in three countries (Cameroon, Gabon, and Republic of the Congo). Most logging companies followed a standardized inventory protocol (Réjou-Méchain et al., 2011). These forest inventory data covered about 11 million ha (Table 1), that are representative of 36% of Central Africa's production forests of this species. The number of trees sampled in Central Africa was 2 960 962 with a density of 0.27 tree ha^{-1}. Large-scale commercial inventories have already been found useful in the identification of large-scale patterns in Central Africa (Réjou-Méchain et al., 2011). Using large-scale data from commercial forest inventories, Réjou-Méchain et al. (2021) jointly model the distribution in the abundance of the most dominant tree species and produce continuous maps of the floristic and functional composition of central African forests.

Table 1. Forest management units (FMU) sampled in Central Africa (Cameroon, CAR: Central African Republic, DRC: Democratic Republic of the Congo, EG: Equatorial Guinea, Gabon and RCongo: Republic of the Congo).

	Sampling	
Country	FMU	Area (ha)
Cameroon	20	2 014 052.79
CAR	-	-
DRC	-	-
EG	-	-
Gabon	43	8 148 906
RCongo	2	938 902
Total	65	11 101 860.79

The Usher matrix model was used to simulate the evolution of the recovery rate of all population and the exploitable stock of each species after logging in Central Africa. According to the Usher assumption, between *t* and *t*+1, an individual can either stay alive in the same class, stay alive and move up to the next class, or die; it cannot move up by more than one class or move backwards, i.e., the individual is free from diameter shrinkage (Picard et al., 2012). The Usher matrix model (U) considers three parameters (mortality, recruitment and growth rate that are constant in time) to estimate the transition probabilities:

$$U = \begin{pmatrix} q_1 + g_1 & g_2 & \cdots & \cdots & g_I \\ p_1 & q_2 & 0 & \cdots & 0 \\ 0 & \ddots & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & p_{I-1} & q_I \end{pmatrix}$$

where q_i is the probability for an individual to stay alive in class i between two consecutive time steps, p_i is the upgrowth transition rate (the probability for an individual to grow up from class i to class i +1), and g_i is the recruitment rate (Picard & Liang, 2014).

Tree mortality, recruitment and growth are three central processes for predicting the dynamics of tropical rainforests, and estimating these three processes requires long-term monitoring in difficult field conditions (Picard & Gourlet-Fleury, 2008). These processes determine the evolution of the species population in the forest stand. The natural mortality is defined as the number of standing dead trees, and few studies have reported estimates of mortality rates in Central Africa. Data about tree mortality are still scarce and it does not allow to precisely model the mortality rate for each species and size class. Given the current state of knowledge, it appears reasonable to use a fixed mortality rate of 1% for all species and size classes, in agreement with the results of Ligot et al. (2022) on 21,180 trees belonging to 42 timber species of Central Africa annually monitored from one to seven years.

The recruitment integrates fruiting and seed dispersal from mother trees, and the survival of plant juveniles until they reach a size threshold where they are included in the stand. The recruitment term in the model is the average annual input of new individuals into the first size class from 20 cm. The recruitment events, like mortality events, are infrequent and thus difficult to model (Karsenty & Gourlet-Fleury, 2006). The population structure showed a single-mode curve with a good representation of the small stems suggesting a good regeneration (Figure 2). According to Ndonda Makemba et al. (2019), population structures of *Cylicodiscus gabunensis* seem to differ according to forest type, with a pattern characterized by a deficit of small-diameter trees in evergreen forests and a better regeneration in semideciduous forests (decreasing exponential), suggesting the different succession stage across forest types. However, different forest concessions have broadly the same logging histories and *Cylicodiscus gabunensis* was not yet being logged in the past. Considering that the seeds are winged, the species is wind dispersed (Doucet, 2003; Meunier et al., 2015). To model the recruitment, we used the hypothesis defined as the recruitment rate that would maintain a constant number of trees in the first diameter class. Claeys et al. (2019) projected the future forest dynamics up to the end of the century and they showed that projected mortality and recruitment rates in 2099 could not differ from the ones observed today. Thus, the hypothesis on the recruitment and the mortality rate is used in the future (up to 100 years) as they do today.

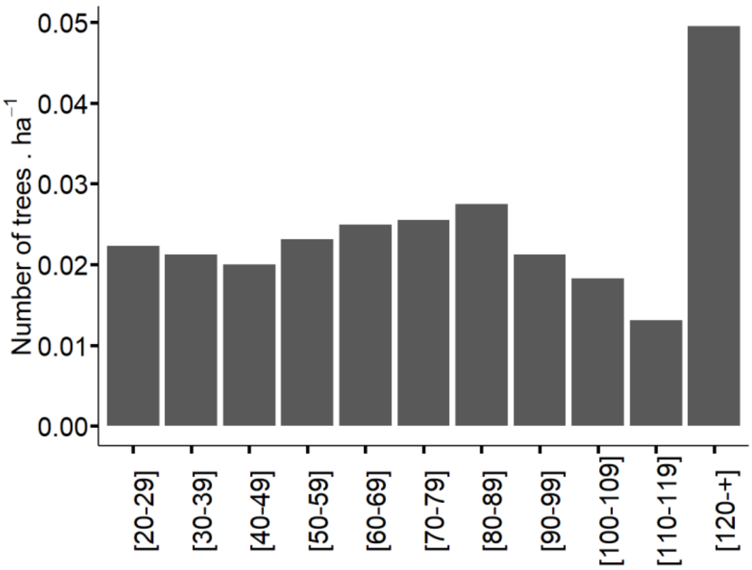

Figure 2. Population structure of *Cylicodiscus gabunensis* (Okan) is defined using the number of trees per ha and per diameter class (from 20 cm of 65 logging concessions in Central Africa covering an area of 11 101 860.79 ha).

Since the mid-1900s, periodic tree monitoring and tree ring analyses have been carried out to study variability in tree growth across species in Central Africa (Durrieu de Madron, Nasi, et al., 2000; Ligot et al., 2019, 2022). We fitted growth models for each species using data from logged and unlogged areas of permanent tree plot monitoring from the DYNAFAC[8] network covering the five Central African countries. From the combined dataset, we identified 965 trees belonging to 5 sites in two countries (Cameroun, and Gabon). Minimum and maximum sampled diameter ranged from 10 to 183 cm. The monitoring period ranged from 2011 to 2021. The mixed second-degree polynomial models (with a random site effect) were fitted for species monitored in several sites. The estimated coefficient from mixed second-degree polynomial model has been used in the simulation in order to estimate the diameter growth (Table 2).

Table 2. Estimated coefficients (a, b and c) of growth models between the increment (ac in cm year^{-1}) and the initial diameter (D in cm). The sample including the number of trees (n) and the number of sites (site) are also given. * significant (p-value < 0.05)

species	n	site	model	a	b	c
Okan	965	5	$ac \sim D + D^2 + (1\|site)$	0.36*	0.009*	-0.00006*

The transition probabilities of three parameters (mortality, growth, and recruitment rate) allowed making the harvested matrix. The logging operations have been modeled using the logging parameters (minimum cutting diameter, cutting and damage rate). The minimum cutting diameters were obtained from decrees of application of the forestry administrations (MCD_A) at the country level and the one used in the management plan (MCD_M, with

[8] https://www.dynafac.org/en

$MCD_M \geq MCD_A$) at the logging company level. At the Central Africa level, we weighted the MCD_A and MCD_M values to the occupied area (**MCD_A = 65 cm** and **MCD_M = 85 cm**). The cutting rate (CA), which defines the proportion of harvested trees (trees with a diameter greater than MCD_A or MCD_M), was given by logging companies, and it was also weighted at the Central Africa level with a value of **53%**. Given the current state of knowledge, it appears reasonable to use a fixed damage rate caused by logging of **7%** of the initial population that disappears (Durrieu de Madron, Fontez, et al., 2000). The average cutting cycle (i.e. the period between two successive logging operations) is 28 years (FRMI, 2018), but we used 25 years to simplify computation of four simulations reaching 100 years (25, 50, 75 and 100 years), as requested by IUCN criterion A.

The Figure 3 shows the PPR in production forests for the *Cylicodiscus gabunensis*. The reduction in the population of each species was then calculated as the difference between the initial numbers of mature individuals and the predicted numbers of mature individuals predicted after 100 years. The PPR in production forest was from **– 64.09 % (MCD_A) to -59.96% (MCD_M)** for the constant recruitment over 100 years.

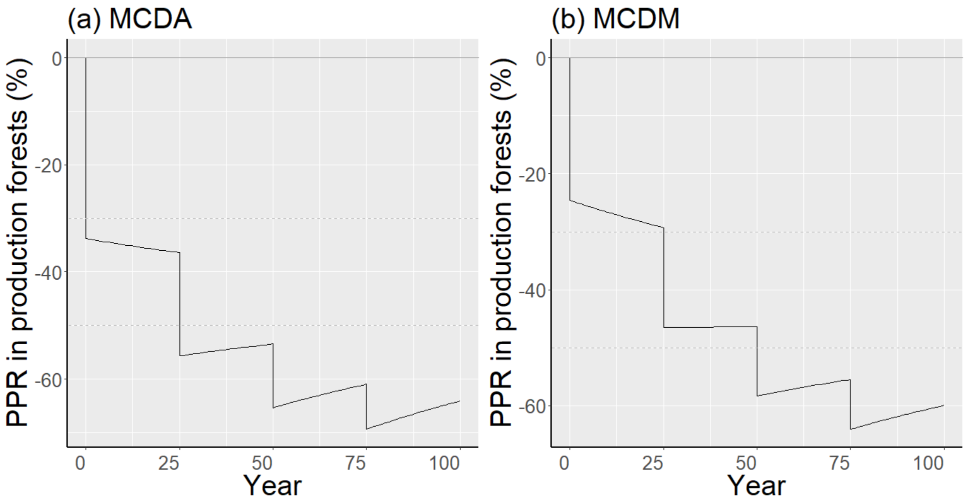

Figure 3. Simulations showing the projected population reduction (PPR) from diameter of mature individuals (20 cm) in production forests for *Cylicodiscus gabunensis* over 100 years for constant recruitment.

PPR in the non-permanent forest domain

The major threats in the non-permanent domain are habitat loss due to the destruction of natural environments because of population growth and urbanization, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Based on the large range of this species in Central Africa (Figure 1), the harvested volume from illegal logging and legal logging are 20% and 80%, respectively (FRMI 2018). In this condition, it was hypothesized that there is 80% of PPR from production forests and 20% of PPR from illegal logging in 100% PPR due to forest logging. Given that the PPR of production forests associated with its forest area was known, we deduced the PPR and forest area of illegal logging from those of the production forests. As a result, 7 708 562.66 ha were affected by the illegal logging for this species. The non-permanent domain area (62 291 332.78 ha) was considered as the area which was related to today's deforestation rate of 0.1% $year^{-1}$ in the geographic range of this species (Eba'a et al., 2022). This is a conservative value since it will probably decrease in the future (Swamy et al., 2018).

The PPR in Central Africa by considering the PPR in production forest, protected area and non-permanent domain was from **– 21.12% (MCD_A) to -19.76% (MCD_M)** for the constant recruitment over 100 years.

PPR in West Africa

In this region, forests are generally not managed in concessions, and the large part of the rainforest has been transformed in cultivated areas (Nix, 2019). Given the high degree of anthropization in this area, the main threats are habitat loss due to the destruction of natural environments and illegal logging, and the trees are frequently felled in fields. Applying the deforestation rate related to agricultural production can be considered as a proxy for tree removal. Thus, the forest areas in West Africa (15 600 000 ha) were subject to a constant annual deforestation rate of 1.20% $year^{-1}$ (Vancutsem et al., 2021). Taking this rate of deforestation as constant over the next 100 years, when it is expected to decline, is a reasonable precautionary measure incorporating illegal logging.

PPR global

We thus had two different PPR: PPR_C in Central Africa and PPR_W in West Africa. The global PPR was then computed after weighting the two values by their relative forest areas:

$$PPR = \frac{(S_C \times PPR_C) + (S_W \times PPR_W)}{S_C + S_W}$$

where S_C and S_W are forest areas in Central and West Africa, respectively.

The criterion A3 based on (c) a decline in area of occupancy (AOO), extent of occurrence (EOO) and/or habitat quality; and (d) potential levels of exploitation, has been computed as follow: (i) 30%≤PPR<50%, the species is considered as Vulnerable (VU); (ii) 50%≤PPR <80%, the species is considered as Endangered (EN), and PPR ≥ 80%, the species is considered as Critically endangered (CR).

The PPR global in the distribution range of *Cylicodiscus gabunensis* was from **– 18.42 % (MCD_A) to -17.25% (MCD_M)** for the constant recruitment over 100 years. This PPR is < 30%, suggesting that this species is not threatened in its geographic area.

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10.5 Annexe 5. *Dacryodes igaganga* - Aubrév. & Pellegr.

Draft

Dacryodes igaganga - Aubrév. & Pellegr.

PLANTAE - TRACHEOPHYTA - MAGNOLIOPSIDA - SAPINDALES - BURSERACEAE - Dacryodes - igaganga

Common Names: Igaganga

Synonyms: *Pachylobus igaganga* (Aubrév. & Pellegr.) Byng & Christenh

Red List Status
LC - Least Concern, A3cd (IUCN version 3.1)

- **Red List Assessment**

- **Assessment Information**

Date of Assessment: 2022-09-01

Assessor(s): Monthe, F., Loubota, G., Texier, N., Stévart, T. & Doucet, JL.

Reviewer(s):

Institution(s):

Acknowledgements: This evaluation was performed by the project «Actualisation du statut de vulnérabilité des espèces ligneuses exploitées en Afrique centrale » grant number C224, funded by PPECF (Programme de Promotion de l'Exploitation Certifiée des Forêts) and the Gembloux Agro-Bio Tech faculty of the University of Liège through the AFRITIMB project subsidised by the FRFS-WISD (grant number PDR-WISD-07). We thank the forestry companies active in Central Africa and the consultancy firms (FRMi, Sylvafrica, and TEREA) for providing the management inventory data, the non-profit organisation Nature+ asbl, and the DYNAFAC collective for providing demographic data (mortality and growth). We express our gratitude to ATIBT (Association Technique Internationale des Bois Tropicaux) and ANPN (Agence Nationale des Parcs Nationaux du Gabon) for supporting this project «Actualisation du statut de vulnérabilité des espèces ligneuses exploitées en Afrique centrale ». We are also grateful to DYNAFAC collective through the P3FAC project funded by FFEM (Fonds Français pour l'Environnement Mondial) (grant number CZZ 2101.01R) and to the Fondation Franklinia for supporting this evaluation.

Regions: Global

- **Identification Description**

Dacryodes igaganga is a tree reaching 25 m in height and 90 cm in diameter, with butts. Its grey to brown trunk is scaly and covered with lenticels. Its light brown fibrous slice has a faint resinous odour and a translucent to brown resinous exudate. Its leaves are composed of 5 to 7 pairs of leaflets, green on both sides. They have simple deciduous hairs on the underside, concentrated on the main vein. The inflorescences are iron-coloured and the fruits, green to red, have a yellow pulp and a stone easily recognisable by its "shield" with a small terminal point. The stone contains a single seed.

Misidentifications are possible with *Dacryodes letestui* (mouvendo), whose leaflets are subsessile and densely hairy, especially on the veins on the lower side.

- **Assessment Rationale**

Dacryodes igaganga is a widespread tree endemic to Atlantic evergreen rainforests, non pioneer, long-lived, non-gregarious species. It is distributed from South-West Cameroon to Mayombe in Democratic Republic of the Congo. Based on a 2 x 2 km cell size, the AOO of this species is estimated as 348 km^2 with a minimum of 42 locations (number of forest management units of different logging companies in Central Africa). This species is not "Vulnerable" status under criterion B2. The EOO is calculated as 302 681 km^2, above the upper threshold for "Vulnerable" status under criterion B1.

Commonly known as igaganga, *D. igaganga* is a timber species but rarely exploited. The minimum cutting diameter (MCD) in Central Africa varies between 50 and 60 cm and is globally higher than the regular fruiting diameter (RFD) of 35 cm diameter at breast height (DBH) (Doucet, 2003), ensuring optimal regeneration of the species. The population structure of this species showed a curve in "decreasing exponential" suggesting a good regeneration with a density of 0.75 $stems.ha^{-1}$ (dbh ≥ 20 cm) in Central Africa (see Supplementary Material). Given its stem density and the mean annual increment of 0.43 ± 0.31 cm/year in Central Africa (see Supplementary Material), we estimate the number of mature individuals over 10 000 across the distribution range, well above the threatened category under criteria C and D.

The most serious long-term threat is the conversion of the forest to agriculture and illegal logging. However, the species is not considered severely fragmented as the 220 known occurrences represent more than 50 localities (IUCN, 2019). Considering the species' generation length (126 years), an inference of population reduction for three generations in the past is impossible following A1 and A2 criteria. Based on simulations with constant recruitment on its distribution range including protected areas, non - permanent forest areas and production forest (logging concessions), we estimated a population increase of **16.27**% in the next 100 years under criterion A3 (see Supplementary Material). An assessment of the population reduction according to criterion A4 considering one to two generations back and one to two generations forward would likely introduce high levels of uncertainty due to the lack of data to efficiently model the reduction of population size in the past. No quantitative analysis of the probability of extinction in the wild was conducted, and therefore criterion E does not apply.

Considering (i) the population density and the natural regeneration, (ii) a MCD higher than RFD, and (iii) the increase of population in the future across the distribution range, the species is assessed as Least Concern (LC), A3cd.

Reasons for change

Reason(s) for Change in Red List Category from the Previous Assessment:

Dacryodes igaganga was previously assessed as "Vulnerable" (https://www.iucnredlist.org/species/32182/9679957) at the African Regional Workshop (Conservation & Sustainable Management of Trees, Zimbabwe, July 1996), 1998, following the A1cd criterion. During the last few years, important data have been produced on distribution andpopulation dynamics (growth, recruitment, mortality) of the species. Moreover, a new version of the IUCN guidelines is available (from version 2.3 to 3.1). Given all these information, it was necessary to produce a new assessment of the species.

• Distribution

• Geographic Range

Dacryodes igaganga is widely distributed from South-West Cameroon to Mayombe (Democratic Republic of the Congo). It is common in lowland rainforest up to 550 m altitude. The extent of occurrence (EOO) in native area is estimated at 302 681 km^2.

• Area of Occupancy (AOO)

Estimated area of occupancy (AOO) - in km2	Justification
348	The AOO has been estimated using ConR based on the 2 × 2 km cell size of 290 occurrences from CJB (Conservatoire et Jardin botaniques de Genève) and RAINBIO

Continuing decline in area of occupancy (AOO)	Qualifier	Justification
Yes	Inferred	The species has suffered from reduction in area of occupancy, due to habitat degradation and deforestation in Central Africa forest (Vancutsem et al., 2021)

• Extent of Occurrence (EOO)

Estimated extent of occurrence (EOO)- in km2	EOO estimate calculated from Minimum Convex Polygon	Justification
302 681	true	Calculated using ConR based on 290 known occurrences from CJB and RAINBIO

Continuing decline in extent of occurrence (EOO)	Qualifier	Justification

Yes	Inferred	The species has certainly undergone extent of occurrence reduction in Central Africa, linked to the reduction in forest area (Vancutsem et al., 2021)

- **Locations Information**

Number of Locations	Justification
40-200	More than 42 localities. Based on the most serious plausible threat (conversion of its habitat) and illegal logging across the distribution range.

Continuing decline in number of locations	Qualifier	Justification
Yes	Inferred	The main threat remains the reduction of the forest area in Central Africa.

Extreme fluctuations in the number of locations	Justification
No	

- **Very restricted AOO or number of locations (triggers VU D2)**

Very restricted in area of occupancy (AOO) and/or # of locations	Justification
No	-

- **Elevation / Depth / Depth Zones**

Elevation Lower Limit (in metres above sea level): 0

Elevation Upper Limit (in metres above sea level): 550

- **Map Status**

Map Status	Use map from previous assessment	How the map was created, including data sources/methods used:	Please state reason for map not available:	Data Sensitive?	Justification	Geographic range this applies to:	Date restriction imposed:
Done	-	Qgis. The dataset was created from a	-	-	-	-	-

	compilation of Rainbio and CJB	

- **Biogeographic Realms**

Biogeographic Realm: Afrotropical

- **Occurrence**

- **Countries of Occurrence**

Country	Presence	Origin	Formerly Bred	Seasonality
Cameroon	Extant	Native	-	Resident
Congo	Extant	Native	-	Resident
Democratic Republic of Congo	Extant	Native	-	Resident
Equatorial Guinea	Extant	Native	-	Resident
Gabon	Extant	Native	-	Resident

- **Population**

Dacryodes igaganga is a Lower Guinean species, distributed from South-West Cameroon to Mayombe (Democratic Republic of the Congo). Its average density is 0.75 stems.ha-1 (dbh ≥ 20 cm) in Central Africa (see Supplementary Material).

The species is not monitored in the plots and trails set up by the DYNAFAC collective. Nevertheless, an average diametric growth rate between 0.19 and 0.35 cm/year was obtained after one year of monitoring (Doucet, 2003). However, long-term monitoring is needed to obtain robust estimates. The legal minimum cutting diameter "MCD " varies across its distribution range, (50 cm in Cameroon, 60 cm in Gabon, Republic of the Congo and Democratic Republic of the Congo). MCD is higher than the regular fruiting diameter (RFD), estimated at 35 cm in Gabon, and the minimum fertility diameter estimated at 35 cm in Central Africa (see Supplementary Material).

Using the Red List criterion A3, the projected population reduction (PPR) to be met in the future (100 years because the generation length of the species is 126 years) of the *D. igaganga* population was assessed across its distribution range. Because *D. igaganga* is a Central African species, the PPR was estimated for the region. Three different PPR were thus estimated: PPRpa in protected areas, PPRpf in production forests and PPRnp in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas. First, protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion which have been the main agents of forest degradation across the region (Abernethy et al., 2016). The population of the species in protected areas covering its range was kept stable in the future over 100 years, suggesting that the PPR in protected areas was 0%. Second, the evolution of the *D. igaganga* population was simulated using an Usher matrix model to estimate the PPR of production forests (logging concessions, PPRpf). The simulations were initialized using the density (number of trees.ha-1) per diameter class (from 35 cm diameter, mature individuals) from forest management inventories of logging companies. The evolution of this initial population depended on several demographics (recruitment, mortality, and growth rate) and logging parameters (minimum cutting diameter, cutting and damage rate) that were adjusted using data of permanent tree plot monitoring. Thus, the density of *D. igaganga* in 100 years was predicted with a logging event every 25 years, which corresponds to the average cutting cycle in Central Africa. PPRpf was then calculated as the difference between initial and final number of trees. Third, the major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Illegal logging and the habitat lost from deforestation rate have been both activities that allowed estimating the PPRnp in non-permanent domains.

The global PPR was then computed after weighting the three values by their relative forest areas. We estimated a population increase of 16.27% in the next 100 years under criterion A3 (for further information about this methodology, see Supplementary Material).

- **Population Information**

Current Population Trend: Increasing

Extreme fluctuations? (in # of mature individuals)	Justification
No	-

Severely fragmented?	Justification
No	-

Continuing decline in mature individuals?	Qualifier	Justification

Continuing decline % in mature individuals within 3 generations or 10 years, whichever is longer (up to max. of 100 years in the future)	Qualifier	Justification

Extreme fluctuations in the number of subpopulations	Justification
	-

Continuing decline in number of subpopulations	Qualifier	Justification
	-	-

All individuals in one subpopulation: No

Number of Subpopulations	Justification	Subpopulation	Subpopulation description	Number of mature	Subpopulation trend	Qualifier	Location type	Number of Subpopulations	Location bounding box	Location coordinates	Notes

- **Population Reduction - Past**

Percent Change in past	Reduction or Increase	Qualifier	Justification

Basis?

Reversible?

Understood?

Ceased?

- **Population Reduction - Future**

Percent Change in future	Reduction or Increase	Qualifier	Justification
16.27%	Increase	Projected	Using the Red List criterion A3, the projected population reduction (PPR) to be met in the future (100 years because the generation length of the species is 126 years) of the *D. igaganga* population was

assessed across its distribution range. Because *D. igaganga* is a Central African species, the PPR was estimated for the region.

Three different PPR were thus estimated: PPRpa in protected areas, PPRpf in production forests and PPRnp in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas. First, protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). The population of the species in protected areas covering its range was kept stable in the future over 100 years, suggesting that the PPR in protected areas was 0%. Second, the evolution of the *D. igaganga* population was simulated using an Usher matrix model to estimate the PPR of production forests (logging concessions, PPRpf). The simulations were initialised using the density (number of trees.ha-1) per diameter class (from 35 cm diameter, mature individuals) from forest management inventories of logging companies. The evolution of this initial population depended on several demographics (recruitment, mortality, and growth rate) and logging parameters (minimum cutting diameter, cutting and damage rate) that were adjusted using data of permanent tree plot monitoring. Thus, the density of *D. igaganga* in 100 years was predicted with a logging event every 25 years, which corresponds to the average cutting cycle in Central Africa. PPRpf was then calculated as the difference between initial and final number of trees. Third, the major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Illegal logging and the habitat lost from deforestation rate have been both activities that allowed estimating the PPRnp in non-permanent domains.

The global PPR was then computed after weighting the three values by their relative forest areas. We estimated a population increase of 16.27% in the next 100 years under criterion A3 (for further information about this methodology, see Supplementary Material).

Basis?

b) an index of abundance appropriate for the taxon, d) actual or potential levels of exploitation

- **Population Reduction - Ongoing**

Both: Percent Change over any 10 year or 3 generation period, whichever is longer, and must include both past and future, future can't go beyond 100 years	Reduction or Increase	Number of years for this period	Qualifier	Justification

Basis?

Reversible?

Understood?

Ceased?

- **Habitats and Ecology**

Dacryodes igaganga is a large tree reaching 25 m in height and 90cm in diameter, long-lived, non-gregarious, non-pioneer and probably shade-tolerant species endemic to moist evergreen forests. The species occurs in lowland rainforest up to 550 m altitude. The species settles in the undergrowth where it can survive and develop, taking advantage of gaps to accelerate its growth.

Few studies have been conducted on the ecology of this species. *D. igaganga* is a dioecious species whose flowering occurs from November to June in Gabon. It is a sarcochorus species whose fruiting is abundant between August-September in Gabon and seeds are dispersed by animals (zoochory) (Doucet, 2003). In Gabon, the minimum fertility is 29 cm (Doucet, 2003), and fruits are regularly observed from 35cm (based on 48 observations) (Doucet, 2003). Long-term monitoring is needed to refine these estimates.

- **IUCN Habitats Classification Scheme**

Habitat	Season	Suitability	Major Importance?
1.6. Forest -> Forest - Subtropical/Tropical Moist Lowland	Reside nt	Suitable	Yes

- **Continuing Decline in Habitat**

Continuing decline in area, extent and/or quality of habitat?	Qualifier	Justification
Yes	Observed	The annual deforestation rate of 0.35% in Central Africa (Vancutsem et al., 2021)

- **Life History**

Generation Length	Justification	Data Quality
126	Minimum estimate of generation length for the species from the average growth rate, and the mean diameter of mature individuals (see Supplementary Material)	good

Age at maturity: female or unspecified
82 Years

Age at Maturity: Male
82 Years

Size at Maturity (in cms): Female
35

Size at Maturity (in cms): Male
35

Reproductive Periodicity
Annual

Annual Rate of Population Increase

Natural Mortality
1% (Ligot et al. 2022)

- **Systems**

System: Terrestrial

- **Plant / Fungi Specific**

Wild relative of a crop? No

Plant and Fungal Growth Forms
Tree - large

- **Use and Trade**

- **General Use and Trade Information**

Dacryodes igaganga is not widely exploited in Central Africa. Its wood is very close to the "ozigo" (*Dacryodes buettneri* (Engl.) H.J.Lam) and the "ossabel" (*Dacryodes normandii* Aubrév. & Pellegr.).

The species can be used for veneers, plywood, joinery and parquetry. It is also suitable for construction, furniture and cabinet making, carpentry, shipbuilding, tool handles, ladders, carvings, toys and novelty items, turning, poles and pilings. It can be used to make paper. Exports of *D. igaganga* are declining in Central Africa. In Gabon, it dropped progressively from 32 690 m^3 in 2000 to 8360 m^3 in 2002, and finally 2 630 m^3 in 2005.

At a local level, the fruits are consumed by the communities.

Subsistence:	Rationale:	Local Commercial:	Further detail including information on economic value if available:
Yes	-	Yes	-

National Commercial Value: Yes

International Commercial Value: Yes

Is there harvest from captive/cultivated sources of this species? Yes

Trend in level of total offtake from wild sources: Stable

Trend in level of total offtake from domesticated sources: Unknown

- **Non- Consumptive Use**

Non-consumptive use of the species? true

- **Threats**

The main threats in the non-permanent domain across the species' distribution range, are mainly related to habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging and the abusive harvesting of plant parts requested as non-wood forest products (Bradshaw et al., 2009). In Central Africa, illegal logging accounts for nearly 46% of total log production (FRMi, 2018). This production generally comes from unallocated forest areas (non-permanent forest domain).

No study considers logging as a direct driver of deforestation because of the low logging densities (1-2 stems per hectare).

- **Threats Classification Scheme**

No past, ongoing, or future threats exist to this species. false

Threat	Timing	Scope	Severity	Impact Score
1.1. Residential & commercial development -> Housing & urban areas	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4
2.1.1. Agriculture & aquaculture -> Annual & perennial non-timber crops -> Shifting agriculture	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
2.2.2. Agriculture & aquaculture -> Wood & pulp plantations -> Agro-industry plantations	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
2.3.2. Agriculture & aquaculture -> Livestock farming & ranching -> Small-holder grazing, ranching or farming	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4
3.2. Energy production & mining -> Mining & quarrying	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5

4.1. Transportation & service corridors -> Roads & railroads	Past, Likely to Return	Minority (<50%)	Slow, Significant Declines	Low Impact: 4
5.3.1. Biological resource use -> Logging & wood harvesting -> Intentional use: (subsistence/small scale) [harvest]	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 4
5.3.2. Biological resource use -> Logging & wood harvesting -> Intentional use: (large scale) [harvest]	Ongoing	Minority (<50%)	Slow, Significant Declines	Medium Impact: 6
7.1.3. Natural system modifications -> Fire & fire suppression -> Trend Unknown/Unrecorded	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4

● Conservation

Dacryodes igaganga does not appear in any *ex situ* collections (BGCI, 2022), but may occur in protected areas considering its distribution range in Central Africa. In certified forest concessions where the species can be exploited, permanent forest plots are usually installed. These plots provide important data for (i) quantifying population dynamics processes at the stand level: mortality, growth and recruitment; (ii) phenological studies to determine the regular fruiting diameter (RFD). These plots are managed in collaboration with forest concessions grouped within the DYNAFAC collective (see here for more information https://www.dynafac.org/fr/p/130/installation-de-dispositifs-de-suivi-de-la-dynamique-forestiere).

D. igaganga is a species of High Conservation Value". The fruits are consumed by the communities. It is therefore considered a High Conservation Value species (HVC5).

In addition, it will also be necessary to :

- Ensure the implementation of the recommendations of the Dynafac collective, including the establishment of a system for monitoring the populations of commercial species in the different forest types defined in a consensual manner;
- Set up monitoring and support systems for the regeneration of commercial species, prioritising species with regeneration deficits;
- Set up programmes to guarantee the phenotypic quality of commercial species populations: seed banks, seed stands, plus trees, seed orchards, conservation plantations;
- Consider threatened species in the delimitation of conservation series and in the identification of High Conservation Values;
- Update conservation statuses on a five-yearly basis, in particular by setting up a system of "green statuses";
- Define red lists adapted to regional or national contexts;
- Evaluate the status of cryptic species or species close to commercial species evaluated during this workshop.

● Conservation Actions In- Place

Action Recovery Plan	Note
No	

Systematic monitoring scheme	Note
No	

Occur in at least one PA	Note
Yes	The species may appear in at least 10 protected areas considering it distribution range

Percentage of population protected by PAs (0-100)	Note
1-10	Considering protected area across species distribution range

Area based regional management plan	Note
Unknown	-

Invasive species control or prevention	Note
No	-

Harvest management plan	Note
Yes	In legal forest concessions, the species is exploited according to a management plan.

Subject to ex-situ conservation	Note
NO	-

Included in international legislation	Note
No	-

Subject to any international management/trade controls	Note

No

- **Important Conservation Actions Needed**

Conservation Actions	Note
3.1.1. Species management -> Species management -> Harvest management	-
3.1.2. Species management -> Species management -> Trade management	-
3.4.2. Species management -> Ex-situ conservation -> Genome resource bank	-

- **Research Needed**

Research	Note
1.2. Research -> Population size, distribution & trends	-
3.1. Monitoring -> Population trends	-
3.2. Monitoring -> Harvest level trends	-
3.3. Monitoring -> Trade trends	-

- **Ecosystem Services**

- **Ecosystem Services Provided by the Species**

	Importance:	Geographic range of benefit:
1. Water Quality	2 - Important	Global
3. Flood Control	2 - Important	Global
4. Climate Regulation	2 - Important	Global
5. Landscape	2 - Important	Global
6. Air Quality	2 - Important	Global
7. Nutrient Cycling	2 - Important	Global
8. Habitat Maintenance	2 - Important	Global

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● SUPPLEMENTARY MATERIAL

Dacryodes igaganga Aubrév. & Pellegr.

● IUCN status using criterion A3

We adopted the criterion A3 to assess the projected population reduction (PPR) to be met in the future (up to a maximum of 100 years) of *Dacryodes igaganga*. To quantify the projected population reduction, simulations must be performed on mature individuals and three generations with maximum 100 years according to **criterion A3**. We estimated mature individuals and generation length, as recommended by the IUCN guidelines.

A **mature individual** is an individual that can reproduce, able to bear flowers or seeds (fertile in plant kingdom). To quantify the mature individuals for each species, we used phenological data from a combined dataset of 48 trees in Gabon (Doucet, 2003). Using the relation between percentage of fertile trees and tree diameter, the **diameter of a mature individual** was obtained by fitting 50% of fertile trees to produce the flower or fruit. The minimum diameter of mature individuals for this species was **35 cm** (Doucet, 2003).

The **generation length** was the report between the mean diameter of mature individuals considering population structure and the mean increment. Given that the diameter of mature individuals was 35 cm, we weighted the total number of trees by their diameter from 35 cm to 125 cm to compute the number of mature individuals. The mean of mature individuals was **54 cm** as the report between the number of mature individuals and total number of trees. The **mean increment** of the species was **0.427 cm**, obtained from 390 observations of published data at the genus level (Dacryodes) in Gabon (Ligot et al., 2022). Thus, the **generation length** was 54 cm / 0.427 cm = **126 years**. The age at maturity (**82 years**) has been estimated as the report between the **minimum diameter of mature individuals** (**35 cm**) and the **mean annual increment** (**0.427 cm)**.

● Estimation of the projected population reduction (PPR)

We adopted the criterion A3 to assess the projected population reduction (PPR) to be met in the future (up to a maximum of 100 years). Because *Dacryodes igaganga* is a widespread species in Central Africa, the PPR was estimated in central Africa.

● PPR in Central Africa

In this region, forest management follows three different modalities: protected areas, production forests (logging concessions) and non-permanent forest domain. Based on occurrences, the natural range of this species includes countries in Central Africa (Figure 1). The total natural area is estimated at 30 218 603.4 ha. Within this area, there are 16 892 962.5 ha (56%) for production forests, 1 940 745.68 ha (6.4%) for protected areas, and 11 384 895.22 ha (37.6%) for the non-permanent domain.

Three different PPR are thus estimated: PPR_{pa} in protected areas, PPR_{pf} in production forests and PPR_{np} in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas and then added to estimate the PPR_C in Central Africa.

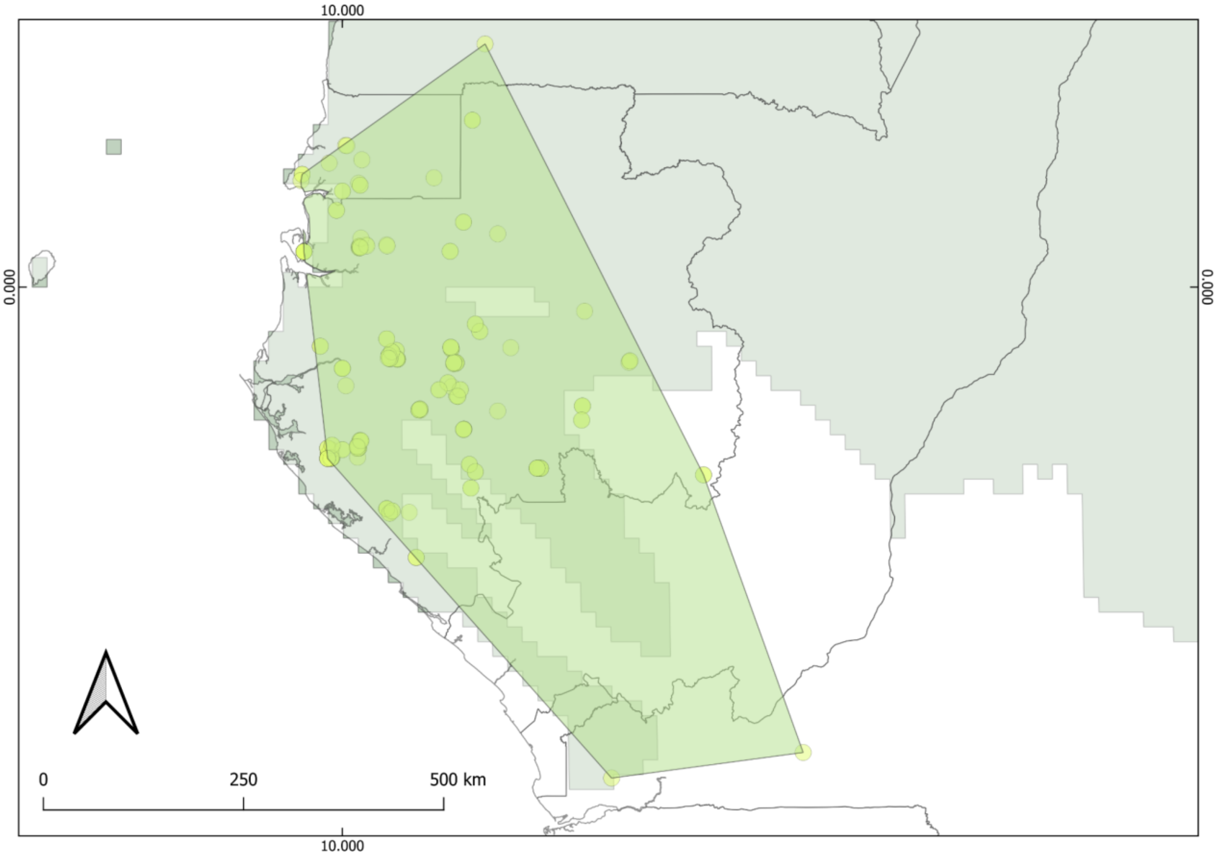

Figure 1. The range of *Dacryodes igaganga* in Central Africa estimated from RAINBIO and CJB data, validated in December 2022 during a workshop with a group of experts in Gabon.

- **PPR in protected areas**

Central Africa countries have allocated a higher proportion of their land to conservation than any other tropical regions, with relatively higher conservation success (Laurance et al., 2012). Indeed, most protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). They are currently representing a large part of forest and tree species conservation in Central Africa. Thus, the population of each species in protected areas (according to FRMI, 2018) covering its range was kept stable in the future over 100 years. **In these conditions, it was hypothesized that the PPR in protected areas for each species is 0%, suggesting no population reduction in the present and future.**

- **PPR in production forests**

To quantify the evolution of the population of each timber species, matrix population models are widely used to study population dynamics (Picard & Liang, 2014). The population of this species was described at time *t* by a vector

N_t corresponding to the density (number of trees ha^{-1}) in each diameter class (from 20 cm diameter to more than 120 cm). The density per diameter class were estimated using data of forest inventories that were carried out in 42 forest management units (FMU) of different logging companies in Gabon. Most logging companies followed a standardized inventory protocol (Réjou-Méchain et al., 2011). These forest inventory data covered about 8 million ha (Table 1), that are representative of 49% of Central Africa's production forests of this species. The number of trees sampled in Gabon was 6 164 195 with a density of 0.75 tree ha^{-1}. Large-scale commercial inventories have already been found useful in the identification of large-scale patterns in Central Africa (Réjou-Méchain et al., 2011). Using a large-scale data of commercial forest inventories, Réjou-Méchain et al. (2021) jointly model the distribution in abundance of the most dominant tree species and produce continuous maps of the floristic and functional composition of central African forests.

Table 1. Forest management units (FMU) sampled in Central Africa (Cameroon, CAR: Central African Republic, DRC: Democratic Republic of the Congo, EG: Equatorial Guinea, Gabon and RCongo: Republic of the Congo).

	Sampling	
Country	FMU	Area (ha)
Cameroon	-	-
CAR	-	-
DRC	-	-
EG	-	-
Gabon	42	8 215 660
RCongo	-	-
Total	42	8 215 660

The Usher matrix model was used to simulate the evolution of the recovery rate of all population and the exploitable stock of each species after logging in Central Africa. According to the Usher assumption, between t and t+1, an individual can either stay alive in the same class, stay alive and move up to the next class, or die; it cannot move up by more than one class or move backwards, i.e., the individual is free from diameter shrinkage (Picard et al., 2012). The Usher matrix model (U) considers three parameters (mortality, recruitment and growth rate that are constant in time) to estimate the transition probabilities:

$$U = \begin{pmatrix} q_1 + g_1 & g_2 & \cdots & \cdots & g_I \\ p_1 & q_2 & 0 & \cdots & 0 \\ 0 & \ddots & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & p_{I-1} & q_I \end{pmatrix}$$

where q_i is the probability for an individual to stay alive in class i between two consecutive time steps, p_i is the upgrowth transition rate (the probability for an individual to grow up from class i to class i +1), and g_i is the recruitment rate (Picard & Liang, 2014).

Tree mortality, recruitment and growth are three central processes for predicting the dynamics of tropical rainforests and estimating these three processes requires long-term monitoring in difficult field conditions (Picard & Gourlet-Fleury, 2008). These processes determine the evolution of the species population in the forest stand. The natural mortality is defined as the number of standing dead trees, and few studies have reported estimates of mortality rates in Central Africa. Data about tree mortality are still scarce and it does not allow to precisely be modelling the mortality rate for each species and size class. Given the current state of knowledge, it appears reasonable to use a fixed mortality rate of 1% for all species and size classes, in agreement with the results of Ligot et al. (2022) on 21,180 trees belonging to 42 timber species of Central Africa annually monitored from one to seven years.

The recruitment integrates fruiting and seed dispersal from mother trees, and the survival of plant juveniles until they reach a size threshold where they are included in the stand. The recruitment term in the model is the average annual input of new individuals into the first size class from 20 cm. The recruitment events, like mortality events, are infrequent and thus difficult to model (Karsenty & Gourlet-Fleury, 2006). The population structure showed a curve in "decreasing exponential" suggesting a good regeneration (Figure 2). To model the recruitment, we used the hypothesis defined as the recruitment rate that would maintain a constant number of trees in the first diameter class. Claeys et al. (2019) projected the future forest dynamics up to the end of the century and they showed that projected mortality and recruitment rates in 2099 could not differ from the ones observed today. Thus, the hypothesis on the recruitment and the mortality rate is used in the future (up to 100 years) as they do today.

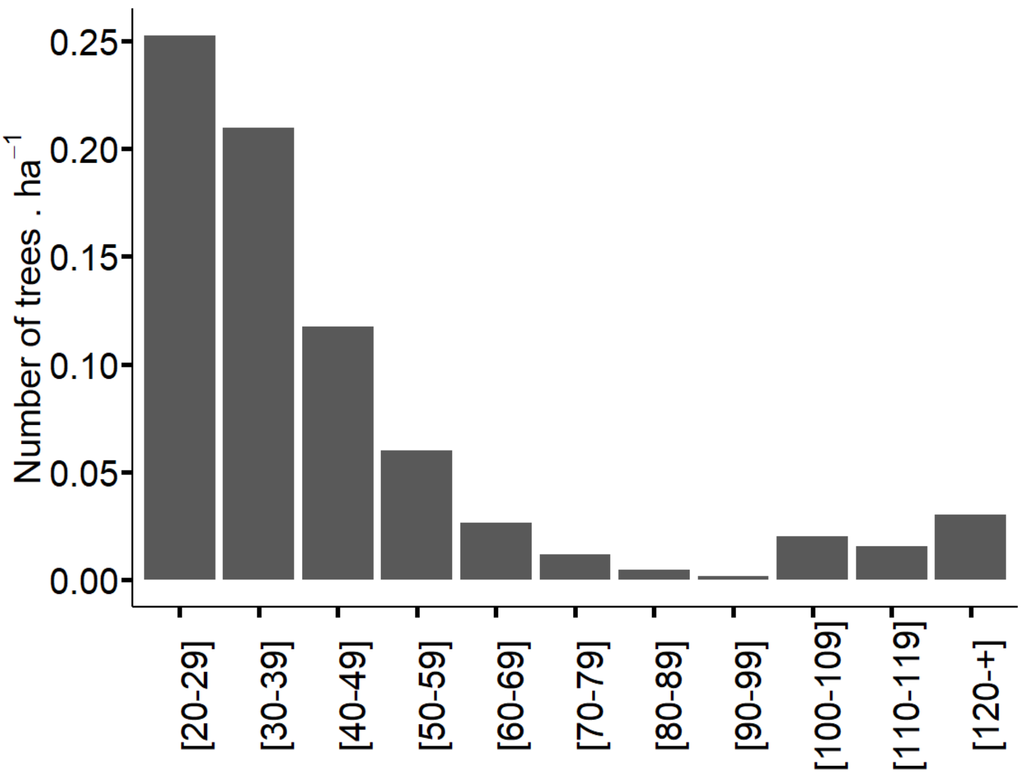

Figure 2. Population structure of *Dacryodes igaganga* (igaganga) defined using the number of trees per ha and per diameter class (from 20 cm of 42 logging concessions in Gabon covering an area of 8 215 660 ha).

Since the mid-1900s, periodic tree monitoring and tree ring analyses have been carried out to study variability in tree growth across species in Central Africa (Durrieu de Madron, Nasi, et al., 2000; Ligot et al., 2019, 2022). We fitted growth models for each species using data from logged and unlogged areas of permanent tree plot monitoring from the DYNAFAC[9] network covering the five Central African countries. From the combined dataset at the genus level (Dacryodes), we identified 390 trees belonging to one site in Gabon. Minimum and maximum sampled diameter ranged from 10 to 102 cm. The monitoring period ranged from 2015 to 2018. The second-degree polynomial model was fitted for this species. The estimated coefficient from the second-degree polynomial model has been used in the simulation in order to estimate the diameter growth (Table 2).

Table 2. Estimated coefficients (a, b, and c) of growth models between the increment (ac in cm year^{-1}) and the initial diameter (D in cm). The sample including the number of trees (n) and the number of sites (site) is also given. * significant (p-value < 0.05) and ^{ns} non-significant (p-value > 0.050)

species	n	site	model	a	b	c
Dacryodes	390	1	$ac \sim D + D^2$	0.19*	0.00096*	-0.00008^{ns}

The transition probabilities of three parameters (mortality, growth, and recruitment rate) allowed making the harvested matrix. The logging operations have been modeled using the logging parameters (minimum cutting diameter, cutting and damage rate). The minimum cutting diameters were obtained from decrees of application of the forestry administrations (MCD_A) at the country level and the one used in the management plan (MCD_M, with $MCD_M \geq MCD_A$) at the logging company level. At the Central Africa level, we weighted the MCD_A and MCD_M values to the occupied area and **$MCD_A = MCD_M = 60$ cm**. The cutting rate (CA), which defines the proportion of harvested trees (trees with a diameter greater than MCD_A or MCD_M), was given by logging companies, and it was also weighted at the Central Africa level with a value of 52%. Given the current state of knowledge, it appears reasonable to use a fixed damage rate caused by logging of 7% of the initial population that disappears (Durrieu de Madron, Fontez, et al., 2000). The average cutting cycle (i.e. the period between two successive logging operations) is 28 years (FRMI, 2018), but we used 25 years to simplify computation of four simulations reaching 100 years (25, 50, 75 and 100 years), as requested by IUCN criterion A.

The Figure 3 shows the PPR in production forests for the *Dacryodes igaganga*. The reduction in the population of each species was then calculated as the difference between the initial numbers of mature individuals and the predicted numbers of mature individuals predicted after 100 years. **The simulations in production forest showed a population increase of 28.72% over 100 years.**

[9] https://www.dynafac.org/en

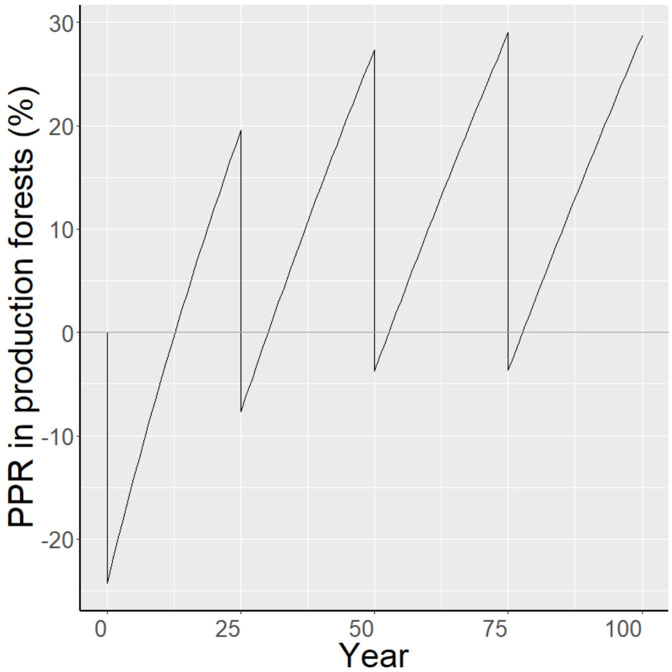

Figure 3. Simulations showing the projected population reduction (PPR) from diameter of mature individuals (35 cm) in production forests for the *Dacryodes igaganga* over 100 years for constant recruitment.

- **PPR in the non-permanent forest domain**

The major threats in the non-permanent domain are habitat loss due to the destruction of natural environments because of population growth and urbanization, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Based on the large range of this species in Central Africa (Figure 1), the harvested volume from illegal logging and legal logging are 11% and 89%, respectively (FRMI 2018). In this condition, it was hypothesized that there is 89% of PPR from production forests and 11% of PPR from illegal logging in 100% PPR due to forest logging. Given that the PPR of production forests associated with its forest area was known, we deduced the PPR and forest area of illegal logging from those of the production forests. As a result, 2 087 894.25 ha were affected by the illegal logging for this species. The non-permanent domain area (11 384 895.22 ha) was considered as the area which was related to today's deforestation rate of 0.07% $year^{-1}$ in the geographic range of this species (Eba'a et al., 2022). This is a conservative value since it will probably decrease in the future (Swamy et al., 2018).

- **PPR global = PPR in Central Africa**

We thus had three different PPR: PPR_{pa} in protected area, PPR_{pf} in production forests, and PPR_{np} in non-permanent domain. The global PPR was then computed after weighting the three values by their relative forest areas:

$$PPR = \frac{(S_{pa} \times PPR_{pa}) + (S_{pf} \times PPR_{pf}) + (S_{np} \times PPR_{np})}{S_{pa} + S_{pf} + S_{np}}$$

where S_{pa}, S_{pf}, and S_{np} are forest areas in protected area, production forests and non-permanent domain, respectively.

The global PPR was then computed after weighting the three values by their relative forest areas. Based on the distribution range of *Dacryodes igaganga,* we estimated a population increase of 16.27% in the next 100 years under criterion A3. This population increase is due to the high number of mature individuals since the minimum diameter of the individuals is 35 cm, the constant recruitment that would maintain a constant number of trees in the first diameter class at each cycle of 25 years, and the low cutting rate (52%).

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10.6 Annexe 6. *Entandrophragma candollei* - Harms

Draft

Entandrophragma candollei **- Harms**

PLANTAE - TRACHEOPHYTA - MAGNOLIOPSIDA - SAPINDALES - MELIACEAE - Entandrophragma - candollei

Common Names: Cedar Kokoti (English), Kosipo, Omu, Penkwa-akoa
Synonyms: *Entandrophragma choriandrum* Harms
Entandrophragma ferruginea A.Chev.

Red List Status
VU – Vulnerable, A3cd (IUCN version 3.1)

- **Red List Assessment**
- **Assessment Information**

Date of Assessment: 2022-09-01
Assessor(s): Monthe, F., Loubota, G., Ligot, G., Texier, N., Stévart, T. & Doucet, JL.
Reviewer(s):
Institution(s):
Acknowledgements: This evaluation was performed by the project «Actualisation du statut de vulnérabilité des espèces ligneuses exploitées en Afrique centrale » grant number C224, funded by PPECF (Programme de Promotion de l'Exploitation Certifiée des Forêts) and the Gembloux Agro-Bio Tech faculty of the University of Liège through the AFRITIMB project subsidised by the FRFS-WISD (grant number PDR-WISD-07). We thank the forestry companies active in Central Africa and the consultancy firms (FRMi, Sylvafrica, and TEREA) for providing the management inventory data, the non-profit organisation Nature+ asbl, and the DYNAFAC collective for providing demographic data (mortality and growth). We express our gratitude to ATIBT (Association Technique Internationale des Bois Tropicaux) and ANPN (Agence Nationale des Parcs Nationaux du Gabon) for supporting this project «Actualisation du statut de vulnérabilité des espèces ligneuses exploitées en Afrique centrale ». We are also grateful to DYNAFAC collective through the P3FAC project funded by FFEM (Fonds Français pour l'Environnement Mondial) (grant number CZZ 2101.01R) and to the Fondation Franklinia for supporting this evaluation.
Regions: Global

- **Identification Description**

Entandrophragma candollei is a very large tree, up to 60 m high and 3 m in diameter, with a massive crown supported by large sinuous branches. It has rounded buttresses . Its lenticellate trunk is straight and cylindrical, beige to greyish, smooth in young trees, and marked with numerous deep depressions giving a prickly appearance, with scales and scars. Its slash is reddish-pink and whitish towards the inside, with orange-yellow granules, and sometimes clusters of gum on old wounds. Its smell is absent or very weak (perfume). Its leaves, grouped at the end of the branches, are paripinnate with 5 to 9 pairs of (sub) opposite leaflets with wavy surfaces. The leaf blade is crossed by numerous tight secondary veins (15-25 pairs), clearly visible and very prominent on the underside, with some intercalary veins. Its long inflorescences of 10-30 cm bear small green flowers. The fruits are large, elongated, green and then brown, cucumber-shaped woody capsules (17-23 x 3-5 cm), sometimes lenticellate, and opening at the top into 5 thick valves. They contain flattened seeds with long straight wings 5-9 cm long.
Misidentifications are possible with other *Entandrophragma* species, mainly with *E. angolense* and *E. congoense* (with a slash without yellowish granules and leaflets with a non-corrugated surface), *E. utile* (whose bark is more fissured lengthwise).

- **Assessment Rationale**

Entandrophragma candollei is a widespread tall tree in evergreen and semi-deciduous guineo-congolian African forest, long-lived, usually non-gregarious species, which forms root associations with arbuscular mycorrhizal fungi. It is distributed from Guinea to Democratic Republic of the Congo. Based on a 2 x 2 km cell size, the AOO of this species is estimated as 512 km^2 with a minimum of 85 locations (number of forest management units of different logging companies in Central Africa). This species is not “Vulnerable” status under criterion B2. The EOO is calculated as 3 625 097 km^2, above the upper threshold for “Vulnerable” status under criterion B1.
Commonly known as Kosipo, it is a timber species in tropical Africa, sought after for the quality of its wood, but less than other Entandrophragma species. The minimum cutting diameter (MCD) varies from 80 and 90 cm in Central Africa and from 90 to 110 cm in West Africa. It is close to the regular fruiting diameter (RFD) of 90 cm diameter at breast height (DBH), which can compromise locally the availability of seed trees. The DYNAFAC collective recommends an MCD of 100 cm in Central Africa to ensure optimal gene flow in populations (DYNAFAC, 2022). The population structure of this species showed a decreasing suggesting a good regeneration, with a density of 0.40 stems.ha^{-1} (dbh ≥ 20 cm) in Central Africa (see Supplementary Material). Given its stem density and the mean annual increment of 0.43 ± 0.41 cm/year in Central Africa (see Supplementary Material), we estimate the number of mature individuals over 10 000 across the distribution range, well above the threatened category under criteria C and D.
The most serious long-term threat is the conversion of the forest to agriculture and illegal logging. However, the species is not considered severely fragmented as 233 known occurrences represent more than 50 localities (sensu Comité des normes et des pétitions de l’UICN, 2019). Considering the species' generation length (199 years), an inference of population reduction for three generations in the past is impossible following A1 and A2 criteria. Based on simulations of the expected population reduction on its distribution range including protected areas, non - permanent forest areas and production forest (logging concessions), we estimated population reduction between 28.43 and 30.82 % in the next 100 years within the threshold to be considered threatened under criterion A3. An assessment of the population reduction according to criterion A4 considering one to two generations back and one to two generations forward would likely introduce high levels of uncertainty due to the lack of data to efficiently

model the reduction of population size in the past. No quantitative analysis of the probability of extinction in the wild was conducted, and therefore criterion E does not apply.

Considering (i) the population density, (ii) the incompatibility between MCD and RFD in some countries of the distribution range, and (iii) the reduction of population in the future across the distribution range within the limit for Vulnerable, the species is assessed as Vulnerable (VU), A3cd.

Reasons for change

Reason(s) for Change in Red List Category from the Previous Assessment:

Entandrophragma candollei was previously assessed as "Vulnerable" (https://www.iucnredlist.org/species/33050/9753509) at the African Regional Workshop (Conservation & Sustainable Management of Trees, Zimbabwe, July 1996), 1998, following the A1cd criterion. During the last few years, important data have been produced on the self-ecology, population dynamics (growth, recruitment, mortality) of the species. Moreover, a new version of the IUCN guidelines is available (from version 2.3 to 3.1). Given all these information, it was necessary to produce a new assessment of the species.

- **Distribution**
- **Geographic Range**

Entandrophragma candollei is widely distributed from Guinea to Democratic Republic of Congo (Kasongo-Yakusu et al., 2018). It is common in semi-deciduous rainforest, especially in areas where the annual rainfall is about 1800 mm. The extent of occurrence (EOO) in native area is estimated 3 625 097 km^2.

- **Area of Occupancy (AOO)**

Estimated area of occupancy (AOO) - in km2	Justification
512	The AOO has been estimated using ConR based on the 2 × 2 km cell size of 233 occurrences from CJB (Conservatoire et Jardin botaniques de Genève) and RAINBIO

Continuing decline in area of occupancy (AOO)	Qualifier	Justification
Yes	Inferred	The species has suffered from reduction in area of occupancy, due to habitat degradation and deforestation in West Africa forest (Vancutsem et al., 2021).

- **Extent of Occurrence (EOO)**

Estimated extent of occurrence (EOO)- in km2	EOO estimate calculated from Minimum Convex Polygon	Justification
3 625 097	true	Calculated using ConR based on 233 known occurrences from CJB (Conservatoire et Jardin botaniques de Genève) and RAINBIO

Continuing decline in extent of occurrence (EOO)	Qualifier	Justification
Yes	Inferred	The species has certainly undergone an extent of occurrence reduction in West Africa, linked to the reduction in forest area (Vancutsem et al., 2021).

- Locations Information

Number of Locations	Justification
80-200	More than 85 localities. Based on the most serious plausible threat (conversion of its habitat) and illegal logging across the distribution range.

Continuing decline in number of locations	Qualifier	Justification
Yes	Inferred	The main threat remains the reduction of the forest area in West Africa.

Extreme fluctuations in the number of locations	Justification
No	

- Very restricted AOO or number of locations (triggers VU D2)

Very restricted in area of occupancy (AOO) and/or # of locations	Justification
No	-

- Elevation / Depth / Depth Zones

Elevation Lower Limit (in metres above sea level): 0

Elevation Upper Limit (in metres above sea level): 1500

- **Map Status**

Map Status	Use map from previous assessment	How the map was created, including data sources/methods used:	Please state reason for map not available:	Data Sensitive?	Justification	Geographic range this applies to:	Date restriction imposed:
Done	-	Qgis. The dataset was created from a compilation of Rainbio and CJB	-	-	-	-	-

- **Biogeographic Realms**

Biogeographic Realm: Afrotropical

- **Occurrence**
- **Countries of Occurrence**

Country	Presence	Origin	Formerly Bred	Seasonality
Cameroon	Extant	Native	-	Resident
Republic of the Congo	Extant	Native	-	Resident
Côte d'Ivoire	Extant	Native	-	Resident
Equatorial Guinea	Extant	Native	-	Resident
Equatorial Guinea -> Equatorial Guinea (mainland)	Extant	Native	-	Resident
Gabon	Extant	Native	-	Resident
Ghana	Extant	Native	-	Resident
Nigeria	Extant	Native	-	Resident
Sierra Leone	Extant	Native	-	Resident
Togo	Extant	Native	-	Resident
Uganda	Extant	Native	-	Resident

- **Population**

Entandrophragma candollei is a guineo-congolian species, widely distributed from Guinea to the Democratic Republic of the Congo. Its average density is 0.40 stems.ha-1 (dbh ≥ 20 cm) in Central Africa (see Supplementary Material). Population densities of *E. candollei* vary according to forest type.

Seedlings grow slowly, reaching 13 cm in height after 5 months and 20-30 cm after 1 year (Kasongo-Yakusu et al., 2018; Nyunaï, 2008). In forest plantations of Guinea the trees reached an average height of 2.7 m after 6 years (Nyunaï, 2008). The average diameter growth of trees with dbh > 10 cm is 0.43 ± 0.41 cm/year in Central Africa (see Supplementary Material), but can vary from 0.17 ± 0.03 to 0.79 ± 0.16 cm/year (Ligot et al., 2022). Seedling mortality is mainly due to fungal, insect attack, predation and/or uprooting by small mammals, and drought (Hall, 2008). However, natural mortality of adult trees has not been studied, nevertheless, an average of 1% was observed for 42 timber species in central Africa (Ligot et al., 2022).

The minimum fertility diameter was estimated at 65 cm in Central Africa and the regular fruiting diameter (RFD) at 90 cm. The legal minimum cutting diameter "MCD" varies across its distribution range, (80 cm in Cameroon, Central Africa Republic, Democratic Republic of the Congo, and Republic of Congo, 90 in Gabon and Liberia, and 110 in Ghana). In Central Africa, except in Gabon, MCD is thus lower than RFD . Situations that could locally affect the availability of seed trees and consequently the natural regeneration of the species.

Using the Red List criterion A3, the projected population reduction (PPR) to be met in the future (100 years because the generation length of the species is 199 years) of the *E. candollei* population was assessed across its distribution range. Because *E. candollei* is a widespread species in West and Central Africa, the PPR was estimated for each region.

In Central Africa, three different PPR were thus estimated: PPRpa in protected areas, PPRpf in production forests and PPRnp in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas. First, protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). The population of the species in protected areas covering its range was kept stable in the future over 100 years, suggesting that the PPR in protected areas was 0%. Second, the evolution of the *E. candollei* population was simulated using an Usher matrix model to estimate the PPR of production forests (logging concessions, PPRpf). The simulations were initialised using the density (number of trees.ha^{-1}) per diameter class (from 65 cm diameter, mature individuals) from forest management inventories of logging companies. The evolution of this initial population depended on several demographics (recruitment, mortality, and growth rate) and logging parameters (minimum cutting diameter, cutting and damage rate) that were adjusted using data of permanent tree plot monitoring. Thus, the density of *E. candollei* in 100 years was predicted with a logging event every 25 years, which corresponds to the average cutting cycle in Central Africa. PPRpf was then calculated as the difference between initial and final number of trees. Third, the major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Illegal logging and the habitat lost from deforestation rate have been both activities that allowed estimating the PPRnp in non-permanent domains.

In West Africa, the forest areas were subject to a constant annual deforestation rate of 1.20% year-1 (Vancutsem et al., 2021). Taking this rate of deforestation as constant over the next 100 years, when it is expected to decline, is a reasonable precautionary measure.

We thus had two different PPR: PPRC in Central Africa and PPRW in West Africa. The global PPR was then computed after weighting the two values by their relative forest areas. The global PPR result was found to vary from 28.43 to 30.82% higher than 30%.

- **Population Information**

Current Population Trend: Decreasing

Extreme fluctuations? (in # of mature individuals)	Justification
No	-

Severely fragmented?	Justification
No	-

Continuing decline in mature individuals?	Qualifier	Justification

Continuing decline % in mature individuals within 3 generations or 10 years, whichever is longer (up to max. of 100 years in the future)	Qualifier	Justification

Extreme fluctuations in the number of subpopulations	Justification
No	-

Continuing decline in number of subpopulations	Qualifier	Justification
No	-	-

All individuals in one subpopulation: No

Number of Subpopulations	Justification	Subpopulation Details	Subpopulation description	Number of mature individuals	Subpopulation trend	Qualifier	Location type	Number of Subpopulations	Location bounding box	Location coordinates	Notes
3	Genetic analyses using 13 nuclear microsatellites for 250 individuals sampled across the										

distribution range of the species (Monthe, 2019)

- **Population Reduction - Past**

Percent Change in past	Reduction or Increase	Qualifier	Justification

Basis?

Reversible?

Understood?

Ceased?

- **Population Reduction - Future**

Percent Change in future	Reduction or Increase	Qualifier	Justification
28 - 30%	Reduction	Projected	Using the Red List criterion A3, the projected population reduction (PPR) to be met in the future (100 years because the generation length of the species is 199 years) of the *E. candollei* population was assessed across its distribution range. Because *E. candollei* is a widespread species in West and Central Africa, the PPR was estimated for each region. In Central Africa, three different PPR were thus estimated: PPRpa in protected areas, PPRpf in production forests and PPRnp in non-

permanent domain. These three different PPR estimates were weighted by their relative forest areas. First, protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). The population of the species in protected areas covering its range was kept stable in the future over 100 years, suggesting that the PPR in protected areas was 0%. Second, the evolution of the *E. candollei* population was simulated using an Usher matrix model to estimate the PPR of production forests (logging concessions, PPRpf). The simulations were initialised using the density (number of trees.ha^{-1}) per diameter class (from 65 cm diameter, mature individuals) from forest management inventories of logging companies. The evolution of this initial population depended on several demographics (recruitment, mortality, and growth rate) and logging parameters (minimum cutting diameter, cutting and damage rate) that were adjusted using data of permanent tree plot monitoring. Thus, the density of *E. candollei* in 100 years was predicted with a logging event every 25 years, which corresponds to the average cutting cycle in Central Africa. PPRpf was then calculated as the difference between initial and final number of trees. Third, the major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Illegal logging and the habitat lost from deforestation rate have been both activities that allowed estimating the PPRnp in non-permanent domains.

In West Africa, the forest areas were subject to a constant annual deforestation rate of 1.20% year-1 (Vancutsem et al., 2021). Taking this rate of deforestation as constant over the next 100 years, when it is expected to decline, is a reasonable precautionary measure.

We thus had three different PPR: PPRC in Central Africa and PPRW in West Africa. The global PPR was then computed after weighting the two values by their relative forest areas. The global PPR result was found to vary from 28.43 to 30.82% higher than 30%.

Basis?
b) an index of abundance appropriate for the taxon, d) actual or potential levels of exploitation

- **Population Reduction - Ongoing**

Both: Percent Change over any 10 year or 3 generation period, whichever is longer, and must include both past and future, future can't go beyond 100 years	Reduction or Increase	Number of years for this period	Qualifier	Justification

Basis?

Reversible?

Understood?

Ceased?

- **Habitats and Ecology**

Entandrophragma candollei is a large tree reaching 60 m in height and 3 m in diameter. It is a ong-lived non pioneer species (Doucet, 2003; Kouadio, 2009; Meunier et al., 2015) and seedlings or saplings can tolerate a certain level of shade (Kasongo-Yakusu et al., 2018). It forms root associations with arbuscular mycorrhizal fungi and is established on very acidic soils (Hall et al., 2003). Hall et al. (2004) reveal that *E. candollei* would preferentially establish on soils with low available phosphorus (P), relatively low pH, and relatively low in exchangeable bases (Ca++, Mg++, Mn++). Its young stems can be found in forest gaps not far from the producer, or in the undergrowth, waiting for an opening to continue their development.

E. candollei bears hermaphrodite flowers. In Ghana, Ivory Coast and Liberia, the trees are leafless for a short period in October, and they usually flower from November to December (Kasongo-Yakusu et al., 2018; Nyunaï, 2008). In the northern Republic of the Congo, flowering occurs from 23 cm in diameter (Ouédraogo et al., 2018). It is a pterochorous species and its seeds are wind dispersed (Doucet, 2003; Kasongo-Yakusu et al., 2018). In Cameroon, Republic of Congo, and Central Africa Republic the fruiting period is respectively between March-May and November, March-April and December and November-April and in Gabon it is between March-April or September-October (Meunier et al., 2015). While in Ghana, Ivory Coast and Liberia the fructification period is from May to August (Kasongo-Yakusu et al., 2018). In favourable conditions (high winds), the fruits can be transported up to 500 m from the tree (Monthe, 2019). Consequently, the seedlings preferentially settle in the direction of the prevailing winds (SSW) in the Northern Republic of the Congo (Monthe, 2019).

- **IUCN Habitats Classification Scheme**

Habitat	Season	Suitability	Major Importance?
1.6. Forest -> Forest - Subtropical/Tropical Moist Lowland	Resident	Suitable	Yes

- **Continuing Decline in Habitat**

Continuing decline in area, extent and/or quality of habitat?	Qualifier	Justification
Yes	Observed	The annual deforestation rate of 0.35% and 1.2% in Central and West Africa respectively (Vancutsem et al., 2021).

- **Life History**

Generation Length	Justification	Data Quality
199	Minimum estimate of generation length for the species from the average growth rate, and the mean diameter of mature individuals (see Supplementary Material).	good

Age at maturity: female or unspecified
150 Years

Age at Maturity: Male
150 Years

Size at Maturity (in cms): Female
65

Size at Maturity (in cms): Male
65

Reproductive Periodicity
Annual

Annual Rate of Population Increase

Natural Mortality
1% (Ligot et al. 2022)

- **Systems**

System: Terrestrial

- **Plant / Fungi Specific**

Wild relative of a crop? No

Plant and Fungal Growth Forms
Tree - large

- **Use and Trade**
- **General Use and Trade Information**

Entandrophragma candollei is frequently exploited in Central Africa (Eba'a Atyi et al., 2022).

At industrial level, *E. candollei* is used for construction, exterior and interior joinery, shipbuilding, furniture making, cabinetry, veneers and plywood. It is suitable for flooring, interior trim, vehicle frames, toys, trinkets, boxes, crates and turning (Kasongo-Yakusu et al., 2018; Nyunaï, 2008). In 1970, Ivory Coast was the main exporter of *E. candollei*, with annual exports of 77 000 m³ of logs and 6 000 m³ of sawn wood. *E. candollei* is one of Ghana's most valuable timber species for export. Between 1996 and 2005, Gabon exported 2,100 m³ of logs/year. In 2003, Cameroon exported 4 000 m³ of logs and 19 250 m³ of sawn wood. In the same period, the Central African Republic exported 1 000 m³.. In 2010, Cameroon, the Republic of Congo and the Democratic Republic of Congo exported 11 661, 5 211 and 3 551 m³ respectively (ATIBT, 2010).. More globally, in 2016, Central Africa, produce 118 756 m³ (FRMi, 2018) and 72 933 m³ of log in 2018 (Eba'a Atyi et al., 2022).

At a local level, the bark of *E. candollei* can be used in traditional medicine. Externally, the juice of the bark is used as an analgesic, and the juice of the root bark is applied to snake bites.

Subsistence:	Rationale:	Local Commercial:	Further detail including information on economic value if available:
Yes	-	Yes	-

National Commercial Value: Yes

International Commercial Value: Yes

Is there harvest from captive/cultivated sources of this species? Yes

Trend in level of total offtake from wild sources: Stable

Trend in level of total offtake from domesticated sources: Unknown

- **Non- Consumptive Use**

Non-consumptive use of the species? true

- **Threats**

The main threats in the non-permanent domain across the species' distribution range, are mainly related to habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging and the abusive harvesting of plant parts requested as non-wood forest products (Bradshaw et al., 2009). In Central Africa, illegal logging accounts for nearly 46% of total log production (FRMi, 2018). This production generally comes from unallocated forest areas (non-permanent forest domain).

E. candollei is exploited in Central Africa. In West and East Africa, forests are generally not managed in concessions, and the large part of the rainforest has been transformed into cultivated areas (Nix, 2019).

- **Threats Classification Scheme**

No past, ongoing, or future threats exist to this species. false

Threat	Timing	Scope	Severity	Impact Score
1.1. Residential & commercial development -> Housing & urban areas	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4
2.1.1. Agriculture & aquaculture -> Annual & perennial non-timber crops -> Shifting agriculture	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
2.2.2. Agriculture & aquaculture -> Wood & pulp plantations -> Agro-industry plantations	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5

2.3.2. Agriculture & aquaculture -> Livestock farming & ranching -> Small-holder grazing, ranching or farming	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4
3.2. Energy production & mining -> Mining & quarrying	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
4.1. Transportation & service corridors -> Roads & railroads	Past, Likely to Return	Minority (<50%)	Slow, Significant Declines	Low Impact: 4
5.3.1. Biological resource use -> Logging & wood harvesting -> Intentional use: (subsistence/small scale) [harvest]	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 4
5.3.2. Biological resource use -> Logging & wood harvesting -> Intentional use: (large scale) [harvest]	Ongoing	Minority (<50%)	Slow, Significant Declines	Medium Impact: 6
7.1.3. Natural system modifications -> Fire & fire suppression -> Trend Unknown/Unrecorded	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4

• Conservation

Entandrophragma candollei appear in 4 ex situ collections (BGCI, 2022), and may occur in many protected areas considering its distribution range. In legal forest concessions where the species is exploited, permanent forest plots are usually installed. These plots provide important data for (i) quantifying population dynamics processes at the stand level: mortality, growth and recruitment; (ii) phenological studies to determine the regular fruiting diameter (RFD).

These plots are managed in collaboration with forest concessions grouped within the DYNAFAC collective (see here for more information https://www.dynafac.org/fr/p/130/installation-de-dispositifs-de-suivi-de-la-dynamique-forestiere). Compilation of these data provide important additional information for targeted silvicultural measures for the sustainable management of this species. First summaries have provided information on important parameters such as: mortality, growth, etc. (DYNAFAC, 2022; Ligot et al., 2022). Based on almost 40 years of monitoring forest dynamics in Central Africa, the DYNAFAC collective recommends a MCD of 100 cm in Central Africa to maintain optimal gene flow and optimal regeneration (DYNAFAC, 2022). DYNAFAC also recommends the preservation of additional seed trees or the implementation of regeneration support techniques to ensure the long-term maintenance of populations. *E. candollei* is also monitored in nurseries and planted in various forest concessions.

Logging in Central Africa is subject to strict legislation, species can only be harvested above a certain diameter and measures must be taken to ensure the renewal of the resource (Fargeot et al., 2004). Indeed, management plans for tropical rainforests require the determination of a minimum cutting diameter (MCD) to ensure a minimum renewal rate at the end of a rotation period (duration between two cuts on the same cutting base), the minimum reconstitution rate (40-50% depending on the country) as well as the rotation duration, being imposed by forestry legislation (Durrieu de Madron and Forni, 1997).

In addition, it will also be necessary to :

- Ensure the implementation of the recommendations of the Dynafac collective, including the establishment of a system for monitoring the populations of commercial species in the different forest types defined in a consensual manner;
- Set up monitoring and support systems for the regeneration of commercial species, prioritising species with regeneration deficits;
- Set up programmes to guarantee the phenotypic quality of commercial species populations: seed banks, seed stands, plus trees, seed orchards, conservation plantations;
- Consider threatened species in the delimitation of conservation series and in the identification of High Conservation Values;
- Update conservation statuses on a five-yearly basis, in particular by setting up a system of "green statuses";
- Define red lists adapted to regional or national contexts;
- Evaluate the status of cryptic species or species close to commercial species evaluated during this workshop.

- **Conservation Actions In- Place**

Action Recovery Plan	Note
Yes	Enrichment within legal forest concessions

Systematic monitoring scheme	Note
Yes	The species is monitored in permanent plots installed within forestry companies in Central Africa (see https://www.dynafac.org/fr)

Occur in at least one PA	Note
Yes	The species may appear in at least 100 protected areas considering it distribution range

Percentage of population protected by PAs (0-100)	Note
1-10	Considering protected area across species distribution range

Area based regional management plan	Note
Unknown	-

Invasive species control or prevention	Note
No	-

Harvest management plan	Note
Yes	In legal forest concessions, the species is exploited according to a management plan.

Subject to ex-situ conservation	Note
NO	-

Included in international legislation	Note
No	-

Subject to any international management/trade controls	Note
No	

- Important Conservation Actions Needed

Conservation Actions	Note
3.1.1. Species management -> Species management -> Harvest management	-
3.1.2. Species management -> Species management -> Trade management	-
3.4.2. Species management -> Ex-situ conservation -> Genome resource bank	-

- Research Needed

Research	Note
1.2. Research -> Population size, distribution & trends	-
3.1. Monitoring -> Population trends	-
3.2. Monitoring -> Harvest level trends	-
3.3. Monitoring -> Trade trends	-

- Ecosystem Services

- Ecosystem Services Provided by the Species

	Importance:	Geographic range of benefit:
1. Water Quality	2 - Important	Global
3. Flood Control	2 - Important	Global
4. Climate Regulation	2 - Important	Global
5. Landscape	2 - Important	Global
6. Air Quality	2 - Important	Global
7. Nutrient Cycling	2 - Important	Global
8. Habitat Maintenance	2 - Important	Global

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• SUPPLEMENTARY MATERIAL

Entandrophragma candollei - Harms

• IUCN status using criterion A3

We adopted the criterion A3 to assess the projected population reduction (PPR) to be met in the future (up to a maximum of 100 years) of *Entandrophragma candollei*. To quantify the projected population reduction, simulations must be performed on mature individuals and three generations with maximum 100 years according to **criterion A3**. We estimated mature individuals and generation length, as recommended by the IUCN guidelines.

A **mature individual** is an individual that can reproduce, able to bear flowers or seeds (fertile in plant kingdom). To quantify the mature individuals for each species, we used phenological data of DYNAFAC network[10] from a combined dataset of 57 trees belonging to three sites in three countries (Cameroun, Central African Republic, and Republic of Congo). Minimum and maximum sampled diameters ranged from 12 to 162 cm (median 42 cm). The monitoring period ranged from 2015 to 2021(Ouédraogo et al., 2018). We assumed that the monitoring period was long enough to capture at least one reproductive event per tree such that trees without observed flowering/fruiting events were considered non-reproductive (63 percent of all monitored trees were non-reproductive). We used the methodology for the size at reproduction of canopy tree species in Central Africa (Ouédraogo et al., 2018): the **diameter of a mature individual** was obtained after fitting logistic regressions and the level of 50% of the probability to produce the flower or fruit was adopted for this species. Using this approach, the diameter of a mature individual was obtained after setting the 50% probability to produce flowers or fruits. The minimum diameter of mature individuals for this species was **65 cm**.

The **generation length** was the report between the mean diameter of mature individuals considering population structure and the mean increment. Given that the minimum diameter of mature individuals was 65 cm, we weighted the total number of trees by their diameter from 65 cm to 125 cm (see Figure 1) to compute the number of mature individuals. The mean diameter of mature individuals was **86 cm**. The **mean increment** of the species was **0.432 cm**, obtained from 818 observations of published data (Ligot et al., 2022) and unpublished data in two countries (Cameroon and Republic of Congo). Thus, the **generation length** was 86 cm / 0.432 cm = **199 years**. The age at maturity (**150 years**) has been estimated as the report between the **minimum diameter of mature individuals** (**65 cm**) and the **mean annual increment** (**0.432 cm)**.

• Estimation of the projected population reduction (PPR)

We adopted the criterion A3 to assess the projected population reduction (PPR) to be met in the future (up to a maximum of 100 years). *Entandrophragma candollei*, is found in Guineo–Congolian rainforest species, widely distributed mainly from Guinea-Bissau to Democratic Republic of Congo. The geographic range of species was in

[10] https://www.dynafac.org/en

two regions (Central Africa and West Africa) characteristic of two biogeographical regions across the tropical African forests (Fayolle et al., 2014). According to each region, different data (deforestation annual rate, growth, mortality, recruitment, forest inventory, etc.) have been used with logging data in Central Africa. Thus, the PPR was estimated for each region and the global PPR was then computed after weighting the two values by their relative forest areas.

- **PPR in Central Africa**

In this region, forest management follows three different modalities: protected areas, production forests (logging concessions) and non-permanent forest domain. Based on occurrences, the natural range of this species includes all countries in Central Africa (Figure 1). The total natural area is estimated at 200 997 912.5 ha. Within this area, there are 56 434 869.2 ha (28.1%) for production forests, 17 677 021.3 ha (8.8%) for protected areas, and 126 886 022 ha (63.1%) for the non-permanent domain.

Three different PPR were thus estimated: PPR_{pa} in protected areas, PPR_{pf} in production forests and PPR_{np} in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas and then added to estimate the PPR_C in Central Africa.

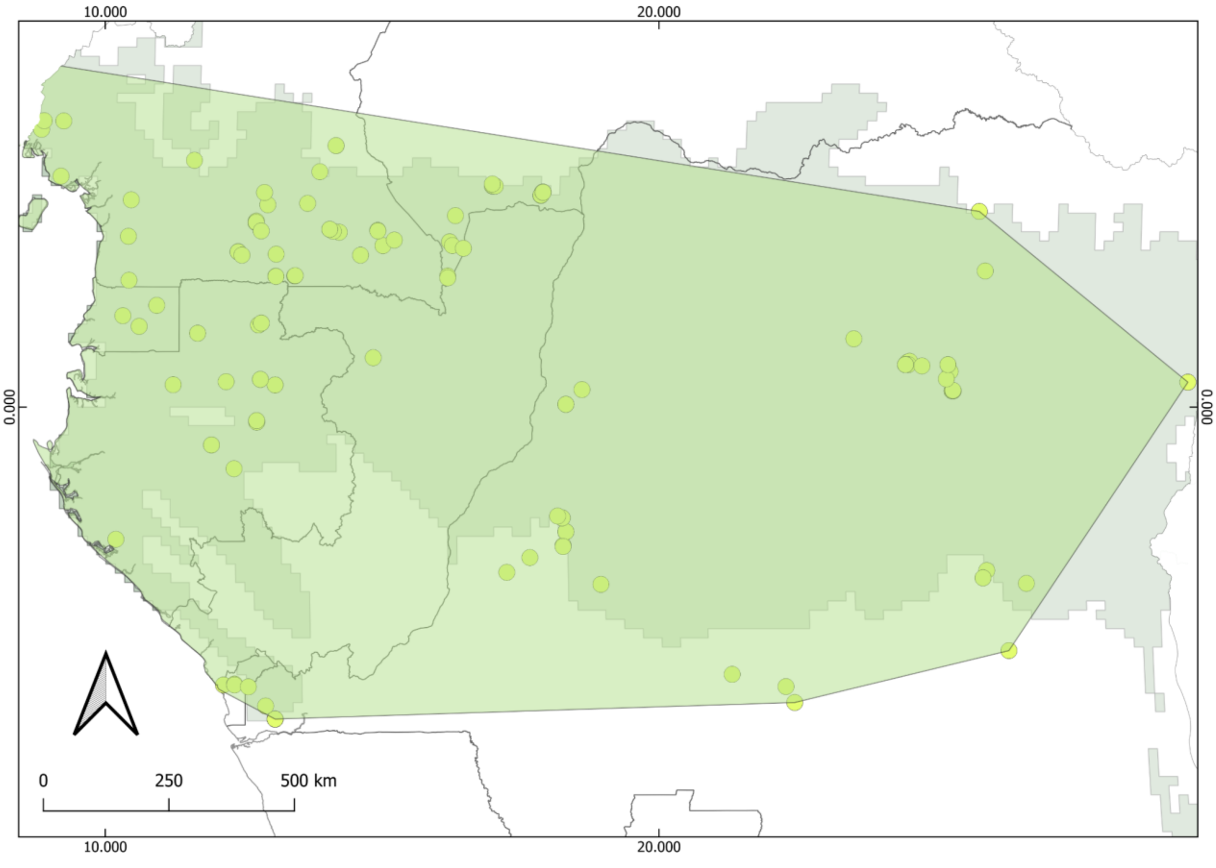

Figure 1. The range of *Entandrophragma candollei* in Central Africa estimated from RAINBIO and CJB data, validated in December 2022 during a workshop with a group of experts in Gabon.

- **PPR in protected areas**

Central Africa countries have allocated a higher proportion of their land to conservation than any other tropical regions, with relatively higher conservation success (Laurance et al., 2012). Indeed, most protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). They are currently representing a large part of forest and tree species conservation in Central Africa. Thus, the population of each species in protected areas (according to FRMI, 2018) covering its range was kept stable in the future over 100 years. **In these conditions, it was hypothesized that the PPR in protected areas for each species is 0%, suggesting no population reduction in the present and future.**

- **PPR in production forests**

To quantify the evolution of the population of each timber species, matrix population models are widely used to study population dynamics (Picard & Liang, 2014). The population of this species was described at time t by a vector N_t corresponding to the density (number of trees ha^{-1}) in each diameter class (from 20 cm diameter to more than 120 cm). The density per diameter class was estimated using data from forest inventories that were carried out in 85 forest management units (FMU) of different logging companies in five countries (Cameroon, Central African Republic, Democratic Republic of the Congo, Gabon, and Republic of the Congo). Most logging companies followed a standardized inventory protocol (Réjou-Méchain et al., 2011). These forest inventory data covered about 19 million ha (Table 1), that are representative of 33% of Central Africa's production forests of this species. The number of trees sampled in Central Africa was 7 522 971 with a density of 0.400 tree ha^{-1}. Large-scale commercial inventories have already been found useful in the identification of large-scale patterns in Central Africa (Réjou-Méchain et al., 2011). Using large-scale data from commercial forest inventories, Réjou-Méchain et al. (2021) jointly model the distribution in the abundance of the most dominant tree species and produce continuous maps of the floristic and functional composition of central African forests.

Table 1. Forest management units (FMU) sampled in Central Africa (Cameroon, CAR: Central African Republic, DRC: Democratic Republic of the Congo, EG: Equatorial Guinea, Gabon and RCongo: Republic of the Congo).

	Sampling	
Country	FMU	Area (ha)
Cameroon	21	1 839 643.78
CAR	7	2 165 837
DRC	15	4 348 051
EG	-	-
Gabon	34	6 474 443
RCongo	8	4 005 312
Total	85	18 833 286.78

The Usher matrix model was used to simulate the evolution of the recovery rate of all population and the exploitable stock of each species after logging in Central Africa. According to the Usher assumption, between t and t+1, an individual can either stay alive in the same class, stay alive and move up to the next class, or die; it cannot move up by more than one class or move backwards, i.e., the individual is free from diameter shrinkage (Picard et al., 2012). The Usher matrix model (U) considers three parameters (mortality, recruitment and growth rate that are constant in time) to estimate the transition probabilities:

$$U = \begin{pmatrix} q_1 + g_1 & g_2 & \cdots & \cdots & g_I \\ p_1 & q_2 & 0 & \cdots & 0 \\ 0 & \ddots & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & p_{I-1} & q_I \end{pmatrix}$$

where q_i is the probability for an individual to stay alive in class i between two consecutive time steps, p_i is the upgrowth transition rate (the probability for an individual to grow up from class i to class $i+1$), and g_i is the recruitment rate (Picard & Liang, 2014).

Tree mortality, recruitment and growth are three central processes for predicting the dynamics of tropical rainforests and estimating these three processes requires long-term monitoring in difficult field conditions (Picard & Gourlet-Fleury, 2008). These processes determine the evolution of the species population in the forest stand. The natural mortality is defined as the number of standing dead trees, and few studies have reported estimates of mortality rates in Central Africa. Data about tree mortality are still scarce and it does not allow to precisely model the mortality rate for each species and size class. Given the current state of knowledge, it appears reasonable to use a fixed mortality rate of 1% for all species and size classes, in agreement with the results of Ligot et al. (2022) on 21,180 trees belonging to 42 timber species of Central Africa annually monitored from one to seven years.

The recruitment integrates fruiting and seed dispersal from mother trees, and the survival of plant juveniles until they reach a size threshold where they are included in the stand. The recruitment term in the model is the average annual input of new individuals into the first size class from 20 cm. The recruitment events, like mortality events, are infrequent and thus difficult to model (Karsenty & Gourlet-Fleury, 2006). The population structure showed a single-mode curve with a good representation of the small stems suggesting a good regeneration (Figure 2). Simulations in production forests were performed using the minimum diameter of mature individuals. For this species, the minimum diameter of mature individuals was 65 cm. Since trees recruited from 20 cm with a growth of 0.432 cm per year, it takes more than 100 years for these trees to reach 65 cm to be considered in the simulation. Given that the simulation has been performed over 100 years, there was not a tree recruitment effect in the PPR results in production forests. To model the recruitment, we used the hypothesis defined as the recruitment rate that would maintain a constant number of trees in the first diameter class. Claeys et al. (2019) projected the future forest dynamics up to the end of the century and they showed that projected mortality and recruitment rates in 2099 could not differ from the ones observed today. Thus, the hypothesis on the recruitment and the mortality rate is used in the future (up to 100 years) as they do today.

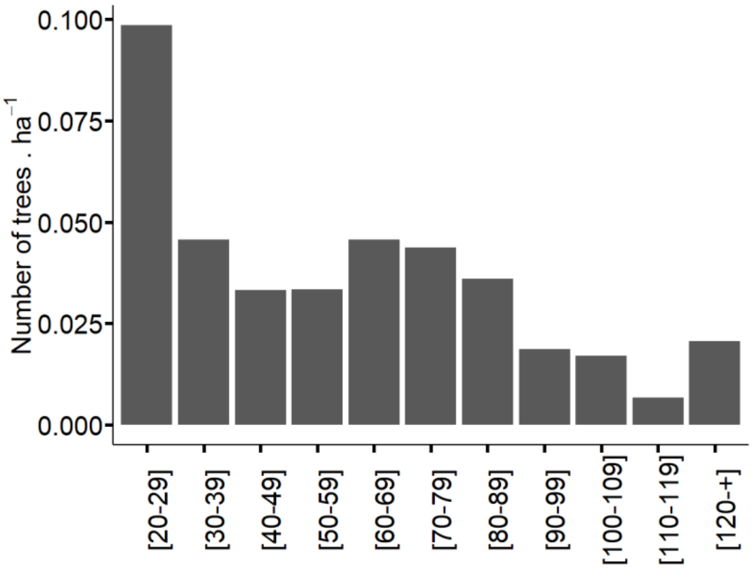

Figure 2. The population structure of *Entandrophragma candollei* (kosipo) is defined using the number of trees per ha and per diameter class (from 20 cm of 85 logging concessions covering an area of 18 833 286.78 ha in Central Africa).

Since the mid-1900s, periodic tree monitoring and tree ring analyses have been carried out to study variability in tree growth across species in Central Africa (Durrieu de Madron, Nasi, et al., 2000; Ligot et al., 2019, 2022). We fitted growth models for each species using data from logged and unlogged areas of permanent tree plot monitoring from the DYNAFAC[11] network covering the five Central African countries. From the combined dataset, we identified 91 trees in Gabon. Minimum and maximum sampled diameter ranged from 10 to 204 cm. The monitoring period ranged from 2005 to 2017. The mixed second-degree polynomial model (with random site effect) was fitted for this species. The estimated coefficient from second-degree polynomial model has been used in the simulation to estimate the diameter growth (Table 2).

Table 2. Estimated coefficients (a, b and c) of growth models between the increment (ac in cm year^{-1}) and the initial diameter (D in cm). The sample including the number of trees (n) and the number of sites (site) are also given. * significant (p-value < 0.05) and ^{ns} non-significant (p-value > 0.050)

species	n	site	model	a	b	c
kosipo	822	6	ac ~ D + D^2 +(1|site)	-0.07^{ns}	0.016*	-0.00007*

The transition probabilities of three parameters (mortality, growth, and recruitment rate) allowed making the harvested matrix. The logging operations have been modeled using the logging parameters (minimum cutting diameter, cutting and damage rate). The minimum cutting diameters were obtained from decrees of application of

[11] https://www.dynafac.org/en

the forestry administrations (MCD_A) at the country level and the one used in the management plan (MCD_M, with $MCD_M \geq MCD_A$) at the logging company level. At the Central Africa level, we weighted the MCD_A and MCD_M values to the occupied area (**MCD_A = 80 and MCD_M = 90 cm**). The cutting rate (CA), which defines the proportion of harvested trees (trees with a diameter greater than MCD_A or MCD_M), was given by logging companies, and it was also weighted at the Central Africa level with a value of 86%. Given the current state of knowledge, it appears reasonable to use a fixed damage rate caused by logging of 7% of the initial population that disappears (Durrieu de Madron, Fontez, et al., 2000). The average cutting cycle (i.e. the period between two successive logging operations) is 28 years (FRMI, 2018), but we used 25 years to simplify computation of four simulations reaching 100 years (25, 50, 75 and 100 years), as requested by IUCN criterion A.

The Figure 3 shows the PPR in production forests for the *Entandrophragma candollei*. The reduction in the population of each species was then calculated as the difference between the initial numbers of mature individuals and the predicted numbers of mature individuals (55 cm) predicted after 100 years. The PPR in production forest was from **− 73.83 % (MCD_A) to − 68.05 (MCD_M) over 100 years.**

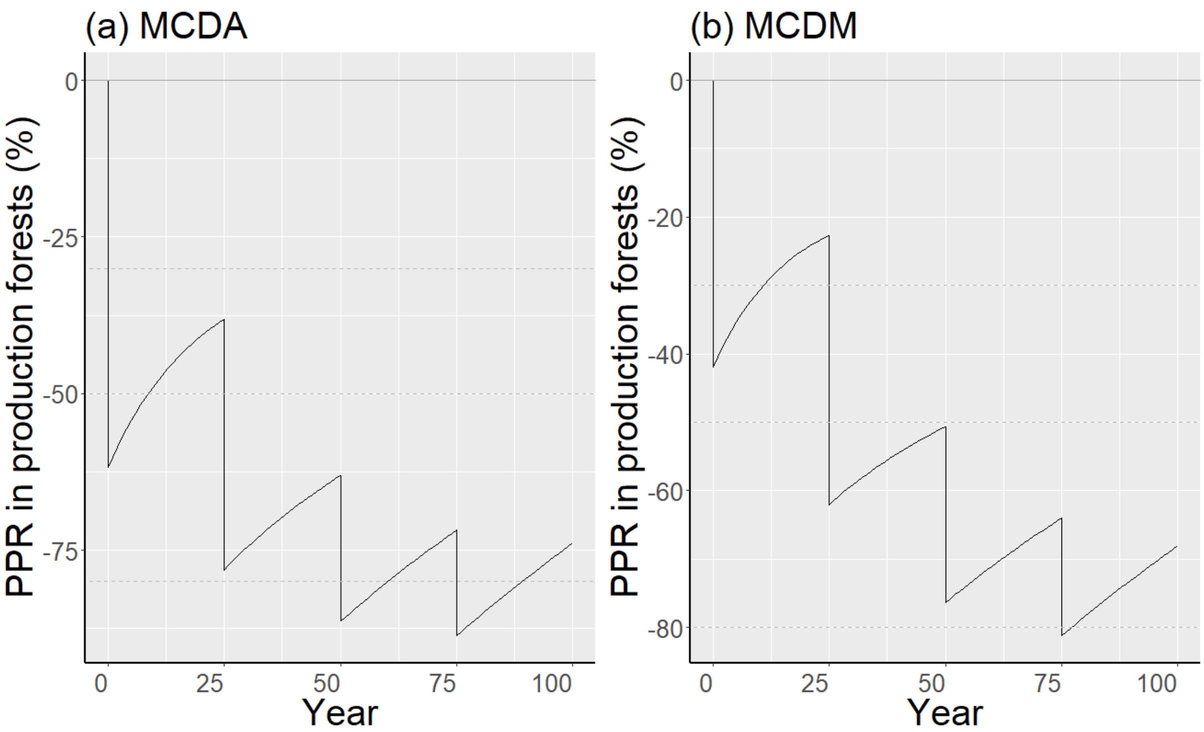

Figure 3. Simulations showing the projected population reduction (PPR) from diameter of mature individuals (65 cm) in production forests for the *Entandrophragma candollei* over 100 years for constant recruitment.

- **PPR in the non-permanent forest domain**

The major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanization, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Based on the large range of this species in Central Africa, the harvested volume from illegal logging and legal logging are 46% and 54%, respectively (FRMI

2018). In this condition, it was hypothesized that there is 54% of PPR from production forests and 46% of PPR from illegal logging in 100% PPR due to forest logging. Given that the PPR of production forests associated with its forest area was known, we deduced the PPR and forest area of illegal logging from those of the production forests. As a result, 48 074 147.9 ha were affected for the illegal logging for this species. The non-permanent domain area (126 886 022 ha) was considered as the area which was related to today's deforestation rate of 0.35% $year^{-1}$ in Central Africa (Vancutsem et al., 2021). This is a conservative value since it will probably decrease in the future (Swamy et al., 2018).

The PPR in Central Africa by considering the PPR in production forest, protected area and non-permanent domain was**– 30.36 % (MCD_A) to – 32.92 (MCD_M) over 100 years.**

- **PPR in West Africa**

In this region, forests are generally not managed in concessions, and the large part of the rainforest has been transformed in cultivated areas (Nix, 2019). Given the high degree of anthropization in this area, the main threats are the habitat loss due to the destruction of natural environments and illegal logging, and the trees are frequently felled in fields. Applying the deforestation rate related to agricultural production can be considered as a proxy for tree removal. Thus, the forest areas in West Africa (15 600 000 ha) were subject to a constant annual deforestation rate of 1.20% $year^{-1}$ (Vancutsem et al., 2021). Taking this rate of deforestation as constant over the next 100 years, when it is expected to decline, is a reasonable precautionary measure incorporating illegal logging.

- **PPR global**

We thus had two different PPR: PPR_C in Central Africa and PPR_W in West Africa. The global PPR was then computed after weighting the two values by their relative forest areas:

$$PPR = \frac{(S_C \times PPR_C) + (S_W \times PPR_W)}{S_C + S_W}$$

where S_C and S_W are forest areas in Central and West Africa, respectively.

The criterion A3 based on (c) a decline in area of occupancy (AOO), extent of occurrence (EOO) and/or habitat quality; and (d) potential levels of exploitation, has been computed as follow: (i) 30%≤PPR<50%, the species is considered as Vulnerable (VU); (ii) 50%≤PPR <80%, the species is considered as Endangered (EN), and PPR ≥ 80%, the species is considered as Critically endangered (CR).

The PPR global in distribution range of the *Entandrophragma candollei* was The PPR in production forest was from **– 28.43 % (MCD_A) to – 30.36 (MCD_M) over 100 years.** This PPR is > 30% and < 50%, suggesting that this species is threatened under the status of **Vulnerable (VU)** in its geographic area.

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10.7 Annexe 7. *Entandrophragma cylindricum* - (Sprague) Sprague

Draft

Entandrophragma cylindricum - (Sprague) Sprague

PLANTAE - TRACHEOPHYTA - MAGNOLIOPSIDA - SAPINDALES - MELIACEAE - Entandrophragma – cylindricum

Common Names: Sapelli (French), Sapele (English), Aboudikrou, Ijebu, Libuyu, Muyovu, Ogiekpogo, Owura, Penkwa, Sapelli, Ubilesan

Synonyms: *Entandrophragma lebrunii* Staner (1930)
Entandrophragma angolense Auct. Non C.DC.
Entandrophragma tomentosum A.Chev. ex Hutch. & Dalziel (1928)
Entandrophragma rufum A.Chev. (1909)
Pseudocedrela cylindrica Sprague

Red List Status
NT – Near Threatened, A3cd (IUCN version 3.1)

- **Red List Assessment**

- **Assessment Information**

Date of Assessment: 2022-09-01
Assessor(s): Monthe, F., Loubota, G., Ligot, G., Texier, N., Stévart, T. & Doucet, JL.
Reviewer(s):
Institution(s):
Acknowledgements: This evaluation was performed by the project «Actualisation du statut de vulnérabilité des espèces ligneuses exploitées en Afrique centrale » grant number C224, funded by PPECF (Programme de Promotion de l'Exploitation Certifiée des Forêts) and the Gembloux Agro-Bio Tech faculty of the University of Liège through the AFRITIMB project subsidised by the FRFS-WISD (grant number PDR-WISD-07). We thank the forestry companies active in Central Africa and the consultancy firms (FRMi, Sylvafrica, and TEREA) for providing the management inventory data, the non-profit organisation Nature+ asbl, and the DYNAFAC collective for providing demographic data (mortality and growth). We express our gratitude to ATIBT (Association Technique Internationale des Bois Tropicaux) and ANPN (Agence Nationale des Parcs Nationaux du Gabon) for supporting this project «Actualisation du statut de vulnérabilité des espèces ligneuses exploitées en Afrique centrale ». We are also grateful to DYNAFAC collective through the P3FAC project funded by FFEM (Fonds Français pour l'Environnement Mondial) (grant number CZZ 2101.01R) and to the Fondation Franklinia for supporting this evaluation.

Regions: Global

- **Identification Description**

Entandrophragma cylindricum, is a very large tree that can exceed 60 m in height and more than 2 m in diameter, with a rounded and dark crown. With age, it develops thick buttresses at its base, sometimes very large. Its straight and cylindrical trunk, silver-grey to brown, is finely roughened with lenticels in young trees. It is then covered with scales which, when detached, form numerous depressions in older trees, giving it a pitted appearance. Its slash is pinkish to orange, turning quickly to brown, it gives off a very strong perfume. Its leaves, grouped at the end of the branches, are composed of 10 to 18 leaflets, usually alternate. The limb papyraceous to slightly coriaceous is of variable form, asymmetrical with some spaced secondary veins (6-10 pairs) joined together in arch before the margin. Its 7-25 cm long inflorescences are composed of green flowers. Its fruits are elongated capsules that look like cigars (10-22 x 2.5-4 cm), opening at the top in 5 valves with a relatively smooth surface and black on the ground. They contain light brown flattened seeds with long straight wings 6-11 cm long.

- **Assessment Rationale**

Entandrophragma cylindricum is a widespread tall tree in African moist evergreen and semi-deciduous Guineo-Congolian forest, long-lived, non-pioneer light-demanding and usually non-gregarious species, which forms root associations with arbuscular mycorrhizal fungi. It is distributed from Sierra Leone to Uganda. Based on a 2 x 2 km cell size, the AOO of this species is estimated as 608 km^2 with a minimum of 70 locations (number of forest management units of different logging companies in Central Africa). This species is not "Vulnerable" status under criterion B2. The EOO is calculated as 4 091 026 km^2, above the upper threshold for "Vulnerable" status under criterion B1.

Commonly known as Sapelli or Sapele, it is the second most exploited forest species in Central Africa, highly sought after for the quality of its wood. The minimum cutting diameter (MCD) varies from 80 and 100 cm in Central Africa and from 60 to 110 cm in West Africa. It is lower or higher than the regular fruiting diameter (RFD) estimated at 80 cm diameter at breast height (DBH), which can compromise the availability of seed trees. The DYNAFAC collective recommends a MCD of 90 cm in Central Africa to ensure optimal gene flow in populations (DYNAFAC, 2022). The population structure of this species shows a curve suggesting a good regeneration, with a density of 0.70 stems.ha^{-1} (dbh ≥ 20 cm) in Central Africa (see Supplementary Material). Given its stem density and the mean annual increment of 0.63 ± 0.55 cm/year in Central Africa (see Supplementary Material), we estimate the number of mature individuals over 10 000 across the distribution range, well above the threatened category under criteria C and D.

The most serious long-term threat is the conversion of the forest to agriculture, and illegal logging. However, the species is not considered severely fragmented as 366 known occurrences represent more than 50 localities (sensu Comité des normes et des pétitions de l'UICN, 2019). Considering the species' generation length (127 years), an inference of population reduction for three generations in the past is impossible following A1 and A2 criteria. Based on simulations of the expected population reduction on its distribution range including protected areas, non - permanent forest areas and production forest (logging concessions), we estimated population reduction of 16.21 %

in the next 100 years below the threshold to be considered threatened under criterion A3. An assessment of the population reduction according to criterion A4 considering one to two generations back and one to two generations forward would likely introduce high levels of uncertainty due to the lack of data to efficiently model the reduction of population size in the past. No quantitative analysis of the probability of extinction in the wild was conducted, and therefore criterion E does not apply.
Considering (i) the population density, (ii) the incompatibility between MCD and RFD in some countries, and (iii) the reduction of population in the future across the distribution range below the upper threshold for Vulnerable, the species is assessed as near threatened NT, A3cd, and it can be threatened (VU) in future on the criterion A3 with a high level of exploitation.

Reasons for change

Reason(s) for Change in Red List Category from the Previous Assessment:

Entandrophragma cylindricum was previously assessed as "Vulnerable" (https://www.iucnredlist.org/species/33051/9753619) at the African Regional Workshop (Conservation & Sustainable Management of Trees, Zimbabwe, July 1996), 1998, following the A1cd criterion. During the last few years, important data have been produced on the self-ecology, population dynamics (growth, recruitment, mortality) of the species. Moreover, a new version of the IUCN guidelines is available (from version 2.3 to 3.1). Given all these information, it was necessary to produce a new assessment of the species.

- **Distribution**

- **Geographic Range**

Entandrophragma cylindricum is widely distributed from Sierra Leone to Uganda, as well as in Cabinda (Angola) (Kasongo-Yakusu et al., 2018; Kémeuzé, 2008). It is very common in semi-deciduous rainforest, especially on the sites of former human activities. The extent of occurrence (EOO) in native area is estimated at 4 091 026 km^2. Its extension goes from 12° North latitude to 5° South latitude.

- **Area of Occupancy (AOO)**

Estimated area of occupancy (AOO) - in km2	Justification
608	The AOO has been estimated using ConR based on the 2 × 2 km cell size of 366 occurrences from CJB (Conservatoire et Jardin botaniques de Genève) and RAINBIO

Continuing decline in area of occupancy (AOO)	Qualifier	Justification

Yes	Inferred	The species has suffered from reduction in Area of Occupancy, due to habitat degradation and deforestation in West and Central Africa forest (Vancutsem et al., 2021)

- Extent of Occurrence (EOO)

Estimated extent of occurrence (EOO)- in km2	EOO estimate calculated from Minimum Convex Polygon	Justification
4 091 026	true	Calculated using ConR based on 366 known occurrences from CJBD and RAINBIO

Continuing decline in extent of occurrence (EOO)	Qualifier	Justification
Yes	Inferred	The species has certainly undergone Extent of Occurrence reduction in West Africa, linked to the reduction in forest area (Vancutsem et al., 2021)

- Locations Information

Number of Locations	Justification
70-200	More than 70 localities. Based on the most serious plausible threat (conversion of its habitat) and illegal logging across the distribution range.

Continuing decline in number of locations	Qualifier	Justification
Yes	Inferred	The main threat remains the reduction of the forest area in West Africa.

Extreme fluctuations in the number of locations	Justification
No	

- Very restricted AOO or number of locations (triggers VU D2)

Very restricted in area of occupancy (AOO) and/or # of locations	Justification
No	-

- **Elevation / Depth / Depth Zones**

Elevation Lower Limit (in metres above sea level):

Elevation Upper Limit (in metres above sea level):

- **Map Status**

Map Status	Use map from previous assessment	How the map was created, including data sources/methods used:	Please state reason for map not available:	Data Sensitive?	Justification	Geographic range this applies to:	Date restriction imposed:
Done	-	Qgis. The dataset was created from a compilation of Rainbio and CJB	-	-	-	-	-

- **Biogeographic Realms**

Biogeographic Realm: Afrotropical

- **Occurrence**

- **Countries of Occurrence**

Country	Presence	Origin	Formerly Bred	Seasonality
Angola (Cabinda)	Extant	Native	-	Resident
Cameroon	Extant	Native	-	Resident
Central Africa Republic	Extant	Native	-	Resident
Côte d'Ivoire	Extant	Native	-	Resident
Equatorial Guinea	Extant	Native	-	Resident
Gabon	Extant	Native	-	Resident
Ghana	Extant	Native	-	Resident
Liberia	Extant	Native	-	Resident
Nigeria	Extant	Native	-	Resident
Republic of the Congo	Extant	Native	-	Resident
Sierra Leone	Extant	Native	-	Resident
Togo	Extant	Native	-	Resident
Uganda	Extant	Native	-	Resident

Entandrophragma cylindricum is a guineo-congolian species, widely distributed from Sierra Leone to Uganda, as well as Angola (Cabinda). Its average density is 0.70 stem.ha-1 (dbh ≥ 20 cm) in Central Africa (see Supplementary Material). This density can locally reach 3 stems.ha^{-1} in some populations in Eastern Cameroon, Ivory Coast, Liberia or Northern Republic of the Congo (Kasongo-Yakusu et al., 2018; Monthe, 2019)..

The survival rate of *E. cylindricum* seedlings after six months in the understory guineo-congolian forests is 12%, and only 1% of seedlings reach the gaulis stage (Hall et al., 2003; Tabi Eckebil et al., 2017). Seedling mortality is mainly due to fungal, insect attack, predation and/or uprooting by small mammals, and drought (Hall, 2008). Trees planted in the open area in Ivory Coast reached an average height of 5.4 m and an average stem diameter of 10 cm after 7 years, with a survival rate of 74% (Kémeuzé, 2008). The average diameter growth is 0.63 ± 0.55 cm/year in Central Africa for trees with a dbh>10 cm (see Supplementary Material. Natural mortality of adult trees has not been studied in detail, nevertheless, an average of 1% was observed for 42 timber species in central Africa (Ligot et al., 2022).

The minimum fertility diameter is estimated at 35 cm in Central Africa and the regular fruiting diameter (RFD) between 80 cm and 90 cm, depending on the country (see Supplementary Material). The legal minimum cutting diameter "MCD" varies across its distribution range (60 cm in Ivory Coast, 80 cm in Cameroon, Central Africa Republic, Democratic Republic of Congo, and Republic of Congo, 90 in Gabon and Liberia, and 110 in Ghana) (Kasongo-Yakusu et al., 2018; Sépulchre et al., 2008). In some countries (Ivory Coast and Congo), the MCD is lower than, situations that could affect the availability of seed trees and consequently the natural regeneration of the species. However in some logging concessions *E. cylindricum* is planted (Doucet et al., 2016).

Using the Red List criterion A3, the projected population reduction (PPR) to be met in the future (100 years because the generation length of the species is 127 years) of the *E. cylindricum* population was assessed across its distribution range. Because *E. cylindricum* is a widespread species in West, East and Central Africa, the PPR was estimated for each region.

In Central Africa, three different PPR were thus estimated: PPRpa in protected areas, PPRpf in production forests and PPRnp in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas. First, protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). The population of the species in protected areas covering its range was kept stable in the future over 100 years, suggesting that the PPR in protected areas was 0%. Second, the evolution of the *E. cylindricum* population was simulated using an Usher matrix model to estimate the PPR of production forests (logging concessions, PPRpf). The simulations were initialised using the density (number of trees.ha^{-1}) per diameter class (from 35 cm diameter, mature individuals) from forest management inventories of logging companies. The evolution of this initial population depended on several demographics (recruitment, mortality, and growth rate) and logging parameters (minimum cutting diameter, cutting and damage rate) that were adjusted using data of permanent tree plot monitoring. Thus, the density of *E. cylindricum* in 100 years was predicted with a logging event every 25 years, which corresponds to the average cutting cycle in Central Africa. PPRpf was then calculated as the difference between initial and final number of trees. Third, the major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Illegal logging and the habitat lost from deforestation rate have been both activities that allowed estimating the PPRnp in non-permanent domains.

In West and East Africa, the forest areas were subject to a constant annual deforestation rate of 1.20% $year^{-1}$ and 1.53% $year^{-1}$ respectively (Vancutsem et al., 2021). Taking this rate of deforestation as constant over the next 100 years, when it is expected to decline, is a reasonable precautionary measure.

We thus had three different PPR: PPR in Central Africa, PPR in West Africa, and PPR in East Africa. The global PPR was then computed after weighting the three values by their relative forest areas. The global PPR result was found to be 16.21%, lower than 30%.

- **Population Information**

Current Population Trend: Decreasing

Extreme fluctuations? (in # of mature individuals)	Justification
No	-

Severely fragmented?	Justification
No	-

Continuing decline in mature individuals?	Qualifier	Justification

Continuing decline % in mature individuals within 3 generations or 10 years, whichever is longer (up to max. of 100 years in the future)	Qualifier	Justification

Extreme fluctuations in the number of subpopulations	Justification
No	-

Continuing decline in number of subpopulations	Qualifier	Justification
No	-	-

All individuals in one subpopulation: No

Number of Subpopulations	Justification	Subpopulation Details	Subpopulation description	Number of mature individuals	Subpopulation trend	Qualifier	Location type	Number of Subpopulations	Location bounding box	Location coordinates	Notes

3	Genetic analyses using 8 nuclear microsatellites for 513 individuals sampled across the distribution range of the species (Monthe, 2019)	

- **Population Reduction - Past**

Percent Change in past	Reduction or Increase	Qualifier	Justification

Basis?

Reversible?

Understood?

Ceased?

- **Population Reduction - Future**

Percent Change in future	Reduction or Increase	Qualifier	Justification
16.21%	Reduction	Projected	Using the Red List criterion A3, the projected population reduction (PPR) to be met in the future (100 years because the

generation length of the species is 127 years) of the *E. cylindricum* population was assessed across its distribution range. Because *E. cylindricum* is a widespread species in West, East and Central Africa, the PPR was estimated for each region.

In Central Africa, three different PPR were thus estimated: PPRpa in protected areas, PPRpf in production forests and PPRnp in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas. First, protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). The population of the species in protected areas covering its range was kept stable in the future over 100 years, suggesting that the PPR in protected areas was 0%. Second, the evolution of the *E. cylindricum* population was simulated using an Usher matrix model to estimate the PPR of production forests (logging concessions, PPRpf). The simulations were initialized using the density (number of $trees.ha^{-1}$) per diameter class (from 35 cm diameter, mature individuals) from forest management inventories of logging companies. The evolution of this initial population depended on several demographics (recruitment, mortality, and growth rate) and logging parameters (minimum cutting diameter, cutting and damage rate) that were adjusted using data of permanent tree plot monitoring. Thus, the density of *E. cylindricum* in 100 years was predicted with a logging event every 25 years, which corresponds to the average cutting cycle in Central Africa. PPRpf was then calculated as the difference between initial and final number of trees. Third, the major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Illegal logging and the habitat lost from deforestation rate have been both activities that allowed estimating the PPRnp in non-permanent domains.

In West and East Africa, the forest areas were subject to a constant annual deforestation rate of 1.20% $year^{-1}$ and 1.53% $year^{-1}$ respectively (Vancutsem et al., 2021). Taking this rate of deforestation as constant over the next 100 years, when it is expected to decline, is a reasonable precautionary measure.

	We thus had three different PPR: PPR in Central Africa, PPR in West Africa, and PPR in East Africa. The global PPR was then computed after weighting the three values by their relative forest areas. The global PPR result was found to be 16.21%, lower than 30%.

Basis?
b) an index of abundance appropriate for the taxon, d) actual or potential levels of exploitation

- **Population Reduction - Ongoing**

Both: Percent Change over any 10 year or 3 generation period, whichever is longer, and must include both past and future, future can't go beyond 100 years	Reduction or Increase	Number of years for this period	Qualifier	Justification

Basis?

Reversible?

Understood?

Ceased?

- **Habitats and Ecology**

Entandrophragma cylindricum is a large tree reaching 60 m in height and 2 m in diameter. It is a non pioneer light-demanding, long-lived species (Doucet, 2003; Kouadio, 2009; Meunier et al., 2015). Its seedlings can tolerate a certain level of shade (Kasongo-Yakusu et al., 2018). It forms root associations with arbuscular mycorrhizal fungi and establishes in well-drained areas on deep soils, with rainfall between 1 600 mm and 2 000 mm/year, and average temperature between 24 and 26 °C (Hall et al., 2003; Hawthorne, 1995). Hall et al. (2004) reveals that *E. cylindricum* preferentially establish on soils with low available phosphorus (P), relatively high pH, low Al++ and relatively rich in exchangeable bases (Ca++, Mg++, Mn++). Its young stems can found in forest gaps not far from the producer, or in the undergrowth, waiting for an opening to continue their development.

Entandrophragma cylindricum bears hermaphrodite flowers. In Ghana, Ivory Coast and Liberia, trees are deciduous for a short period in October–November; flowering occurs near the middle of the dry season in February–March. In the Central African Republic the trees change leaves from November to January (Kasongo-Yakusu et al., 2018; Kémeuzé, 2008). First flowers are observed at a minimum of 17 cm DBH in Cameroon, 27 cm in Central Africa Republic and 44 cm in northern Republic of Congo (Ouédraogo et al., 2018). It is a pterochorous species and its seeds are wind dispersed (Doucet, 2003; Kasongo-Yakusu et al., 2018). In Cameroon, Central Africa Republic and the Republic of the Congo, the fruiting period is respectively between June-August, June-July, March-July, and probably between February-April in Gabon (Daïnou et al., 2021; Meunier et al., 2015). In Ghana, Ivory Coast and Liberia the fructification period is from May to August (Kasongo-Yakusu et al., 2018). In favourable conditions (high winds), the seeds can be transported up to 600 m from the tree (Monthe et al., 2017).

- **IUCN Habitats Classification Scheme**

Habitat	Season	Suitability	Major Importance?
1.6. Forest -> Forest - Subtropical/Tropical Moist Lowland	Resident	Suitable	Yes

- **Continuing Decline in Habitat**

Continuing decline in area, extent and/or quality of habitat?	Qualifier	Justification
Yes	Observed	The annual deforestation rate of 0.35%, 1.2% and 1.53% in Central, West and East Africa respectively (Vancutsem et al., 2021).

- **Life History**

Generation Length	Justification	Data Quality
127	Minimum estimate of generation length for the species from the average growth rate, and the mean diameter of mature individuals (see Supplementary Material),	good

Age at maturity: female or unspecified
56 Years

Age at Maturity: Male

56 Years

Size at Maturity (in cms): Female
35

Size at Maturity (in cms): Male
35

Reproductive Periodicity
Annual

Annual Rate of Population Increase

Natural Mortality
1% (Ligot et al. 2022)

- **Systems**

System: Terrestrial

- **Plant / Fungi Specific**

Wild relative of a crop? No

Plant and Fungal Growth Forms
Tree - large

- **Use and Trade**

- **General Use and Trade Information**

Entandrophragma cylindricum is the second most exploited species in Central Africa (Eba'a Atyi et al., 2022). At industrial level, the wood *E. cylindricum* is highly valued for flooring, interior joinery, interior trim, panelling, stairs, furniture, cabinet work, musical instruments, carvings, ship building, veneer and plywood. It is suitable for construction, vehicle bodies, toys, novelties, boxes, crates and turnery (Kasongo-Yakusu et al., 2018; Kémeuzé, 2008).

Over the years, *E. cylindricum* exports were relocated from West Africa in the 1960s to Central Africa, which is now the main production area. In the 1960s, Ghana and Ivory Coast were the main countries exporting *E. cylindricum*, with an average of more than 100 000 m³ of logs harvested per year, mainly from Ivory Coast, a volume equivalent to all the exports from Central African countries. However, since the beginning of the 2000s, the trend has been reversed, exports of *E. cylindricum* from Central Africa equal to four times those from West Africa. In 2010, Cameroon, the Republic of Congo and the Democratic Republic of Congo exported 66 945, 273 385 and 29 370 m³ respectively and only 8 746 in Ghana (ATIBT, 2010). In 2016, Central Africa, produce 1 148 634 m³ (FRMi, 2018) and 814 036 m³ log in 2018 (Eba'a Atyi et al., 2022).

At a local level, the bark is used in traditional medicine. Bark decoctions or macerations are taken to treat bronchitis, lung complaints, colds, oedema and as anodyne, whereas bark pulp is applied externally to furuncles and wounds. Bark extracts have been used as protectant of stored maize (Kémeuzé, 2008). Caterpillars of the butterfly *Imbrasia oyemensis* are commonly found on the leaves; they are edible and in some countries much sought after for human consumption (Tabi Eckebil et al., 2017).

Other recognized uses for *E. cylindricum* are related to the chemical properties of its bark. These properties would be linked to the presence of terpenes of which six molecules have already been isolated (3-hydroxy-copa-2-en, 2α-hydroxy-copa-3-en, 10-hydroxy-trans-calamenene, T-cadinol, ledol and mustacon). These molecules also play a role in the defense of the tree against attacks by wood-eating insects such as *Trogoderma granarium*, *Tribolium confusum* and *Sitophilus granarius* (Tabi Eckebil et al., 2017). Furthermore, cis-vaccenic acid, a major fatty acid contained in *E. cylindricum* seeds, could be used for the manufacture of an industrial form of plastic (Kémeuzé, 2008).

Subsistence:	Rationale:	Local Commercial:	Further detail including information on economic value if available:
Yes	-	Yes	-

National Commercial Value: Yes

International Commercial Value: Yes

Is there harvest from captive/cultivated sources of this species? Yes

Trend in level of total offtake from wild sources: Stable

Trend in level of total offtake from domesticated sources: Unknown

- **Non- Consumptive Use**

Non-consumptive use of the species? true

- **Threats**

The main threats in the non-permanent domain across the species' distribution range, are mainly related to habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging and the abusive harvesting of plant parts requested as non-wood forest products (Bradshaw et al., 2009). In Central Africa, illegal logging accounts for nearly 46% of total log production (FRMi, 2018). This production generally comes from unallocated forest areas (non-permanent forest domain).

Entandrophragma cylindricum is exploited in Central Africa. In West and East Africa, forests are generally not managed in concessions, and the large part of the rainforest has been transformed in cultivated areas (Nix, 2019).

- **Threats Classification Scheme**

No past, ongoing, or future threats exist to this species. false

Threat	**Timing**	**Scope**	**Severity**	**Impact Score**
1.1. Residential & commercial development -> Housing & urban areas	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4
2.1.1. Agriculture & aquaculture -> Annual & perennial non-timber crops -> Shifting agriculture	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
2.2.2. Agriculture & aquaculture -> Wood & pulp plantations -> Agro-industry plantations	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
2.3.2. Agriculture & aquaculture -> Livestock farming & ranching -> Small-holder grazing, ranching or farming	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4
3.2. Energy production & mining -> Mining & quarrying	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
4.1. Transportation & service corridors -> Roads & railroads	Past, Likely to Return	Minority (<50%)	Slow, Significant Declines	Low Impact: 4
5.3.1. Biological resource use -> Logging & wood harvesting -> Intentional use: (subsistence/small scale) [harvest]	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 4
5.3.2. Biological resource use -> Logging & wood harvesting -> Intentional use: (large scale) [harvest]	Ongoing	Minority (<50%)	Slow, Significant Declines	Medium Impact: 6
7.1.3. Natural system modifications -> Fire & fire suppression -> Trend Unknown/Unrecorded	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4

- **Conservation**

Entandrophragma cylindricum appears in 5 ex situ collections (BGCI, 2022), and may occur in many protected areas considering its distribution range. In legal forest concessions where the species is exploited, permanent forest plots are usually installed. These plots provide important data for (i) quantifying population dynamics processes at the stand level: mortality, growth and recruitment; (ii) phenological studies to determine the regular fruiting diameter (RFD).

These plots are managed in collaboration with forest concessions grouped within the DYNAFAC collective (see here for more information https://www.dynafac.org/fr/p/130/installation-de-dispositifs-de-suivi-de-la-dynamique-forestiere). Compilation of these data provide important additional information for targeted silvicultural measures for the sustainable management of this species. First summaries have provided information on important parameters such as: mortality, growth, etc. (DYNAFAC, 2022; Ligot et al., 2022). Based on almost 40 years of monitoring forest dynamics in Central Africa, the DYNAFAC collective recommends a MCD of 90 cm in Central Africa to maintain optimal gene flow and optimal regeneration (DYNAFAC, 2022). DYNAFAC also recommends the preservation of additional seed trees or the implementation of regeneration support techniques to ensure the long-term maintenance of populations. *E. cylindricum* is also monitored in nurseries and planted in various forest concessions.

Logging in Central Africa is subject to strict legislation, species can only be harvested above a certain diameter and measures must be taken to ensure the renewal of the resource (Fargeot et al., 2004). Indeed, management plans for tropical rainforests require the determination of a minimum cutting diameter (MCD) to ensure a minimum renewal rate at the end of a rotation period (duration between two cuts on the same cutting base), the minimum reconstitution rate (40-50% depending on the country) as well as the rotation duration, being imposed by forestry legislation (Durrieu de Madron and Forni, 1997).

Entandrophragma cylindricum is a species of "High Conservation Value", its bark is used in traditional medicine (HVC5). It provides an edible caterpillar *Imbrasia oyemensis* which is the most appreciated and commercialized (HVC6). It can be preserved or planted for the shade it provides to crops. However, as many other logged species, they suffer from illegal timber trade, therefore it is crucial to develop effective monitoring and prevention systems.

In addition, it will also be necessary to :

- Ensure the implementation of the recommendations of the Dynafac collective, including the establishment of a system for monitoring the populations of commercial species in the different forest types defined in a consensual manner;
- Set up monitoring and support systems for the regeneration of commercial species, prioritising species with regeneration deficits;
- Set up programmes to guarantee the phenotypic quality of commercial species populations: seed banks, seed stands, plus trees, seed orchards, conservation plantations;
- Consider threatened species in the delimitation of conservation series and in the identification of High Conservation Values;
- Update conservation statuses on a five-yearly basis, in particular by setting up a system of "green statuses";
- Define red lists adapted to regional or national contexts;
- Evaluate the status of cryptic species or species close to commercial species evaluated during this workshop.

- **Conservation Actions In- Place**

Action Recovery Plan	Note
Yes	Enrichment within forest concessions

Systematic monitoring scheme	Note
Yes	The species is monitored in permanent plots installed within forestry companies in Central Africa (see https://www.dynafac.org/fr)

Occur in at least one PA	Note
Yes	The species may appear in at least 100 protected areas considering it distribution range

Percentage of population protected by PAs (0-100)	Note
1-10	Considering protected area across species distribution range

Area based regional management plan	Note
Unknown	-

Invasive species control or prevention	Note
No	-

Harvest management plan	Note
Yes	In legal forest concessions, the species is exploited according to a management plan.

Subject to ex-situ conservation	Note
No	-

Included in international legislation	Note
No	-

Subject to any international management/trade controls	Note
No	

- **Important Conservation Actions Needed**

Conservation Actions	Note
3.1.1. Species management -> Species management -> Harvest management	-
3.1.2. Species management -> Species management -> Trade management	-
3.4.2. Species management -> Ex-situ conservation -> Genome resource bank	-

- **Research Needed**

Research	Note
1.2. Research -> Population size, distribution & trends	-
1.3. Research -> Life history & ecology	-
3.1. Monitoring -> Population trends	-
3.2. Monitoring -> Harvest level trends	-
3.3. Monitoring -> Trade trends	-

- **Ecosystem Services**

- **Ecosystem Services Provided by the Species**

	Importance:	Geographic range of benefit:
1. Water Quality	2 - Important	Global
3. Flood Control	2 - Important	Global
4. Climate Regulation	2 - Important	Global
5. Landscape	2 - Important	Global
6. Air Quality	2 - Important	Global
7. Nutrient Cycling	2 - Important	Global
8. Habitat Maintenance	2 - Important	Global

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Entandrophragma cylindricum – (Sprague) Sprague

● IUCN status using criterion A3

We adopted the criterion A3 to assess the projected population reduction (PPR) to be met in the future (up to a maximum of 100 years) of *Entandrophragma cylindricum*. To quantify the projected population reduction, simulations must be performed on mature individuals and three generations with maximum 100 years according to **criterion A3**. We estimated mature individuals and generation length, as recommended by the IUCN guidelines.

A **mature individual** is an individual that can reproduce, able to bear flowers or seeds (fertile in plant kingdom). To quantify the mature individuals for each species, we used phenological data of DYNAFAC network[12] from a combined dataset of 478 trees belonging to six sites in four countries (Cameroun, Central African Republic, Gabon, and Republic of Congo). Minimum and maximum sampled diameters ranged from 10 to 179 cm (median 53 cm). The monitoring period ranged from 2004 to 2021. We assumed that the monitoring period was long enough to capture at least one reproductive event per tree such that trees without observed flowering/fruiting events were considered non-reproductive (43 percent of all monitored trees were non-reproductive). We used the methodology for the size at reproduction of canopy tree species in Central Africa (Ouédraogo et al., 2018): the **diameter of a mature individual** was obtained after fitting logistic regressions and the level of 50% of the probability to produce the flower or fruit was adopted for this species. Using this approach, the diameter of a mature individual was obtained after setting the 50% probability to produce flowers or fruits. The minimum diameter of mature individuals for this species was **35 cm**.

The **generation length** was the report between the mean diameter of mature individuals considering population structure and the mean increment. Given that the minimum diameter of mature individuals was 35 cm, we weighted the total number of trees by their diameter from 35 cm to 125 cm (see Figure 1) to compute the number of mature individuals. The mean of mature individuals was **79 cm**. The **mean annual increment** of the species was **0.63 cm**, obtained from 1666 observations of Ligot et al. (2022) and unpublished data in Cameroon, and Republic of Congo. Thus, the **generation length** was 79 cm / 0.62 cm = **127 years**. The age at maturity (**56 years**) has been estimated as the report between the **minimum diameter of mature individuals** (**35 cm**) and the **mean annual increment** (**0.62 cm**).

● Estimation of the projected population reduction (PPR)

We adopted the criterion A3 to assess the projected population reduction (PPR) to be met in the future (up to a maximum of 100 years) of *Entandrophragma cylindricum*. *Entandrophragma cylindricum*, is found in Guineo–Congolian rainforest species, widely from distributed mainly from West Africa to East Africa (Kasongo Yakusu et al., 2021). The geographic range of species was in three regions (Central Africa, West Africa, and East Africa) characteristic of three biogeographical regions across the tropical African forests (Fayolle et al., 2014). According

[12] https://www.dynafac.org/en

to each region, different data (deforestation annual rate, growth, mortality, recruitment, forest inventory, etc.) have been used with logging data in Central Africa. Thus, the PPR was estimated for each region and the global PPR was then computed after weighting the three values by their relative forest areas.

- **PPR in Central Africa**

In this region, forest management follows three different modalities: protected areas, production forests (logging concessions) and non-permanent forest domain. Based on occurrences, the natural range of this species includes all countries in Central Africa (Figure 1). The total natural area is estimated at 200 963 258.5 ha. Within this area, there are 56 391 190.3 ha (28.1%) for production forests, 19 140 377.5 ha (9.5%) for protected areas, and 125 431 690.7 ha (62.4%) for the non-permanent domain. Three different PPR were thus estimated: PPR_{pa} in protected areas, PPR_{pf} in production forests and PPR_{np} in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas and then added to estimate the PPR_C in Central Africa.

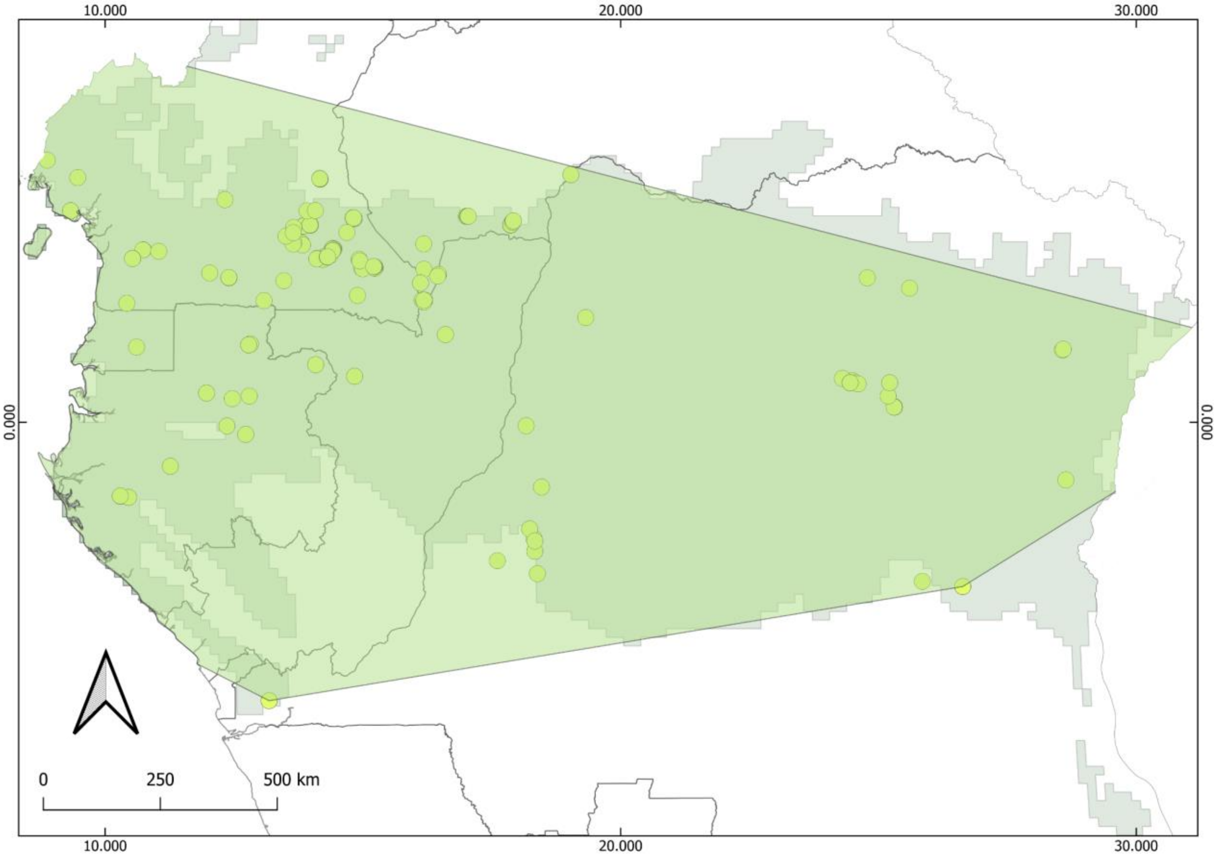

Figure 1. The range of *Entandrophragma cylindricum* in Central Africa estimated from RAINBIO and CJB data, validated in December 2022 during a workshop with a group of experts in Gabon.

- **PPR in protected areas**

Central Africa countries have allocated a higher proportion of their land to conservation than any other tropical regions, with relatively higher conservation success (Laurance et al., 2012). Indeed, most protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). They are currently representing a large part of forest and tree species conservation in Central Africa. Thus, the population of each species in protected areas (according to FRMI, 2018) covering its range was kept stable in the future over 100 years. **In these conditions, it was hypothesized that the PPR in protected areas for each species is 0%, suggesting no population reduction in the present and future.**

- **PPR in production forests**

To quantify the evolution of the population of each timber species, matrix population models are widely used to study population dynamics (Picard & Liang, 2014). The population of this species was described at time t by a vector N_t corresponding to the density (number of trees ha^{-1}) in each diameter class (from 20 cm diameter to more than 120 cm). The density per diameter class was estimated using data of forest inventories that were carried out in 70 forest management units (FMU) of different logging companies in five countries (Cameroon, Central African Republic, Democratic Republic of the Congo, Gabon, and Republic of the Congo). Most logging companies followed a standardized inventory protocol (Réjou-Méchain et al., 2011). These forest inventory data covered about 17 million ha (Table 1), that are representative of 30% of Central Africa's production forests of this species. The number of trees sampled in Central Africa was 12 050 317 with a density of 0.728 tree ha^{-1}. Large-scale commercial inventories have already been found useful in the identification of large-scale patterns in Central Africa (Réjou-Méchain et al., 2011). Using large-scale data from commercial forest inventories, Réjou-Méchain et al. (2021) jointly model the distribution in abundance of the most dominant tree species and produce continuous maps of the floristic and functional composition of central African forests.

Table 1. Forest management units (FMU) sampled in Central Africa (Cameroon, CAR: Central African Republic, DRC: Democratic Republic of the Congo, EG: Equatorial Guinea, Gabon and RCongo: Republic of the Congo).

	Sampling	
Country	FMU	Area (ha)
Cameroon	20	2 005 336.78
CAR	7	2 165 837
DRC	14	3 951 528
EG	-	-
Gabon	21	4 406 245
RCongo	8	4 005 312
Total	70	16 534 258.78

The Usher matrix model was used to simulate the evolution of the recovery rate of all population and the exploitable stock of each species after logging in Central Africa. According to the Usher assumption, between t and t+1, an individual can either stay alive in the same class, stay alive and move up to the next class, or die; it cannot move up by more than one class or move backwards, i.e., the individual is free from diameter shrinkage (Picard et al.,

2012). The Usher matrix model (U) considers three parameters (mortality, recruitment and growth rate that are constant in time) to estimate the transition probabilities:

$$U = \begin{pmatrix} q_1 + g_1 & g_2 & \cdots & \cdots & g_I \\ p_1 & q_2 & 0 & \cdots & 0 \\ 0 & \ddots & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & p_{I-1} & q_I \end{pmatrix}$$

where q_i is the probability for an individual to stay alive in class i between two consecutive time steps, p_i is the upgrowth transition rate (the probability for an individual to grow up from class i to class i +1), and g_i is the recruitment rate (Picard & Liang, 2014).

Tree mortality, recruitment and growth are three central processes for predicting the dynamics of tropical rainforests and estimating these three processes requires long-term monitoring in difficult field conditions (Picard & Gourlet-Fleury, 2008). These processes determine the evolution of the species population in the forest stand. The natural mortality is defined as the number of standing dead trees, and few studies have reported estimates of mortality rates in Central Africa. Data about tree mortality are still scarce and it does not allow to precisely model the mortality rate for each species and size class. Given the current state of knowledge, it appears reasonable to use a fixed mortality rate of 1% for all species and size classes, in agreement with the results of Ligot et al. (2022) on 21,180 trees belonging to 42 timber species of Central Africa annually monitored from one to seven years.

The recruitment integrates fruiting and seed dispersal from mother trees, and the survival of plant juveniles until they reach a size threshold where they are included in the stand. The recruitment term in the model is the average annual input of new individuals into the first size class from 20 cm. The recruitment events, like mortality events, are infrequent and thus difficult to model (Karsenty & Gourlet-Fleury, 2006). The population structure showed a curve in "decreasing exponential" suggesting a good regeneration (Figure 2). To model the recruitment, we used the hypothesis defined as the recruitment rate that would maintain a constant number of trees in the first diameter class. Claeys et al. (2019) projected the future forest dynamics up to the end of the century and they showed that projected mortality and recruitment rates in 2099 could not differ from the ones observed today. Thus, the hypothesis on the recruitment and the mortality rate is used in the future (up to 100 years) as they do today.

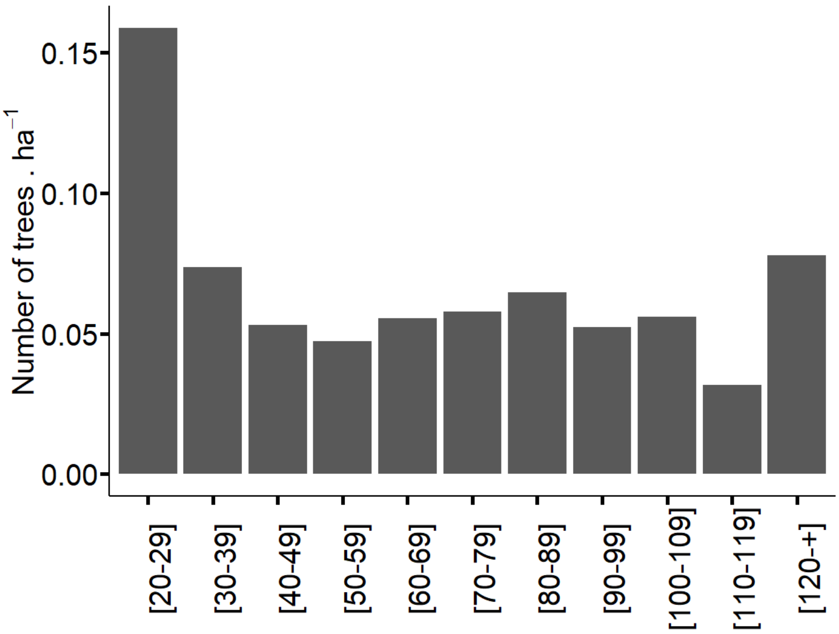

Figure 2. Population structure of *Entandrophragma cylindricum* (sapelli) defined using the number of trees per ha and per diameter class (from 20 cm of 70 logging concessions covering an area of 16 534 258.78 ha in Central Africa).

Since the mid-1900s, periodic tree monitoring and tree ring analyses have been carried out to study variability in tree growth across species in Central Africa (Durrieu de Madron, Nasi, et al., 2000; Ligot et al., 2019, 2022). We fitted growth models for each species using data from logged and unlogged areas of permanent tree plot monitoring from the DYNAFAC[13] network covering the five Central African countries. From the combined dataset, we identified 1666 trees belonging to 7 sites in two countries (Cameroun, and Republic of Congo). Minimum and maximum sampled diameter ranged from 10 to 177 cm. The monitoring period ranged from 2005 to 2018. The mixed second-degree polynomial models (with a random site effect) were fitted for species monitored in several sites. The estimated coefficient from mixed second-degree polynomial model has been used in the simulation to estimate the diameter growth (Table 2).

Table 2. Estimated coefficients (a, b and c) of growth models between the increment (ac in cm year^{-1}) and the initial diameter (D in cm). The sample including the number of trees (n) and the number of sites (site) are also given. * significant (p-value < 0.05) and ^{ns} non-significant (p-value > 0.050)

species	n	site	model	a	b	c
Sapelli	1666	7	ac ~ D + D^2 + (1|site)	-0.007*	0.022*	-0.0002*

[13] https://www.dynafac.org/en

The transition probabilities of three parameters (mortality, growth, and recruitment rate) allowed making the harvested matrix. The logging operations have been modeled using the logging parameters (minimum cutting diameter, cutting and damage rate). The minimum cutting diameters were obtained from decrees of application of the forestry administrations (MCD_A) at the country level and the one used in the management plan (MCD_M, with $MCD_M \geq MCD_A$) at the logging company level. At the Central Africa level, we weighted the MCD_A and MCD_M values to the occupied area (**$MCD_A = MCD_M = 85$ cm**). The cutting rate (CA), which defines the proportion of harvested trees (trees with a diameter greater than MCD_A or MCD_M), was given by logging companies, and it was also weighted at the Central Africa level with a value of **86%**. Given the current state of knowledge, it appears reasonable to use a fixed damage rate caused by logging of **7%** of the initial population that disappears (Durrieu de Madron, Fontez, et al., 2000). The average cutting cycle (i.e. the period between two successive logging operations) is 28 years (FRMI, 2018), but we used 25 years to simplify computation of four simulations reaching 100 years (25, 50, 75 and 100 years), as requested by IUCN criterion A.

The Figure 3 shows the PPR in production forests for the *Entandrophragma cylindricum*. The reduction in the population of each species was then calculated as the difference between the initial numbers of mature individuals and the predicted numbers of mature individuals predicted after 100 years. **The PPR in production forest was – 39.49 % over 100 years.**

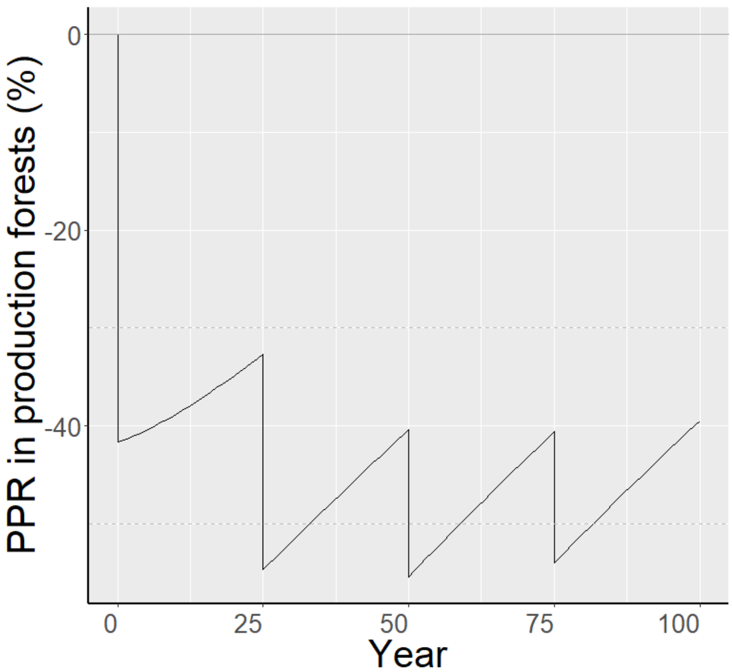

Figure 3. Simulations showing the projected population reduction (PPR) from diameter of mature individuals (35 cm) in production forests for the *Entandrophragma cylindricum* for constant recruitment over 100 years.

- **PPR in the non-permanent forest domain**

The major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanization, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Based on the large range of this species in Central Africa, the harvested volume from illegal logging and legal logging are 46% and 54%, respectively (FRMI 2018). In this condition, it was hypothesized that there is 54% of PPR from production forests and 46% of PPR from illegal logging in 100% PPR due to forest logging. Given that the PPR of production forests associated with its forest area was known, we deduced the PPR and forest area of illegal logging from those of the production forests. As a result, 48 036 939.9 ha were affected for the illegal logging for this species. The non-permanent domain area (125 431 690.7 ha) was considered as the area which was related to today's deforestation rate of 0.35% year^{-1} in Central Africa (Vancutsem et al., 2021). This is a conservative value since it will probably decrease in the future (Swamy et al., 2018).

The PPR in Central Africa by considering the PPR in production forest, protected area and non-permanent domain was − 17.7% over 100 years.

- **PPR in West and East Africa**

In these two regions, forests are generally not managed in concessions, and the large part of the rainforest has been transformed in cultivated areas (Nix, 2019). Given the high degree of anthropization in this area, the main threats are the habitat loss due to the destruction of natural environments and illegal logging, and the trees are frequently felled in fields. Applying the deforestation rate related to agricultural production can be considered as a proxy for tree removal. Thus, the forest areas in West Africa (15 600 000 ha) and East Africa (6 400 000 ha) were subject to a constant annual deforestation rate of 1.20% year^{-1} and 1.53% year^{-1} respectively (Vancutsem et al., 2021). Taking this rate of deforestation as constant over the next 100 years, when it is expected to decline, is a reasonable precautionary measure incorporating illegal logging.

- **PPR global**

We thus had three different PPR: PPR_C in Central Africa, PPR_W in West Africa, and PPR_E in East Africa. The global PPR was then computed after weighting the three values by their relative forest areas:

$$PPR = \frac{(S_C \times PPR_C) + (S_W \times PPR_W) + (S_E \times PPR_E)}{S_C + S_W + S_E}$$

where S_C, S_W, and S_E are forest areas in Central, West and East Africa, respectively.

The criterion A3 based on (c) a decline in area of occupancy (AOO), extent of occurrence (EOO) and/or habitat quality; and (d) potential levels of exploitation, has been computed as follow: (i) 30%≤PPR<50%, the species is considered as Vulnerable (VU); (ii) 50%≤PPR <80%, the species is considered as Endangered (EN), and PPR ≥ 80%, the species is considered as Critically endangered (CR).

The PPR global in distribution range of the *Entandrophragma cylindricum* was **− 16.21%**. This PPR is < 30%, suggesting that this species is not threatened in its geographic area.

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10.8 Annexe 8. *Entandrophragma utile* - (Dawe et Sprague) Sprague

Draft

Entandrophragma utile - (Dawe et Sprague) Sprague

PLANTAE - TRACHEOPHYTA - MAGNOLIOPSIDA - SAPINDALES - MELIACEAE - Entandrophragma - utile

Common Names: Sipo

Synonyms: *Entandrophragma roburoides Vermoesen (1921)*
Entandrophragma thomasii Ledoux (1932)
Entandrophragma macrocarpum A.Chev. (1909)
Pseudocedrela utilis Dawe & Sprague (1906)

Red List Status
LC– Least Concern, A3cd (IUCN version 3.1)

- **Red List Assessment**

- **Assessment Information**

Date of Assessment: 2022-09-01

Assessor(s): Monthe, F., Loubota, G., Ligot, G., Texier, N., Stévart, T. & Doucet, JL.

Reviewer(s):

Institution(s):

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Regions: Global

- **Identification Description**

Entandrophragma utile, is a very large tree that can exceed 60 m in height and 2 m in diameter, with a powerful hemispherical crown. As it matures, it becomes buttressed at its base. Its trunk is straight and cylindrical, silver-grey to blackish-grey, smooth with lenticels when young, then becomes rough and finally marked with vertical cracks and elongated scales. Its pink-red slash, sometimes with white vertical stripes, is not very odorous (perfume). There is a whitish film between the dead and living bark, and its whitish inner layer slowly turns brown. Its leaves are paripinnate with numerous alternate leaflets (16-24-(48)), elongated and asymmetrical. The blade is leathery and marked with tufts of hairs in the axils of the secondary veins (12-16 pairs). Its inflorescences from 10 to 25 cm long are composed of small green flowers. Its fruits are big elongated and club-shaped capsules (18-28 x 5-7 cm), with 5 very thick woody valves whose black surface is very rough with reddish brown lenticels, opening by the top and remaining fixed at the base. They contain flattened seeds, usually reddish brown, with long straight wings 5-11 cm long.

- **Assessment Rationale**

Entandrophragma utile is a widespread tall tree in African moist evergreen and semi-deciduous guineo-congolian forest, long-lived, non-pioneer light-demanding and usually non-gregarious species, which forms root associations with arbuscular mycorrhizal fungi. It is distributed from Sierra Leone to Uganda. Based on a 2 x 2 km cell size, the AOO of this species is estimated as 536 km^2 with a minimum of 77 locations (number of forest management units of different logging companies in Central Africa). This species is not "Vulnerable" status under criterion B2. The EOO is calculated as 6 110 352 km^2, above the upper threshold for "Vulnerable" status under criterion B1.
Commonly known as Sipo, it is an important timber species in tropical Africa, highly sought after for the quality of its wood. The minimum cutting diameter (MCD) varies from 80 and 90 cm in Central Africa and from 60 to 110 cm in West Africa. It is lower or higher than the regular fruiting diameter (RFD) estimated at 80 cm diameter at breast height (dbh), which can locally compromise the availability of seed trees. The DYNAFAC collective recommends a MCD of 100 cm in Central Africa to ensure optimal gene flow in populations (DYNAFAC, 2022). The population structure of this species showed a decreasing curve suggesting a good regeneration, with a density of 0.10 $stem.ha^{-1}$ (dbh ≥ 20 cm) in Central Africa (see Supplementary Material). Given its stem density and the mean annual increment of 0.50 ± 0.42 cm/year in Central Africa (see Supplementary Material), we estimate the number of mature individuals over 10 000 across the distribution range, well above the threatened category under criteria C and D.
The most serious long-term threat is the conversion of the forest to agriculture, and illegal logging. However, the species is not considered severely fragmented as 217 known occurrences represent more than 50 localities (sensu Comité des normes et des pétitions de l'UICN, 2019). Considering the species' generation length (137 years), an inference of population reduction for three generations in the past is impossible following A1 and A2 criteria. Based on simulations of the expected population reduction on its distribution range including protected areas, non - permanent forest areas and production forest (logging concessions), we estimated population reduction from 1.86 to 2.89 % in the next 100 years below the threshold to be considered threatened under criterion A3. An assessment of the population reduction according to criterion A4 considering one to two generations back and one to two generations forward would likely introduce high levels of uncertainty due to the lack of data to efficiently model the reduction of population size in the past. No quantitative analysis of the probability of extinction in the wild was conducted, and therefore criterion E does not apply.

Considering (i) the population density, (ii) the incompatibility between MCD and RFD in some countries and (iii) the reduction of population in the future across the distribution range below the upper threshold for Vulnerable, the species is assessed as Least Concern (LC), A3cd.

Reasons for change

Reason(s) for Change in Red List Category from the Previous Assessment:

Entandrophragma utile was previously assessed as "Vulnerable" (https://www.iucnredlist.org/species/32236/9690202) at the African Regional Workshop (Conservation & Sustainable Management of Trees, Zimbabwe, July 1996), 1998, following the A1cd criterion. During the last few years, important data have been produced on the self-ecology, population dynamics (growth, recruitment, mortality) of the species. Moreover, a new version of the IUCN guidelines is available (from version 2.3 to 3.1). Given all these information, it was necessary to produce a new assessment of the species.

- **Distribution**
- **Geographic Range**

Entandrophragma utile is widely distributed from Sierra Leone to Uganda, as well as Angola (Kasongo-Yakusu et al., 2018). *E. utile* is primarily a lowland tree species occurring between 0-500 m altitude in West Africa and below 1 400 m altitude in Uganda. It is very common in semi-deciduous rainforest, especially on the sites of former human activities. The extent of occurrence (EOO) in native area is estimated 6 110 352 km^2.

- **Area of Occupancy (AOO)**

Estimated area of occupancy (AOO) - in km2	Justification
536	The AOO has been estimated using ConR based on the 2 × 2 km cell size of 217 occurrences from CJB (Conservatoire et Jardin botaniques de Genève) and RAINBIO

Continuing decline in area of occupancy (AOO)	Qualifier	Justification
Yes	Inferred	The species has suffered from reduction in area of occupancy, due to habitat degradation and deforestation in West Africa forest (Vancutsem et al., 2021)

- **Extent of Occurrence (EOO)**

Estimated extent of occurrence (EOO)- in km2	EOO estimate calculated from Minimum Convex Polygon	Justification
6 110 352	true	Calculated using ConR based on 217 known occurrences from CJB (Conservatoire et Jardin botaniques de Genève) and RAINBIO

Continuing decline in extent of occurrence (EOO)	Qualifier	Justification
Yes	Inferred	The species has certainly undergone extent of occurrence reduction in West Africa, linked to the reduction in forest area (Vancutsem et al., 2021)

- **Locations Information**

Number of Locations	Justification
70-200	More than 77 localities. Based on the most serious plausible threat (conversion of its habitat) and illegal logging across the distribution range.

Continuing decline in number of locations	Qualifier	Justification
Yes	Inferred	The main threat remains the reduction of the forest area in West Africa.

Extreme fluctuations in the number of locations	Justification
No	

- **Very restricted AOO or number of locations (triggers VU D2)**

Very restricted in area of occupancy (AOO) and/or # of locations	Justification
No	-

- **Elevation / Depth / Depth Zones**

Elevation Lower Limit (in metres above sea level): 0

Elevation Upper Limit (in metres above sea level): 1400

- **Map Status**

Map Status	Use map from previous assessment	How the map was created, including data sources/methods used:	Please state reason for map not available:	Data Sensitive?	Justification	Geographic range this applies to:	Date restriction imposed:
Done	-	Qgis. The dataset was created from a compilation of Rainbio and CJB	-	-	-	-	-

- **Biogeographic Realms**

Biogeographic Realm: Afrotropical

- **Occurrence**

- **Countries of Occurrence**

Country	Presence	Origin	Formerly Bred	Seasonality
Angola	Extant	Native	-	Resident
Cameroon	Extant	Native	-	Resident
Central Africa Republic	Extant	Native	-	Resident
Côte d'Ivoire	Extant	Native	-	Resident
Equatorial Guinea	Extant	Native	-	Resident
Gabon	Extant	Native	-	Resident
Ghana	Extant	Native	-	Resident
Liberia	Extant	Native	-	Resident
Nigeria	Extant	Native	-	Resident
Republic of the Congo	Extant	Native	-	Resident
Sierra Leone	Extant	Native	-	Resident
Uganda	Extant	Native	-	Resident

- **Population**

Entandrophragma utile is a guineo-congolian species, widely distributed from Sierra Leone to Uganda, as well as Angola. Its average density is 0.10 $stem.ha^{-1}$ (dbh ≥ 20 cm) in Central Africa (see Supplementary Material). This density can locally reach 1 $stem.ha^{-1}$ in some populations in Eastern Cameroon, Ivory Coast and Liberia (Kasongo-Yakusu et al., 2018).

Seedling mortality is mainly due to fungal, insect attack, predation and/or uprooting by small mammals, and drought (Hall, 2008). Seedlings grow slowly, reaching 1 to 1.5 min height after 4 years in Ghanaian forests (Kasongo-Yakusu et al., 2018; Mujuni, 2008). The average diameter growth for trees with dbh > 10 cm is 0.50 ± 0.42 cm/year in Central Africa (see Supplementary Material).). Natural mortality of adult trees has not been studied, nevertheless, an average of 1% was observed for 42 timber species in central Africa (Ligot et al., 2022).

The minimum fertility diameter was estimated at 20 cm in Central Africa and the regular fruiting diameter (RFD) at 80 cm observed in Uganda (see Supplementary Material).The legal minimum cutting diameter "MCD" varies across its distribution range, (60 in Ivory Coast, 80 cm in Cameroon, Central Africa Republic, Democratic Republic of the Congo, and Republic of Congo, 90 in Gabon and Liberia, and 110 in Ghana) (Kasongo-Yakusu et al., 2018; Sépulchre et al., 2008). Except in Ivory Coast, MCD is equal or higher than RFD, a situation that could affect the availability of seed trees and consequently the natural regeneration of the species.
Using the Red List criterion A3, the projected population reduction (PPR) to be met in the future (100 years because the generation length of the species is 137 years) of the *E. utile* population was assessed across its distribution range. Because *E. utile* is a widespread species in West, East and Central Africa, the PPR was estimated for each region.

In Central Africa, three different PPR were thus estimated: PPRpa in protected areas, PPRpf in production forests and PPRnp in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas. First, protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). The population of the species in protected areas covering its range was kept stable in the future over 100 years, suggesting that the PPR in protected areas was 0%. Second, the evolution of the *E. utile* population was simulated using an Usher matrix model to estimate the PPR of production forests (logging concessions, PPRpf). The simulations were initialised using the density (number of trees.ha^{-1}) per diameter class (from 20 cm diameter, mature individuals) from forest management inventories of logging companies. The evolution of this initial population depended on several demographics (recruitment, mortality, and growth rate) and logging parameters (minimum cutting diameter, cutting and damage rate) that were adjusted using data of permanent tree plot monitoring. Thus, the density of *E. utile* in 100 years was predicted with a logging event every 25 years, which corresponds to the average cutting cycle in Central Africa. PPRpf was then calculated as the difference between initial and final number of trees. Third, the major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Illegal logging and the habitat lost from deforestation rate have been both activities that allowed estimating the PPRnp in non-permanent domains.

In West and East Africa, the forest areas were subject to a constant annual deforestation rate of 1.20% year-1 and 1.53% year-1 respectively (Vancutsem et al., 2021). Taking this rate of deforestation as constant over the next 100 years, when it is expected to decline, is a reasonable precautionary measure.

We thus had three different PPR: PPR in Central Africa, PPR in West Africa and PPR in East Africa. The global PPR was then computed after weighting the three values by their relative forest areas. The global PPR result was found to be 1.86 to 2.89 %, lower than 30%.

- **Population Information**

Current Population Trend: Decreasing

Extreme fluctuations? (in # of mature individuals)	Justification
No	-

Severely fragmented?	Justification
No	-

Continuing decline in mature individuals?	Qualifier	Justification

Continuing decline % in mature individuals within 3 generations or 10 years, whichever is longer (up to max. of 100 years in the future)	Qualifier	Justification

Extreme fluctuations in the number of subpopulations	Justification
No	-

Continuing decline in number of subpopulations	Qualifier	Justification
No	-	-

All individuals in one subpopulation: No

Number of Subpopulations	Justification	Subpopulation Details	Subpopulation description	Number of mature individuals	Subpopulation trend	Qualifier	Location type	Number of Subpopulations	Location bounding box	Location coordinates	Notes
2	Genetic analyses using 22 nuclear microsatellites for 139 individuals sampled across the distribution range of the										

	species (Mon the, 2019)	

- **Population Reduction - Past**

Percent Change in past	Reduction or Increase	Qualifier	Justification

Basis?

Reversible?

Understood?

Ceased?

- **Population Reduction - Future**

Percent Change in future	Reduction or Increase	Qualifier	Justification
1.86 to 2.89 %	Reduction	Projected	Using the Red List criterion A3, the projected population reduction (PPR) to be met in the future (100 years because the generation length of the species is 137 years) of the *E. utile* population was assessed across its distribution range. Because *E. utile* is a widespread species in West, East and Central Africa, the PPR was estimated for each region. In Central Africa, three different PPR were thus estimated: PPRpa in protected areas, PPRpf in production forests and PPRnp in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas. First, protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the

main agents of forest degradation across the region (Abernethy et al., 2016). The population of the species in protected areas covering its range was kept stable in the future over 100 years, suggesting that the PPR in protected areas was 0%. Second, the evolution of the *E. utile* population was simulated using an Usher matrix model to estimate the PPR of production forests (logging concessions, PPRpf). The simulations were initialised using the density (number of trees.ha^{-1}) per diameter class (from 20 cm diameter, mature individuals) from forest management inventories of logging companies. The evolution of this initial population depended on several demographics (recruitment, mortality, and growth rate) and logging parameters (minimum cutting diameter, cutting and damage rate) that were adjusted using data of permanent tree plot monitoring. Thus, the density of *E. utile* in 100 years was predicted with a logging event every 25 years, which corresponds to the average cutting cycle in Central Africa. PPRpf was then calculated as the difference between initial and final number of trees. Third, the major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Illegal logging and the habitat lost from deforestation rate have been both activities that allowed estimating the PPRnp in non-permanent domains.

In West and East Africa, the forest areas were subject to a constant annual deforestation rate of 1.20% year-1 and 1.53% year-1 respectively (Vancutsem et al., 2021). Taking this rate of deforestation as constant over the next 100 years, when it is expected to decline, is a reasonable precautionary measure.

We thus had three different PPR: PPR in Central Africa, PPR in West Africa and PPR in East Africa. The global PPR was then computed after weighting the three values by their relative forest areas. The global PPR result was found to be 1.86 to 2.89 %, lower than 30%.

Basis?
b) an index of abundance appropriate for the taxon, d) actual or potential levels of exploitation

- **Population Reduction - Ongoing**

Both: Percent Change over any 10 year or 3 generation period, whichever is longer, and must include both past and future, future can't go beyond 100 years	Reduction or Increase	Number of years for this period	Qualifier	Justification

Basis?

Reversible?

Understood?

Ceased?

- **Habitats and Ecology**

Entandrophragma utile is a large tree reaching 60 m in height and 2 m in diameter. It is a non-pioneer light-demanding, long-lived species (Doucet, 2003; Kouadio, 2009; Meunier et al., 2015), with seeedlings that can tolerate a certain level of shade (Kasongo-Yakusu et al., 2018). It forms root associations with arbuscular mycorrhizal fungi and established in well-drained areas on deep soils. (Hall et al., 2003). Hall et al. (2004) found no association between soil parameters or topography and the distribution of *E. utile.* Its young stems can be found in forest gaps not far from the producer, or in the undergrowth, waiting for an opening to continue their development.

Few studies have been conducted on the ecology of this species. However, *E. utile* bears hermaphrodite flowers, which usually blooms between January and February in West Africa. It is a pterochorous species and its seeds are wind dispersed (Doucet, 2003; Kasongo-Yakusu et al., 2018). In Uganda, fruits are regularly observed from 80 cm (Mujuni, 2008). Parentage analyses based on genetic data reveal that individuals in the [40-60 cm] DBH class are already involved in seed production in the Northern Republic of the Congo (Monthe, 2019). In Central Africa, the fruits are generally observed during the first six months of the year (Daïnou et al., 2021; Meunier et al., 2015), itis probably the case throughout its distribution range (Kasongo-Yakusu et al., 2018; Mujuni, 2008). In favourable conditions (high winds), the seeds can be transported up to 600 m from the tree (Monthe, 2019). Consequently, the seedlings preferentially settle in the direction of the prevailing winds (W) in the Northern Republic of the Congo (Monthe, 2019).

- **IUCN Habitats Classification Scheme**

Habitat	Season	Suitability	Major Importance?
1.6. Forest -> Forest - Subtropical/Tropical Moist Lowland	Resident	Suitable	Yes

- **Continuing Decline in Habitat**

Continuing decline in area, extent and/or quality of habitat?	Qualifier	Justification
Yes	Observed	Despite the annual deforestation rate of 0.35%, 1.2% and 1.53% in Central, West and East Africa respectively (Vancutsem et al., 2021)

- **Life History**

Generation Length	Justification	Data Quality
137	Minimum estimate of generation length for the species from the average growth rate, and the mean diameter of mature individuals (see Supplementary Material).	good

Age at maturity: female or unspecified
40 Years

Age at Maturity: Male
40 Years

Size at Maturity (in cms): Female
20

Size at Maturity (in cms): Male
20

Reproductive Periodicity
Annual

Annual Rate of Population Increase

Natural Mortality
1% (Ligot et al. 2022)

- **Systems**

System: Terrestrial

- **Plant / Fungi Specific**

Wild relative of a crop? No

Plant and Fungal Growth Forms
Tree - large

- **Use and Trade**
- **General Use and Trade Information**

Entandrophragma utile is among the most important timber species in Central Africa (Eba'a Atyi et al., 2022). At industrial level, the wood of *E. utile* is used for exterior and interior joinery, interior trim, paneling, stairs, furniture, cabinetry, shipbuilding, veneers and plywood. It is suitable for construction, parquetry, carpentry, box making, carving and turning. The wood has always been used to make canoes. Wood that cannot be used as lumber can be used for firewood and charcoal making (Kasongo-Yakusu et al., 2018; Mujuni, 2008).

From 1964 to 1972, average annual exports (logs and sawnwood) in Ivory Coast were 656 000 m³, dropping to 56 000 m³ in 1983. In Ghana, *E. utile* is an important timber species for export. In 2003, the Central African Republic exported 7000 m³ and the Republic of Congo exported 38 000 m³ (Mujuni, 2008). In 2010, Cameroon, the Republic of Congo and the Democratic Republic of the Congo exported 13 328, 47 361, and 15 693 m³ respectively (ATIBT, 2010). In 2016, Central Africa produced 83 948 m³ (FRMi, 2018) and 14 336 m³ of log in 2018 (Eba'a Atyi et al., 2022).

At a local level, the bark is used in traditional medicine in Central Africa. The juice of the bark is taken or used in baths to treat stomach aches and kidney pains, it is rubbed to relieve rheumatism, and it is used both in eye installation in case of inflammation. The massage based on a maceration of bark is considered tonic and stimulating. The bark, carbonised and reduced to powder, with the addition of salt and palm oil, is rubbed on scarifications to relieve headaches. In Cameroon, the bark is used to treat malaria. In Nigeria, it is claimed to cure peptic ulcers. The valves of the fruit have been used as spoons.

Subsistence:	Rationale:	Local Commercial:	Further detail including information on economic value if available:
Yes	-	Yes	-

National Commercial Value: Yes

International Commercial Value: Yes

Is there harvest from captive/cultivated sources of this species? Yes

Trend in level of total offtake from wild sources: Stable

Trend in level of total offtake from domesticated sources: Unknown

- **Non- Consumptive Use**

Non-consumptive use of the species? true

- **Threats**

The main threats in the non-permanent domain across the species' distribution range, are mainly related to habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging and the abusive harvesting of plant parts requested as non-wood forest products (Bradshaw et al., 2009). In Central Africa, illegal logging accounts for nearly 46% of total log production (FRMi, 2018).This production generally comes from unallocated forest areas (non-permanent forest domain).

Entandrophragma utile is exploited in Central Africa. In West and East Africa, forests are generally not managed in concessions, and the large part of the rainforest has been transformed into cultivated areas (Nix, 2019).

- **Threats Classification Scheme**

No past, ongoing, or future threats exist to this species. false

Threat	Timing	Scope	Severity	Impact Score
1.1. Residential & commercial development -> Housing & urban areas	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4
2.1.1. Agriculture & aquaculture -> Annual & perennial non-timber crops -> Shifting agriculture	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5

2.2.2. Agriculture & aquaculture -> Wood & pulp plantations -> Agro-industry plantations	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
2.3.2. Agriculture & aquaculture -> Livestock farming & ranching -> Small-holder grazing, ranching or farming	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4
3.2. Energy production & mining -> Mining & quarrying	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
4.1. Transportation & service corridors -> Roads & railroads	Past, Likely to Return	Minority (<50%)	Slow, Significant Declines	Low Impact: 4
5.3.1. Biological resource use -> Logging & wood harvesting -> Intentional use: (subsistence/small scale) [harvest]	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 4
5.3.2. Biological resource use -> Logging & wood harvesting -> Intentional use: (large scale) [harvest]	Ongoing	Minority (<50%)	Slow, Significant Declines	Medium Impact: 6
7.1.3. Natural system modifications -> Fire & fire suppression -> Trend Unknown/Unrecorded	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4

- **Conservation**

Entandrophragma utile appears in 4 ex situ collections (BGCI, 2022), and may occur in many protected areas considering its distribution range. In certified forest concessions where the species is exploited, or permanent forest plots are usually installed. These plots provide important data for (i) quantifying population dynamics processes at the stand level: mortality, growth and recruitment; (ii) phenological studies to determine the regular fruiting diameter (RFD).

These plots are managed in collaboration with forest concessions grouped within the DYNAFAC collective (see https://www.dynafac.org/fr/p/130/installation-de-dispositifs-de-suivi-de-la-dynamique-forestiere). Compilation of these data provide important additional information for targeted silvicultural measures for the sustainable management of this species. First summaries have provided information on important parameters such as: mortality, growth, etc. (DYNAFAC, 2022; Ligot et al., 2022). Based on almost 40 years of monitoring forest dynamics in Central Africa, the DYNAFAC collective recommends a MCD of 100 cm in Central Africa to maintain optimal gene flow and optimal regeneration (DYNAFAC, 2022). DYNAFAC also recommends the preservation of additional seed trees or the implementation of regeneration support techniques to ensure the long-term maintenance of populations. *E. utile* is also monitored in nurseries and planted in various forest concessions.

Logging in Central Africa is subject to strict legislation, species can only be harvested above a certain diameter and measures must be taken to ensure the renewal of the resource (Fargeot et al., 2004). Indeed, management plans for tropical rainforests require the determination of a minimum cutting diameter (MCD) to ensure a minimum renewal rate at the end of a rotation period (duration between two cuts on the same cutting base), the minimum reconstitution rate (40-50% depending on the country) as well as the rotation duration, being imposed by forestry legislation (Durrieu de Madron and Forni, 1997).

In addition, it will also be necessary to :

- Ensure the implementation of the recommendations of the Dynafac collective, including the establishment of a system for monitoring the populations of commercial species in the different forest types defined in a consensual manner;
- Set up monitoring and support systems for the regeneration of commercial species, prioritising species with regeneration deficits;
- Set up programmes to guarantee the phenotypic quality of commercial species populations: seed banks, seed stands, plus trees, seed orchards, conservation plantations;
- Consider threatened species in the delimitation of conservation series and in the identification of High Conservation Values;
- Update conservation statuses on a five-yearly basis, in particular by setting up a system of "green statuses";
- Define red lists adapted to regional or national contexts;
- Evaluate the status of cryptic species or species close to commercial species evaluated during this workshop.

- **Conservation Actions In- Place**

Action Recovery Plan	Note
Yes	Enrichment within legal forest concessions

Systematic monitoring scheme	Note
Yes	The species is monitored in permanent plots installed within forestry companies in Central Africa (see https://www.dynafac.org/fr)

Occur in at least one PA	Note
Yes	The species may appear in at least 100 protected areas considering it distribution range

Percentage of population protected by PAs (0-100)	Note
1-10	Considering protected area across species distribution range

Area based regional management plan	Note

Unknown	-

Invasive species control or prevention	Note
No	-

Harvest management plan	Note
Yes	In legal forest concessions, the species is exploited according to a management plan.

Subject to ex-situ conservation	Note
NO	-

Included in international legislation	Note
No	-

Subject to any international management/trade controls	Note
No	

- **Important Conservation Actions Needed**

Conservation Actions	Note
3.1.1. Species management -> Species management -> Harvest management	-
3.1.2. Species management -> Species management -> Trade management	-
3.4.2. Species management -> Ex-situ conservation -> Genome resource bank	-

- **Research Needed**

Research	Note
1.2. Research -> Population size, distribution & trends	-
1.3. Research -> Life history & ecology	-
3.1. Monitoring -> Population trends	-
3.2. Monitoring -> Harvest level trends	-
3.3. Monitoring -> Trade trends	-

- **Ecosystem Services**

- **Ecosystem Services Provided by the Species**

	Importance:	Geographic range of benefit:
1. Water Quality	2 - Important	Global
3. Flood Control	2 - Important	Global
4. Climate Regulation	2 - Important	Global
5. Landscape	2 - Important	Global
6. Air Quality	2 - Important	Global
7. Nutrient Cycling	2 - Important	Global
8. Habitat Maintenance	2 - Important	Global

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• SUPPLEMENTARY MATERIAL

Entandrophragma utile - (Dawe et Sprague) Sprague

• IUCN status using criterion A3

We adopted the criterion A3 to assess the projected population reduction (PPR) to be met in the future (up to a maximum of 100 years) of *Entandrophragma utile*. To quantify the projected population reduction, simulations must be performed on mature individuals and three generations with a maximum of 100 years according to **criterion A3**. We estimated mature individuals and generation length, as recommended by the IUCN guidelines.

A **mature individual** is an individual that can reproduce, able to bear flowers or seeds (fertile in plant kingdom). To quantify the mature individuals for each species, we used phenological data of DYNAFAC network[14] from a combined dataset of 23 trees belonging to two sites in two countries (Cameroun, and Gabon). Minimum and maximum sampled diameters ranged from 10 to 112 cm (median 57 cm). The monitoring period ranged from 2004 to 2021. We assumed that the monitoring period was long enough to capture at least one reproductive event per tree such that trees without observed flowering/fruiting events were considered non-reproductive (13 percent of all monitored trees were non-reproductive). We used the methodology for the size at reproduction of canopy tree species in Central Africa (Ouédraogo et al., 2018): the **diameter of a mature individual** was obtained after fitting logistic regressions and the level of 50% of the probability to produce the flower or fruit was adopted for this species. Using this approach, the diameter of a mature individual was obtained after setting the 50% probability to produce flowers or fruits. The minimum diameter of mature individuals for this species was **20 cm**.

The **generation length** was the report between the mean diameter of mature individuals considering population structure and the mean increment. Given that the minimum diameter of mature individuals was 20 cm, we weighted the total number of trees by their diameter from 20 cm to 125 cm (see Figure 1) to compute the number of mature individuals. The mean of mature individuals was **69 cm**. The **mean annual increment** of the species was **0.503 cm**, obtained from 448 observations of published data (Ligot et al., 2022) and unpublished data in two countries (Cameroon, and Republic of Congo). Thus, the **generation length** was 69 cm / 0.503 cm = **137 years**. The age at maturity (**40 years**) has been estimated as the report between the **minimum diameter of mature individuals** (**20 cm**) and the **mean annual increment (0.503 cm)**.

• Estimation of the projected population reduction (PPR)

We adopted the criterion A3 to assess the projected population reduction (PPR) to be met in the future (up to a maximum of 100 years) of *Entandrophragma utile*. *Entandrophragma utile*, is found in Guineo–Congolian rainforest species, widely from distributed mainly from West Africa to East Africa (Kasongo Yakusu et al., 2021). The geographic range of species was in three regions (Central Africa, West Africa, and East Africa) characteristic of three biogeographical regions across the tropical African forests (Fayolle et al., 2014). According to each region,

[14] https://www.dynafac.org/en

different data (deforestation annual rate, growth, mortality, recruitment, forest inventory, etc.) have been used with logging data in Central Africa. Thus, the PPR was estimated for each region and the global PPR was then computed after weighting the three values by their relative forest areas.

- **PPR in Central Africa**

In this region, forest management follows three different modalities: protected areas, production forests (logging concessions) and non-permanent forest domain. Based on occurrences, the natural range of this species includes all countries in Central Africa (Figure 1). The total natural area is estimated at 200 478 352.5 ha. Within this area, there are 56 427 195.5 ha (28.2%) for production forests, 20 506 982.6 ha (10.2%) for protected areas, and 123 544 174.4 ha (61.6%) for the non-permanent domain. Three different PPR were thus estimated: PPR_{pa} in protected areas, PPR_{pf} in production forests and PPR_{np} in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas and then added to estimate the PPR_C in Central Africa.

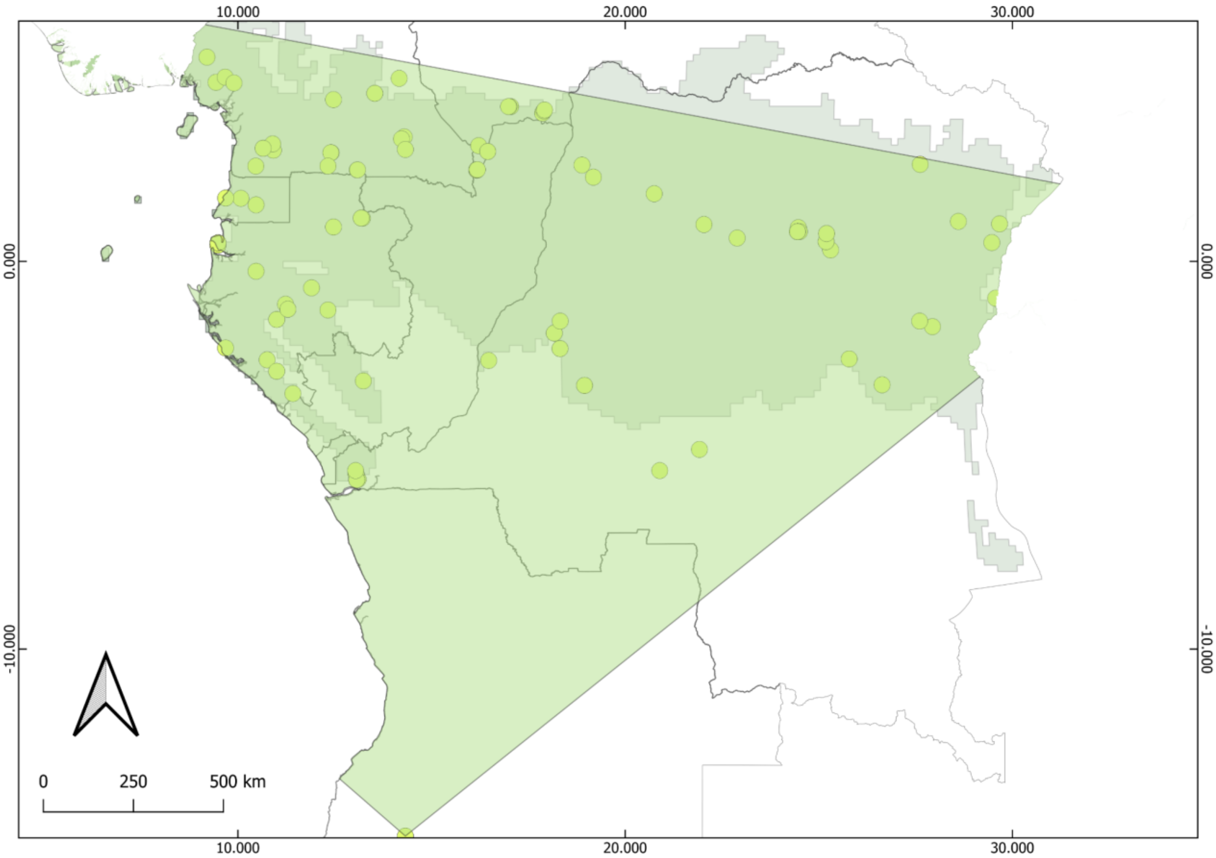

Figure 1. The range of *Entandrophragma utile* in Central Africa estimated from RAINBIO and CJB data, validated in December 2022 during a workshop with a group of experts in Gabon.

- **PPR in protected areas**

Central Africa countries have allocated a higher proportion of their land to conservation than any other tropical regions, with relatively higher conservation success (Laurance et al., 2012). Indeed, most protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that

have been the main agents of forest degradation across the region (Abernethy et al., 2016). They are currently representing a large part of forest and tree species conservation in Central Africa. Thus, the population of each species in protected areas (according to FRMI, 2018) covering its range was kept stable in the future over 100 years. **In these conditions, it was hypothesized that the PPR in protected areas for each species is 0%, suggesting no population reduction in the present and future.**

- **PPR in production forests**

To quantify the evolution of the population of each timber species, matrix population models are widely used to study population dynamics (Picard & Liang, 2014). The population of this species was described at time *t* by a vector N_t corresponding to the density (number of trees ha^{-1}) in each diameter class (from 20 cm diameter to more than 120 cm). The density per diameter class was estimated using data from forest inventories that were carried out in 77 forest management units (FMU) of different logging companies in five countries (Cameroon, Central African Republic, Democratic Republic of the Congo, Gabon, and Republic of the Congo). Most logging companies followed a standardized inventory protocol (Réjou-Méchain et al., 2011). These forest inventory data covered about 18 million ha (Table 1), that are representative of 31% of Central Africa's production forests of this species. The number of trees sampled in Central Africa was 1 229 776 with a density of 0.07 tree ha^{-1}. Large-scale commercial inventories have already been found useful in the identification of large-scale patterns in Central Africa (Réjou-Méchain et al., 2011). Using large-scale data from commercial forest inventories, Réjou-Méchain et al. (2021) jointly model the distribution in the abundance of the most dominant tree species and produce continuous maps of the floristic and functional composition of central African forests.

Table 1. Forest management units (FMU) sampled, and areas affected to different management modalities in Central Africa (Cameroon, CAR: Central African Republic, DRC: Democratic Republic of the Congo, EG: Equatorial Guinea, Gabon and RCongo: Republic of the Congo). The relative proportion (value in %) for the sampled area is also given according to the areas of production forest of each country.

	Sampling	
Country	FMU	Area (ha)
Cameroon	21	1 839 647.78
CAR	7	2 165 837
DRC	14	3 951 528
EG	-	-
Gabon	27	5 557 591
RCongo	8	4 005 312
Total	77	17 519 915.78

The Usher matrix model was used to simulate the evolution of the recovery rate of all population and the exploitable stock of each species after logging in Central Africa. According to the Usher assumption, between *t* and *t*+1, an individual can either stay alive in the same class, stay alive and move up to the next class, or die; it cannot move up by more than one class or move backwards, i.e., the individual is free from diameter shrinkage (Picard et al.,

2012). The Usher matrix model (U) considers three parameters (mortality, recruitment and growth rate that are constant in time) to estimate the transition probabilities:

$$U = \begin{pmatrix} q_1 + g_1 & g_2 & \cdots & \cdots & g_I \\ p_1 & q_2 & 0 & \cdots & 0 \\ 0 & \ddots & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & p_{I-1} & q_I \end{pmatrix}$$

where q_i is the probability for an individual to stay alive in class i between two consecutive time steps, p_i is the upgrowth transition rate (the probability for an individual to grow up from class i to class i +1), and g_i is the recruitment rate (Picard & Liang, 2014).

Tree mortality, recruitment and growth are three central processes for predicting the dynamics of tropical rainforests and estimating these three processes requires long-term monitoring in difficult field conditions (Picard & Gourlet-Fleury, 2008). These processes determine the evolution of the species population in the forest stand. The natural mortality is defined as the number of standing dead trees, and few studies have reported estimates of mortality rates in Central Africa. Data about tree mortality are still scarce and it does not allow to precisely model the mortality rate for each species and size class. Given the current state of knowledge, it appears reasonable to use a fixed mortality rate of 1% for all species and size classes, in agreement with the results of Ligot et al. (2022) on 21,180 trees belonging to 42 timber species of Central Africa annually monitored from one to seven years.

The recruitment integrates fruiting and seed dispersal from mother trees, and the survival of plant juveniles until they reach a size threshold where they are included in the stand. The recruitment term in the model is the average annual input of new individuals into the first size class from 20 cm. The recruitment events, like mortality events, are infrequent and thus difficult to model (Karsenty & Gourlet-Fleury, 2006). The population structure showed a curve in "decreasing exponential" suggesting a good regeneration (Figure 2). To model the recruitment, we used the hypothesis defined as the recruitment rate that would maintain a constant number of trees in the first diameter class. Claeys et al. (2019) projected the future forest dynamics up to the end of the century and they showed that projected mortality and recruitment rates in 2099 could not differ from the ones observed today. Thus, the hypothesis on the recruitment and the mortality rate is used in the future (up to 100 years) as they do today.

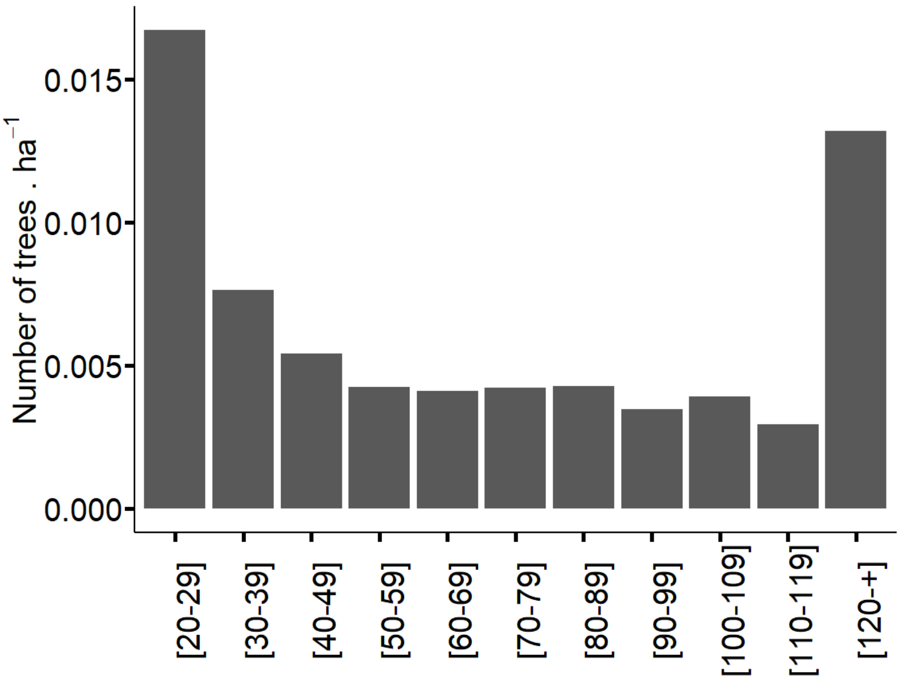

Figure 2. Population structure of *Entandrophragma utile* (sipo) defined using the number of trees per ha and per diameter class (from 20 cm of 77 logging concessions covering an area of 17 519 915.78 ha in Central Africa).

Since the mid-1900s, periodic tree monitoring and tree ring analyses have been carried out to study variability in tree growth across species in Central Africa (Durrieu de Madron, Nasi, et al., 2000; Ligot et al., 2019, 2022). We fitted growth models for each species using data from logged and unlogged areas of permanent tree plot monitoring from the DYNAFAC[15] network covering the five Central African countries. From the combined dataset, we identified 448 trees belonging to 6 sites in two countries (Cameroun, and Republic of Congo). Minimum and maximum sampled diameters ranged from 10 to 198 cm. The monitoring period ranged from 2005 to 2018. The mixed second-degree polynomial models (with a random site effect) were fitted for species monitored in several sites. The estimated coefficient from mixed second-degree polynomial model has been used in the simulation to estimate the diameter growth (Table 2).

Table 2. Estimated coefficients (a, b and c) of growth models between the increment (ac in cm year^{-1}) and the initial diameter (D in cm). The sample including the number of trees (n) and the number of sites (site) are also given. * significant (p-value < 0.05) and ^{ns} non-significant (p-value > 0.050)

species	n	site	model	a	b	c
Sipo	448	6	ac ~ D + D^2 + (1|site)	0.167*	0.018*	-0.0001*

[15] https://www.dynafac.org/en

The transition probabilities of three parameters (mortality, growth, and recruitment rate) allowed making the harvested matrix. The logging operations have been modeled using the logging parameters (minimum cutting diameter, cutting and damage rate). The minimum cutting diameters were obtained from decrees of application of the forestry administrations (MCD_A) at the country level and the one used in the management plan (MCD_M, with $MCD_M \geq MCD_A$) at the logging company level. At the Central Africa level, we weighted the MCD_A and MCD_M values to the occupied area (**MCD_A = 80 cm and MCD_M = 90 cm)**. The cutting rate (CA), which defines the proportion of harvested trees (trees with a diameter greater than MCD_A or MCD_M), was given by logging companies, and it was also weighted at the Central Africa level with a value of 83%. Given the current state of knowledge, it appears reasonable to use a fixed damage rate caused by logging of 7% of the initial population that disappears (Durrieu de Madron, Fontez, et al., 2000). The average cutting cycle (i.e. the period between two successive logging operations) is 28 years (FRMI, 2018), but we used 25 years to simplify computation of four simulations reaching 100 years (25, 50, 75 and 100 years), as requested by IUCN criterion A.
The Figure 3 shows the PPR in production forests for *Entandrophragma utile*. The reduction in the population of each species was then calculated as the difference between the initial numbers of mature individuals and the predicted numbers of mature individuals predicted after 100 years. **The PPR in production forest** was from **– 8.76% (MCD_A) to -5.24% (MCD_M)** for the constant recruitment over 100 years.

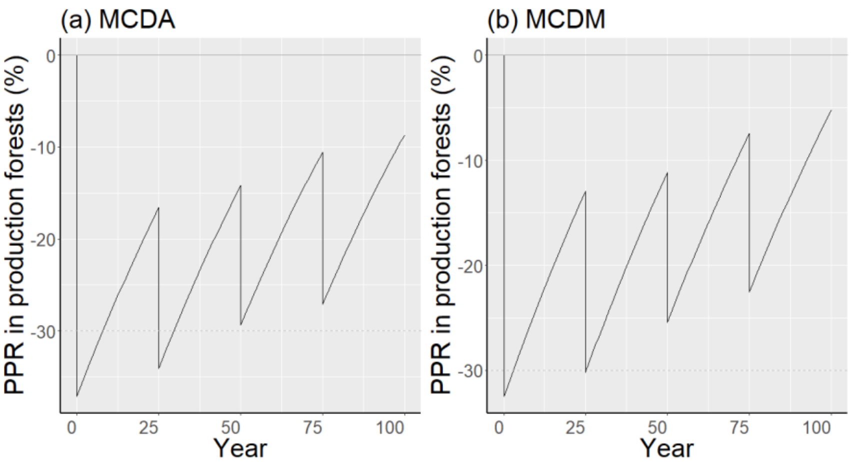

Figure 3. Simulations showing the projected population reduction (PPR) from diameter of mature individuals (20 cm) in production forests for the *Entandrophragma utile* for constant recruitment over 100 years.

- **PPR in the non-permanent forest domain**

The major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanization, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Based on the large range of this species in Central Africa, the harvested volume from illegal logging and legal logging are 46% and 54%, respectively (FRMI 2018). In this condition, it was hypothesized that there is 54% of PPR from production forests and 46% of PPR from illegal logging in 100% PPR due to forest logging. Given that the PPR of production forests associated with its forest area was known, we deduced the PPR and forest area of illegal logging from those of the production forests. As a result, 48 067 611 ha were affected for the illegal logging for this species. The non-permanent domain area (123 544 174.4 ha) was considered as the area which was related to today's deforestation rate of 0.35% $year^{-1}$ in Central Africa (Vancutsem et al., 2021). This is a conservative value since it will probably decrease in the future (Swamy et al., 2018).

The PPR in Central Africa by considering the PPR in production forest, protected area and non-permanent domain was from **– 1.9% (MCD_A) to - 3% (MCD_M)** for the constant recruitment over 100 years.

- **PPR in West and East Africa**

In these two regions, forests are generally not managed in concessions, and the large part of the rainforest has been transformed in cultivated areas (Nix, 2019). Given the high degree of anthropization in this area, the main threats are the habitat loss due to the destruction of natural environments and illegal logging, and the trees are frequently felled in fields. Applying the deforestation rate related to agricultural production can be considered as a proxy for tree removal. Thus, the forest areas in West Africa (15 600 000 ha) and East Africa (6 400 000 ha) were subject to a constant annual deforestation rate of 1.20% $year^{-1}$ and 1.53% $year^{-1}$ respectively (Vancutsem et al., 2021). Taking this rate of deforestation as constant over the next 100 years, when it is expected to decline, is a reasonable precautionary measure incorporating illegal logging.

- **PPR global**

We thus had three different PPR: PPR_C in Central Africa, PPR_W in West Africa, and PPR_E in East Africa. The global PPR was then computed after weighting the three values by their relative forest areas:

$$PPR = \frac{(S_C \times PPR_C) + (S_W \times PPR_W) + (S_E \times PPR_E)}{S_C + S_W + S_E}$$

where S_C, S_W, and S_E are forest areas in Central, West and East Africa, respectively.

The criterion A3 based on (c) a decline in area of occupancy (AOO), extent of occurrence (EOO) and/or habitat quality; and (d) potential levels of exploitation, has been computed as follow: (i) 30%≤PPR<50%, the species is considered as Vulnerable (VU); (ii) 50%≤PPR <80%, the species is considered as Endangered (EN), and PPR ≥ 80%, the species is considered as Critically endangered (CR).

The PPR global in distribution range of *Entandrophragma utile* was from **– 1.89% (MCD_A) to -2.89% (MCD_M)** for the constant recruitment over 100 years. This PPR is < 30%, suggesting that this species is not threatened in its geographic area.

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10.9 Annexe 9. *Erythrophleum ivorense* A. Chev

Draft

***Erythrophleum ivorense* A. Chev.**

PLANTAE - TRACHEOPHYTA - MAGNOLIOPSIDA - FABALES - FABACEAE - Erythrophleum- ivorense

Common Names: Tali (French)

Synonyms:

Red List Status
VU – Vulnerable, A3cd (IUCN version 3.1)

- **Red List Assessment**

- **Assessment Information**

Date of Assessment: 2022-09-01

Assessor(s): Monthe, F., Loubota, G., Ligot, G., Texier, N., Stévart, T. & Doucet, J.L.

Reviewer(s):

Institution(s):

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Regions: Global

- **Identification Description**

Erythrophleum ivorense is a large tree reaching 40 m in height and 1.5 m in diameter with buttresses. The trunk is irregular and short, often with branches. The bark is reddish brown or even blackish. The young individuals have a smooth trunk covered with lenticels, later sinuous ridges are formed which detach themselves in large scales. Its slice is reddish, a red liquid a smell of plantain skin. Its leaves are compound, bipinnate, the 2 to 3 pairs of pinnae being composed of alternate leaflets (4-8.5 × 3-4 cm), with a wedge-shaped to subrounded base. The glabrous blade is brownish and shiny when dry. The small reddish brown flowers (± 3 mm) are subsessile (0.5 mm) and grouped in compact spikes. The fruits are flattened, coriaceous, blackish-brown pods rounded at both ends (7-8 x 3.5-4 cm). They contain 2-10 hard black seeds that look like duiker droppings (1.3-1.5 cm long).

Erythrophleum ivorense and *E. suaveolens* are very difficult to distinguish in the field. If there is any doubt, it is necessary to refer to their respective distribution. Genetic studies have indeed revealed that *E. ivorense* is coastal and *E. suaveolens* is continental (Duminil et al., 2013). There is also a widespread savanna species: *E. africanum* (Welw. ex Benth.) Harms.

- **Assessment Rationale**

Erythrophleum ivorense is a widespread tall tree of tropical Africa semi-deciduous forest, long-lived, pioneer light demanding and usually non-gregarious species, native to dense, evergreen coastal rainforests (Gorel et al., 2015). It is distributed from Gambia to the Republic of Congo (Gorel et al., 2015). Based on a 2 x 2 km cell size, the AOO of this species is estimated as 1172km^2 with a minimum of 27 locations (number of forest management units of different logging companies in Central Africa). This species is not “Vulnerable” status under criterion B2. The EOO is calculated as 2 402 594km^2, above the upper threshold for “Vulnerable” status under criterion B1.

E. ivorense and *E. suaveolens* are very difficult to distinguish in the field and are commonly known as Tali. Together, they are among the most exploited timber species in tropical Africa, sought after for the quality of their wood. The legal minimum cutting diameter “MCD " varies across its distribution range in Central Africa with 50 cm in Cameroon, 60 cm in Republic of Congo and 70 cm in Gabon. These MCD are lower to the regular fruiting diameter (RFD), estimated at 75 cm (DYNAFAC, 2022). The population structure showed a single-mode curve suggesting a regeneration deficit (see Supplementary Material). When present, *E. ivorense* has relatively high population densities of 0.85 stems.ha^{-1} (diameter at breast height, dbh ≥ 20 cm) and fairly fast growth rates of 0.52 ± 0.42 cm/year in Central Africa (see Supplementary Material). Given its stem density and the mean annual increment, we estimate the number of mature individuals over 10 000 across the distribution range, well above the threatened category under criteria C and D.

The most serious long-term threat is the conversion of the forest to agriculture, and illegal logging. However, the species is not considered severely fragmented as 580 known occurrences represent more than 50 localities. Considering the species' generation length of 139 years (see Supplementary Material), an inference of three generations in the past goes back to around 1700 towards the period characterised by high regeneration of light-demanding trees species, resulting from gardening activities of local populations in the forest, creating scattered large openings (Morin-Rivat et al., 2017). So, the species would certainly not be threatened according to the A1 and A2 criteria.

In the legal logging concession of central Africa, the MCD must be adapted to ensure sufficient recovery rates after each cutting cycle (MCD_M). At the Central Africa level, we weighted the MCD and MCD_M values to the occupied area with MCD = 65 cm and MCD_M = 75 cm (see Supplementary Material). To model the recruitment, we used the hypothesis defined as the recruitment rate that would maintain a constant number of trees in the first diameter class. Based on simulations of the expected population reduction on its distribution range including protected areas, non - permanent forest areas and production forest (logging concessions), we estimated population reduction of 37.5-40.9% in the next 100 years below the threshold to be considered threatened under criterion A3 (for further information about this methodology, see Supplementary Material). An assessment of the population reduction according to criterion A4 considering one to two generations back and one to two generations forward would likely introduce high levels of uncertainty due to the lack of data to efficiently model the reduction of population size in the past. No quantitative analysis of the probability of extinction in the wild was conducted, and therefore criterion E does not apply.

Considering (i) the population density, (ii) the population structure, and (iii) the reduction of population in the future across the distribution range within the limit for Vulnerable, the species is assessed as Vulnerable (VU), A3cd.

Reasons for change

Reason(s) for Change in Red List Category from the Previous Assessment:

Erythrophleum ivorense was previously assessed as "Least Concern" (https://www.iucnredlist.org/species/62025422/62025425) (Hills, 2019). During the last few years, important data have been produced on the self-ecology, population dynamics (growth, recruitment, mortality) of the species (DYNAFAC, 2022; Ligot et al., 2022). Moreover, a new version of the IUCN guidelines is available (from version 2.3 to 3.1). Given all these information, it was necessary to produce a new assessment of the species.

• Distribution

• Geographic Range

Erythrophleum ivorense is a widespread species in West and Central Africa with a distribution extending from Gambia, Sierra Leone, Guinea, Ivory Coast, Nigeria, Cameroon, Guinea Equatorial, Gabon, and Republic of Congo (Gorel et al. 2015). The species has a mainly coastal distribution in the Guinean-Congolese regional endemism centre (White, 1983). The extent of occurrence (EOO) in native area is estimated at 2,402,594 km^2.

• Area of Occupancy (AOO)

Estimated area of occupancy (AOO) - in km2	Justification
1172	The AOO has been estimated using ConR based on the 2 × 2 km cell size of 580 occurrences from CJB (Conservatoire et Jardin botaniques de Genève) and RAINBIO

Continuing decline in area of occupancy (AOO)	Qualifier	Justification
Yes	Inferred	The species has suffered from reduction in area of occupancy, due to habitat degradation and deforestation in West Africa forest (Vancutsem et al., 2021).

- **Extent of Occurrence (EOO)**

Estimated extent of occurrence (EOO)- in km2	EOO estimate calculated from Minimum Convex Polygon	Justification
2402594	true	Calculated using ConR based on 499 known occurrences from CJBD and RAINBIO

Continuing decline in extent of occurrence (EOO)	Qualifier	Justification
Yes	Inferred	The species has certainly undergone Extent of Occurrence reduction in West; East and Central Africa, linked to the reduction in forest area (Vancutsem et al., 2021).

- **Locations Information**

Number of Locations	Justification
25- 100	More than 27 localities. Based on the most serious plausible threat (conversion of its habitat) and illegal logging across the distribution range.

Continuing decline in number of locations	Qualifier	Justification
Yes	Inferred	The main threat remains the reduction of the forest area in West Africa.

Extreme fluctuations in the number of locations	Justification
No	

- **Very restricted AOO or number of locations (triggers VU D2)**

Very restricted in area of occupancy (AOO) and/or # of locations	Justification
No	-

- **Elevation / Depth / Depth Zones**

Elevation Lower Limit (in metres above sea level): 50

Elevation Upper Limit (in metres above sea level): 450

- **Map Status**

Map Status	Use map from previous assessment	How the map was created, including data sources/methods used:	Please state reason for map not available:	Data Sensitive?	Justification	Geographic range this applies to:	Date restriction imposed:
Done	-	Qgis. The dataset was created from a compilation of Rainbio and CJB	-	-	-	-	-

- **Biogeographic Realms**

Biogeographic Realm: Afrotropical

- **Occurrence**

- **Countries of Occurrence**

Country	Presence	Origin	Formerly Bred	Seasonality
Cameroon	Extant	Native	-	Resident
Central African Republic;	Extant	Native	-	Resident
Congo	Extant	Native	-	Resident
Côte d'Ivoire	Extant	Native	-	Resident
Equatorial Guinea	Extant	Native	-	Resident
Gabon	Extant	Native	-	Resident
Ghana	Extant	Native	-	Resident
Guinea	Extant	Native	-	Resident
Liberia;	Extant	Native	-	Resident
Nigeria	Extant	Native	-	Resident

Sierra Leone	Extant	Native	-	Resident

- **Population**

Erythrophleum ivorense is a Guinean-Congolian species, native to dense, evergreen coastal rainforests, widely distributed from Gambia to Republic of Congo, with a total absence at the Dahomey interval, which corresponds to an interruption of rainforests by a zone of dry forests and savannas (Akoègninou et al., 2006; Duminil et al., 2013). Its average density is 0.85 stems.ha-1 (dbh ≥ 20 cm) in Central Africa (see Supplementary Material), and 0.70 stems.ha-1 (dbh ≥ 60 cm) in Liberia (Bosch, 2006). This density can be very abundant in secondary forests.

The average diameter growth was 0.52 ± 0.42 cm/year in evergreen stands and in semi-deciduous riverine forest (all diameters combined) in Cameroon (Ligot et al., 2022). A growth rate of 0.50 cm/year was observed on a tree whose diameter had increased from 10 cm to 70 cm in 12 years in Ivory Coast (Détienne et al., 1998). This growth may be much higher at seedling stage. In nurseries, the average germination rate is 45% (25-70%) depending on the efficiency of the pre-treatment. Indeed, seeds can be stored for several years at room temperature or in a cool room (air-conditioned for example Daïnou et al., 2021).

The legal minimum cutting diameter “MCD "varies across its distribution range in Central Africa with 50 cm in Cameroon, 60 cm in Republic of Congo and 70 cm in Gabon. In the legal logging concession of central Africa, the MCD must be adapted to ensure sufficient recovery rates after each cutting cycle (MCD_M). At the Central Africa level, we weighted the MCD and MCD_M values to the occupied area with MCD = 65 cm and MCD_M = 75 cm (see Supplementary Material). These MCD are lower or equal to the regular fruiting diameter (RFD), estimated at 75 cm (DYNAFAC, 2022). Situations that could affect the availability of seed trees and consequently the natural regeneration of the species though, the minimum fertility diameter was set at 35 cm in Central Africa (see Supplementary Material). In West Africa, forests are generally not managed in concessions, and the large part of the rainforest has been transformed into cultivated areas (Nix, 2019).

Using the Red List criterion A3, the projected population reduction (PPR) to be met in the future (100 years because the generation length of the species is 139 years) of the *E. ivorense* population was assessed across its distribution range. Because *E. ivorense* is a widespread species in West and Central Africa, the PPR was estimated for each region. In Central Africa, three different PPR were thus estimated: PPRpa in protected areas, PPRpf in production forests and PPRnp in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas. First, protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). The population of the species in protected areas covering its range was kept stable in the future over 100 years, suggesting that the PPR in protected areas was 0%. Second, the evolution of the *E. ivorense* population was simulated using an Usher matrix model to estimate the PPR of production forests (logging concessions, PPRpf). The simulations were initialised using the density (number of trees.ha-1) per diameter class (from 20 cm diameter, mature individuals) from forest management inventories of logging companies. The evolution of this initial population depended on several demographics (recruitment, mortality, and growth rate) and logging parameters (minimum cutting diameter, cutting and damage rate) that were adjusted using data of permanent tree plot monitoring. Thus, the density of *E. ivorense* in 100 years was predicted with a logging event every 25 years, which corresponds to the average cutting cycle in Central Africa. PPRpf was then calculated as the difference between initial and final number of trees. Third, the major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanization, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Illegal logging and the habitat lost from deforestation rate have been both activities that allowed estimating the PPRnp in non-permanent domains (see Supplementary Material) .

In West Africa, the forest areas were subject to a constant annual deforestation rate of 1.20% year-1 (Vancutsem et al., 2021). Taking this rate of deforestation as constant over the next 100 years, when it is expected to decline, is a reasonable precautionary measure. We thus had two different PPR: PPRC in Central Africa and PPRW in West Africa. The global PPR was then computed after weighting the two values by their relative forest areas. The global PPR result was found to be 37.5-40.9% (for further information about this methodology, see Supplementary Material).

- **Population Information**

Current Population Trend: Decreasing

Extreme fluctuations? (in # of mature individuals)	Justification
No	-

Severely fragmented?	Justification
No	-

Continuing decline in mature individuals?	Qualifier	Justification

Continuing decline % in mature individuals within 3 generations or 10 years, whichever is longer (up to max. of 100 years in the future)	Qualifier	Justification

Extreme fluctuations in the number of subpopulations	Justification
No	-

Continuing decline in number of subpopulations	Qualifier	Justification
No	-	-

All individuals in one subpopulation: No

Number of Subpopulations	Justification	Subpopulation Details	Subpopulation description	Number of mature individuals	Subpopulation trend	Qualifier	Location type	Number of Subpopulations	Location bounding box	Location coordinates	Notes
3	Genetic analyses Using nuclear microsatellites (nSSRs) and chloroplast non-coding sequences (pDNA) for 648 individuals sampled across the distribution range of the species (Duminil et al., 2013)	-	-	-	-	-	-	-	-	-	-

- **Population Reduction - Past**

Percent Change in past	Reduction or Increase	Qualifier	Justification

Basis?

Reversible?

Understood?

Ceased?

- **Population Reduction - Future**

Percent Change in future	Reduction or Increase	Qualifier	Justification
37.5-40.9%	Reduction	Projected/estimated	Using the Red List criterion A3, the projected population reduction (PPR) to be met in the future (100 years because the generation length of the species is 139 years) of the *E. ivorense* population was assessed across its distribution range. Because *E. ivorense* is a widespread species in West and Central Africa, the PPR was estimated for each region. In Central Africa, three different PPR were thus estimated: PPRpa in protected areas, PPRpf in production forests and PPRnp in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas. First, protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). The population of the species in protected areas covering its range was kept stable in the future over 100 years, suggesting that the PPR in protected areas was 0%. Second, the evolution of the *E. ivorense* population was simulated using an Usher matrix model to estimate the PPR of production forests (logging concessions, PPRpf). The simulations were initialised using the density (number of trees.ha-1) per diameter class (from 20 cm diameter, mature individuals) from forest management inventories of logging companies. The evolution of this initial population depended on several demographics (recruitment, mortality, and growth rate) and logging parameters (minimum cutting diameter, cutting and damage rate) that were adjusted using data of

	permanent tree plot monitoring. Thus, the density of *E. ivorense* in 100 years was predicted with a logging event every 25 years, which corresponds to the average cutting cycle in Central Africa. PPRpf was then calculated as the difference between initial and final number of trees. Third, the major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Illegal logging and the habitat lost from deforestation rate have been both activities that allowed estimating the PPRnp in non-permanent domains. In West Africa, the forest areas were subject to a constant annual deforestation rate of 1.20% year-1 (Vancutsem et al., 2021). Taking this rate of deforestation as constant over the next 100 years, when it is expected to decline, is a reasonable precautionary measure. We thus had two different PPR: PPRC in Central Africa and PPRW in West Africa. The global PPR was then computed after weighting the two values by their relative forest areas. The global PPR result was found to be 37.5-40.9%. For further information about this methodology, see the attached Supplementary Information document.

Basis?
b) an index of abundance appropriate for the taxon, d) actual or potential levels of exploitation

- **Population Reduction - Ongoing**

Both: Percent Change over any 10 year or 3 generation period, whichever is longer, and	Reduction or Increase	Number of years for this period	Qualifier	Justification

must include both past and future, future can't go beyond 100 years

Basis?

Reversible?
Yes

Understood?
Yes

Ceased?
No

• Habitats and Ecology

Erythrophleum ivorense is a large tree reaching 40 m in height and 1.5 m in diameter, long-lived, pioneer light-demanding species located in the Atlantic evergreen rainforests of West and Central Africa (Bosch, 2006; Gorel et al., 2015). It is also indicative of secondary forests, where it often forms root associations with arbuscular fungi. The seed is dormant in the soil bank. Its regeneration thrives in large forest openings. In dense forests (little disturbed), its regeneration is often deficient, and the stand consists only of medium to large trees (Gorel et al., 2015). Seedlings quickly require light for further development (Doucet, 2003; Hawthorne, 1995; Meunier et al., 2015)

E. ivorense bears hermaphrodite flowers. Little information is available on the phenology of the species. Flowering may occur from May to October in Central and West Africa (Gorel et al., 2015). Seeds are dispersed by opening the fruit (autochory) and by animals that consume the substance surrounding the seeds (zoochory) (Meunier et al., 2015). In Cameroon and Gabon, the fruiting period is respectively between September - December and March- April (Daïnou et al., 2021; Meunier et al., 2015). Trees bear fruits regularly and abundantly at 75 cm in Cameroon (Daïnou et al., 2021). In this work, we considered mature individuals as those having at least 50% of yielding flowers and/or seeds at a given diameter (35 cm) (see Supplementary Material).

Reforestation with *E. ivorense* is an option in degraded forests where natural regeneration of economically important species is unlikely. During planting of *E. ivorense* in Gabon, Zaou et al. (1998) showed that this species is particularly well adapted to a clear-cut method, which confirms its pioneer temperament. The silviculture of *E. ivorense* is therefore feasible, but its economic value has yet to be demonstrated in Africa (Doucet, 2003).

• IUCN Habitats Classification Scheme

Habitat	Season	Suitability	Major Importance?
1.6. Forest -> Forest - Subtropical/Tropical Moist Lowland	Resident	Suitable	Yes

- **Continuing Decline in Habitat**

Continuing decline in area, extent and/or quality of habitat?	Qualifier	Justification
Yes	Observed	The annual deforestation rate of 0.35% in Central Africa, 1.20% in West Africa and 1.53% in East Africa (Vancutsem et al., 2021). The species can also colonise savannah and other open habitats.

- **Life History**

Generation Length	Justification	Data Quality
139	Minimum estimate of generation length for the species from the average growth rate, and the mean diameter of mature individuals (see Supplementary Material)	good

Age at maturity: female or unspecified
67 Years

Age at Maturity: Male
67 Years

Size at Maturity (in cms): Female
35

Size at Maturity (in cms): Male
35

Reproductive Periodicity
Annual

Annual Rate of Population Increase

Natural Mortality
1% (Ligot et al. 2022)

- **Systems**

System: Terrestrial

- **Plant / Fungi Specific**

Wild relative of a crop? No

Plant and Fungal Growth Forms
Tree - large

- **Use and Trade**

- **General Use and Trade Information**

Erythrophleum ivorense is multipurpose trees characterised by high economic and socio-cultural values (Gorel et al. 2015). Together with *E. suaveolens* they are among the most exploited forest species in tropical Africa (Eba'a Atyi et al., 2022). In 2005 the export of *Erythrophleum* ('tali') logs from Cameroon amounted to 37,500 m^3 and of sawn wood to 38,600 m^3, which made *Erythrophleum* the fourth most important timber of Cameroon. In 2010, Cameroon, the Republic of Congo and the Democratic Republic of the Congo exported 50 634, 13 324, and 2 349 m^3 respectively (ATIBT, 2010). In 2016, Central Africa, produce 454 153 m^3 (FRMi, 2018) and 432 407m^3 of log in 2018 (Eba'a Atyi et al., 2022).

The wood, yellowish brown to reddish brown and darkens in the light, is quite hard and heavy, is suitable for joinery, flooring, railway sleepers, harbour and dock work, turnery, construction and bridges. It is durable with a resistance to fungi, dry wood insects and termites (Gorel et al. 2015).

E. ivorense is an important source of traditional medicines in tropical Africa. The bark, leaves and stem bark are mainly used as anthelmintic, emetic, insect repellent, laxative and traditional medicine for convulsions, malaria, pain, smallpox, swellings and wounds. In Central Africa, the stem bark is mixed with the leaves of *Brenania brieyi*, bark of *Erythrina* spp. and the leafy twigs of *Ficus exasperate* and *Plagiostyles africana* as traditional medicine for blennorrhagia and urethritis. In West Africa, the bark and leaves of *E. ivorense* are mixed with those of *Alstonia boonei*, *Annona muricata*, *Anopyxis klaineana*, *Citrus aurantifolia*, *Citrus sinensis*, *Cocos nucifera*, *Turraeanthus africana* and *Thaumatococcus* spp. as traditional medicine for malaria (Asase et al., 2012). The bark of *E. ivorense* is sold as 'sassy-bark', 'mancona bark', 'casca bark' or 'écorce de tali' in informal herbal medicine markets in West

Africa (Bosch, 2012). But the bark and seeds of *E. ivorense* are considered poisonous and therefore, the species is used as fish poison, arrow poison, poison for rats and game and ordeal poison (Bosch, 2012).

Subsistence:	Rationale:	Local Commercial:	Further detail including information on economic value if available:
Yes	-	Yes	-

National Commercial Value: Yes

International Commercial Value: Yes

Is there harvest from captive/cultivated sources of this species? Yes

Trend in level of total offtake from wild sources: Stable

Trend in level of total offtake from domesticated sources: Unknown

- **Non- Consumptive Use**

Non-consumptive use of the species? true

- **Threats**

The main threats in the non-permanent domain across the species' distribution range, are mainly related to habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging and the abusive harvesting of plant parts requested as non-wood forest products (Bradshaw et al., 2009). In Central Africa, illegal logging accounts for nearly 46% of total log production, or over 650 000 m3 /year (FRMi, 2018). This production generally comes from unallocated forest areas (non-permanent forest domain).

In West and East Africa, forests are generally not managed in concessions, and the large part of the rainforest has been transformed into cultivated areas (Nix, 2019).

- **Threats Classification Scheme**

No past, ongoing, or future threats exist to this species. false

Threat	Timing	Scope	Severity	Impact Score
1.1. Residential & commercial development -> Housing & urban areas	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4
2.1.1. Agriculture & aquaculture -> Annual & perennial non-timber crops -> Shifting agriculture	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
2.2.2. Agriculture & aquaculture -> Wood & pulp plantations -> Agro-industry plantations	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5

2.3.2. Agriculture & aquaculture -> Livestock farming & ranching -> Small-holder grazing, ranching or farming	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4
3.2. Energy production & mining -> Mining & quarrying	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
4.1. Transportation & service corridors -> Roads & railroads	Ongoing	Minority (<50%)	Negligible declines	Past Impact
5.3.1. Biological resource use -> Logging & wood harvesting -> Intentional use: (subsistence/small scale) [harvest]	Ongoing	Minority (<50%)	Rapid Declines	Medium Impact: 6
5.3.2. Biological resource use -> Logging & wood harvesting -> Intentional use: (large scale) [harvest]	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 4
7.1.3. Natural system modifications -> Fire & fire suppression -> Trend Unknown/Unrecorded	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4

- **Conservation**

Erythrophleum ivorense is found in three ex situ collections including seeds being banked at the Millennium Seed Bank, UK (BGCI 2022). It has been found in many protected areas in Central Africa and Banco National Park in Ivory Coast. It is recommended that the population, harvest and trade trends are monitored to detect any future declines.

In certified forest concessions where the species is exploited, trails and or permanent forest plots are usually installed. These plots provide important data for (i) quantifying population dynamics processes at the stand level: mortality, growth and recruitment; (ii) phenological studies to determine the regular fruiting diameter (RFD). These trails and plots are managed in collaboration with forest concessions grouped within the DYNAFAC collective (see here for more information https://www.dynafac.org/fr/p/130/installation-de-dispositifs-de-suivi-de-la-dynamique-forestiere). Compilation of these data provide important additional information for targeted silvicultural measures for the sustainable management of this species. First summaries have provided information on important parameters such as: mortality, growth, etc. (DYNAFAC, 2022; Ligot et al., 2022). Based on almost 40 years of monitoring forest dynamics in Central Africa, the DYNAFAC collective recommends a MCD of 80 cm in Central Africa to maintain optimal gene flow and optimal regeneration (DYNAFAC, 2022). DYNAFAC also recommends the implementation of regeneration support techniques to ensure the long-term maintenance of populations. *E. ivorense* is also monitored in nurseries and planted in various forest concessions. Literature shows the abundance of light-demanding species in African rainforest and the history of shifting cultivation on bushland are closely linked. The light-demanding pioneer species that dominate the canopy of many African forests are thought to have regenerated mainly towards the end of the 19th century, when farmers were abandoning their fields under fields under pressure from settlers (Daïnou et al., 2016; Morin-Rivat et al., 2017; Van Gemerden et al., 2003). Keeping the environment open would ensure good regeneration of the species.

Logging in Central Africa is subject to strict legislation, species can only be harvested above a certain diameter and measures must be taken to ensure the renewal of the resource (Fargeot et al., 2004). Indeed, management plans for tropical rainforests require the determination of a minimum cutting diameter (MCD) to ensure a minimum renewal rate at the end of a rotation period (duration between two cuts on the same cutting base), the minimum reconstitution rate (40-50% depending on the country) as well as the rotation duration, being imposed by forestry legislation (Durrieu de Madron and Forni, 1997).

In addition, it will also be necessary to :

- Ensure the implementation of the recommendations of the Dynafac collective, including the establishment of a system for monitoring the populations of commercial species in the different forest types defined in a consensual manner;
- Set up monitoring and support systems for the regeneration of commercial species, prioritising species with regeneration deficits;
- Set up programmes to guarantee the phenotypic quality of commercial species populations: seed banks, seed stands, plus trees, seed orchards, conservation plantations;
- Consider threatened species in the delimitation of conservation series and in the identification of High Conservation Values;
- Update conservation statuses on a five-yearly basis, in particular by setting up a system of "green statuses";
- Define red lists adapted to regional or national contexts;
- Evaluate the status of cryptic species or species close to commercial species evaluated during this workshop.

- **Conservation Actions In- Place**

Action Recovery Plan	Note
Yes	Reforestation within forest concessions and others in forest gaps, old parks, quarries, and large logging roads

Systematic monitoring scheme	Note
Yes	The species is monitored in permanent plots installed within forestry companies in Central Africa (see here for more information https://www.dynafac.org/fr)

Occur in at least one PA	Note

Yes	The species may appear in at least 100 protected areas considering it distribution range

Percentage of population protected by PAs (0-100)	Note
1-10	Considering protected area across species distribution range

Area based regional management plan	Note
Unknown	-

Invasive species control or prevention	Note
No	-

Harvest management plan	Note
Yes	In certified forest concessions, the species is exploited according to a management plan.

Subject to ex-situ conservation	Note
Yes	Plantations in degraded areas are carried out and planned in Central Africa

Included in international legislation	Note
No	-

Subject to any international management/trade controls	Note
No	

- **Important Conservation Actions Needed**

Conservation Actions	Note
3.1.1. Species management -> Species management -> Harvest management	-
3.1.2. Species management -> Species management -> Trade management	-
3.4.2. Species management -> Ex-situ conservation -> Genome resource bank	-

- **Research Needed**

Research	Note
1.2. Research -> Population size, distribution & trends	-
3.1. Monitoring -> Population trends	-
3.2. Monitoring -> Harvest level trends	-
3.3. Monitoring -> Trade trends	-

• Ecosystem Services

• Ecosystem Services Provided by the Species

	Importance:	Geographic range of benefit:
1. Water Quality	2 - Important	Global
3. Flood Control	2 - Important	Global
4. Climate Regulation	2 - Important	Global
5. Landscape	2 - Important	Global
6. Air Quality	2 - Important	Global
7. Nutrient Cycling	2 - Important	Global
8. Habitat Maintenance	2 - Important	Global

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Erythrophleum ivorense A. Chev.

● IUCN status using criterion A3

We adopted the criterion A3 to assess the projected population reduction (PPR) to be met in the future (up to a maximum of 100 years) of *Erythrophleum ivorense*. To quantify the projected population reduction, simulations must be performed on mature individuals and three generations with maximum 100 years according to **criterion A3**. We estimated mature individuals and generation length, as recommended by the IUCN guidelines.

A **mature individual** is an individual that can reproduce, able to bear flowers or seeds (fertile in plant kingdom). To quantify the mature individuals for each species, we used phenological data of DYNAFAC network[16] from a combined dataset of 445 trees belonging to eight sites in four countries (Cameroun, Central African Republic, Gabon, and Republic of Congo). Minimum and maximum sampled diameters ranged from 10 to 130 cm (median 65 cm). The monitoring period ranged from 2004 to 2021. We assumed that the monitoring period was long enough to capture at least one reproductive event per tree such that trees without observed flowering/fruiting events were considered non-reproductive (about 30 percent of all monitored trees were non-reproductive). We used the methodology for the size at reproduction of canopy tree species in Central Africa (Ouédraogo et al., 2018): the **diameter of a mature individual** was obtained after fitting logistic regressions and the level of 50% of the probability to produce the flower or fruit was adopted for this species. Using this approach, the diameter of a mature individual was obtained after setting the 50% probability to produce flowers or fruits. The minimum diameter of mature individuals for this species was **35 cm**.

The **generation length** was the report between the mean diameter of mature individuals considering population structure and the mean increment. Given that the minimum diameter of mature individuals was 35 cm, we weighted the total number of trees by their diameter from 35 cm to 125 cm (Figure 1) to compute the number of mature individuals. The mean diameter of mature individuals was **73 cm**. The **mean increment** of the species was **0.522 cm**, obtained from 384 observations from logged and unlogged forests of published data in Cameroon (Ligot et al., 2022). Thus, the **generation length** was 73 cm / 0.522 cm = **139 years**. The age at maturity (**67 years**) has been estimated as the report between the **minimum diameter of mature individuals** (**35 cm**) and the **mean annual increment** (**0.522 cm**).

Estimation of the projected population reduction (PPR)

We adopted the criterion A3 to assess the projected population reduction (PPR) to be met in the future (up to a maximum of 100 years). *Erythrophleum ivorense* (Tali_ivo), is found in Guineo–Congolian rainforest species, widely distributed mainly from Gambia to Gabon (Gorel et al., 2015). The geographic range of species was in two regions (Central Africa and West Africa) characteristic of two biogeographical regions across the tropical African

[16] https://www.dynafac.org/en

forests (Fayolle et al., 2014). According to each region, different data (deforestation annual rate, growth, mortality, recruitment, forest inventory, etc.) have been used with logging data in Central Africa. Thus, the PPR was estimated for each region and the global PPR was then computed after weighting the two values by their relative forest areas.

PPR in Central Africa

In this region, forest management follows three different modalities: protected areas, production forests (logging concessions) and non-permanent forest domain. Based on occurrences, the natural range of this species includes all countries in Central Africa (Figure 1). The total natural area is estimated at 73 309 395.33 ha. Within this area, there are 56 483 244.9 ha (77.0%) for production forests, 7 233 596.56 ha (9.9%) for protected areas, and 9 592 553.818 ha (13.1%) for the non-permanent domain. Three different PPR were thus estimated: PPR_{pa} in protected areas, PPR_{pf} in production forests and PPR_{np} in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas and then added to estimate the PPR_{C} in Central Africa.

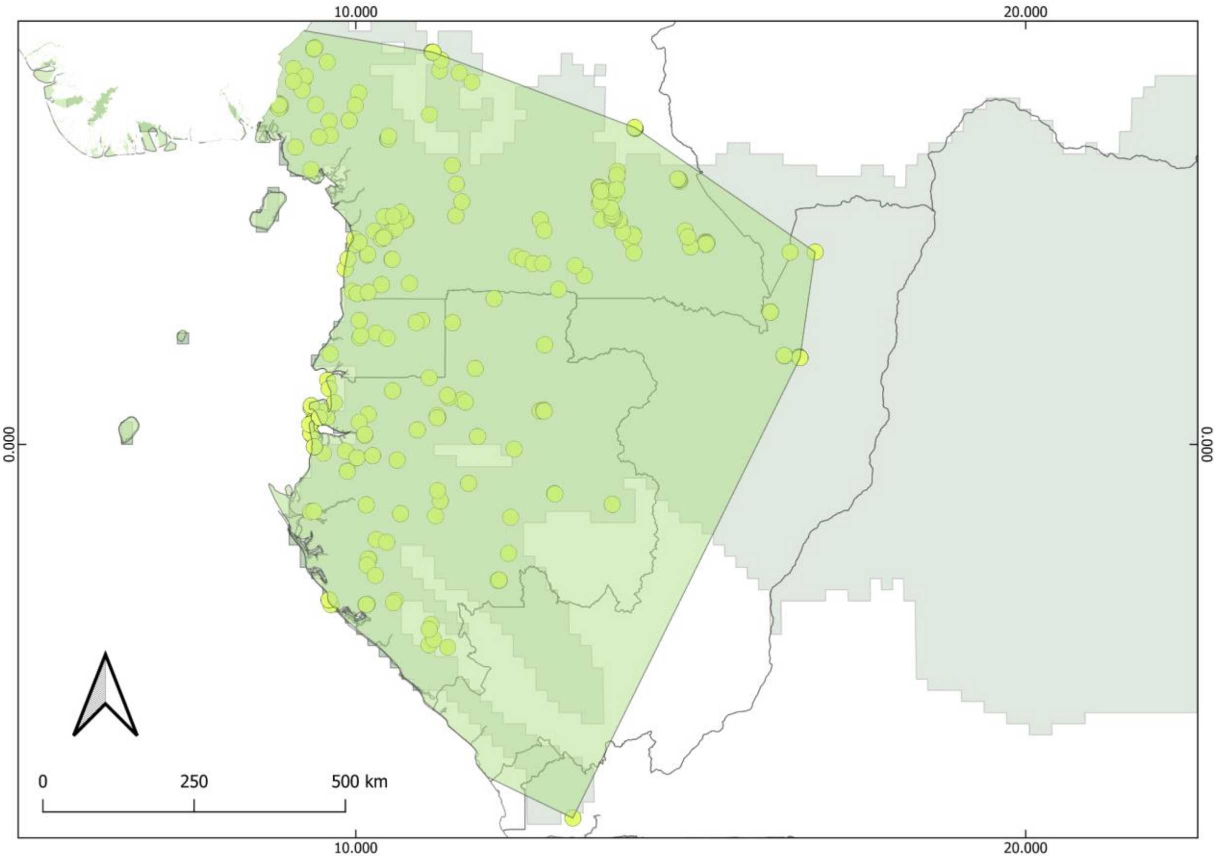

Figure 1. The range of *Erythrophleum ivorense* in Central Africa estimated from RAINBIO and CJB data, validated in December 2022 during a workshop with a group of experts in Gabon.

PPR in protected areas

Central Africa countries have allocated a higher proportion of their land to conservation than any other tropical regions, with relatively higher conservation success (Laurance et al., 2012). Indeed, most protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). They are currently representing a large part of forest and tree species conservation in Central Africa. Thus, the population of each species in protected areas (according to FRMI, 2018) covering its range was kept stable in the future over 100 years. **In these conditions, it was hypothesized that the PPR in protected areas for each species is 0%, suggesting no population reduction in the present and future.**

PPR in production forests

To quantify the evolution of the population of each timber species, matrix population models are widely used to study population dynamics (Picard & Liang, 2014). The population of this species was described at time *t* by a vector N_t corresponding to the density (number of trees ha^{-1}) in each diameter class (from 20 cm diameter to more than 120 cm). The density per diameter class was estimated using data from forest inventories that were carried out in 27 forest management units (FMU) of different logging companies in two countries (Cameroon, and Gabon). Most logging companies followed a standardized inventory protocol (Réjou-Méchain et al., 2011). These forest inventory data covered about 4 million ha (Table 1), that are representative of 7% of Central Africa's production forests of this species. The number of trees sampled in Central Africa was 3 135 902 with a density of 0.851 tree ha^{-1}. Large-scale commercial inventories have already been found useful in the identification of large-scale patterns in Central Africa (Réjou-Méchain et al., 2011). Using large-scale data from commercial forest inventories, Réjou-Méchain et al. (2021) jointly model the distribution in the abundance of the most dominant tree species and produce continuous maps of the floristic and functional composition of central African forests.

Table 1. Forest management units (FMU) sampled in Central Africa (Cameroon, CAR: Central African Republic, DRC: Democratic Republic of the Congo, EG: Equatorial Guinea, Gabon and RCongo: Republic of the Congo).

	Sampling	
Country	FMU	Area (ha)
Cameroon	14	1 376 789.38
CAR	-	-
DRC	-	-
EG	-	-
Gabon	13	2 309 603
RCongo	-	-
Total	27	3 686 392.38

The Usher matrix model was used to simulate the evolution of the recovery rate of all population and the exploitable stock of each species after logging in Central Africa. According to the Usher assumption, between *t* and *t*+1, an individual can either stay alive in the same class, stay alive and move up to the next class, or die; it cannot move up by more than one class or move backwards, i.e., the individual is free from diameter shrinkage (Picard et al., 2012). The Usher matrix model (U) considers three parameters (mortality, recruitment and growth rate that are constant in time) to estimate the transition probabilities:

$$U = \begin{pmatrix} q_1 + g_1 & g_2 & \cdots & \cdots & g_I \\ p_1 & q_2 & 0 & \cdots & 0 \\ 0 & \ddots & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & p_{I-1} & q_I \end{pmatrix}$$

where q_i is the probability for an individual to stay alive in class i between two consecutive time steps, p_i is the upgrowth transition rate (the probability for an individual to grow up from class i to class i +1), and g_i is the recruitment rate (Picard & Liang, 2014).

Tree mortality, recruitment and growth are three central processes for predicting the dynamics of tropical rainforests and estimating these three processes requires long-term monitoring in difficult field conditions (Picard & Gourlet-Fleury, 2008). These processes determine the evolution of the species population in the forest stand. The natural mortality is defined as the number of standing dead trees, and few studies have reported estimates of mortality rates in Central Africa. Data about tree mortality are still scarce and it does not allow to precisely model the mortality rate for each species and size class. Given the current state of knowledge, it appears reasonable to use a fixed mortality rate of 1% for all species and size classes, in agreement with the results of Ligot et al. (2022) on 21,180 trees belonging to 42 timber species of Central Africa annually monitored from one to seven years.

The recruitment integrates fruiting and seed dispersal from mother trees, and the survival of plant juveniles until they reach a size threshold where they are included in the stand. The recruitment term in the model is the average annual input of new individuals into the first size class from 20 cm. The recruitment events, like mortality events, are infrequent and thus difficult to model (Karsenty & Gourlet-Fleury, 2006). The population structure showed a single-mode curve with a good representation of the small stems suggesting a good regeneration (Figure 2). To model the recruitment, we used the hypothesis defined as the recruitment rate that would maintain a constant number of trees in the first diameter class. Claeys et al. (2019) projected the future forest dynamics up to the end of the century and they showed that projected mortality and recruitment rates in 2099 could not differ from the ones observed today. Thus, the hypothesis on the recruitment and the mortality rate is used in the future (up to 100 years) as they do today.

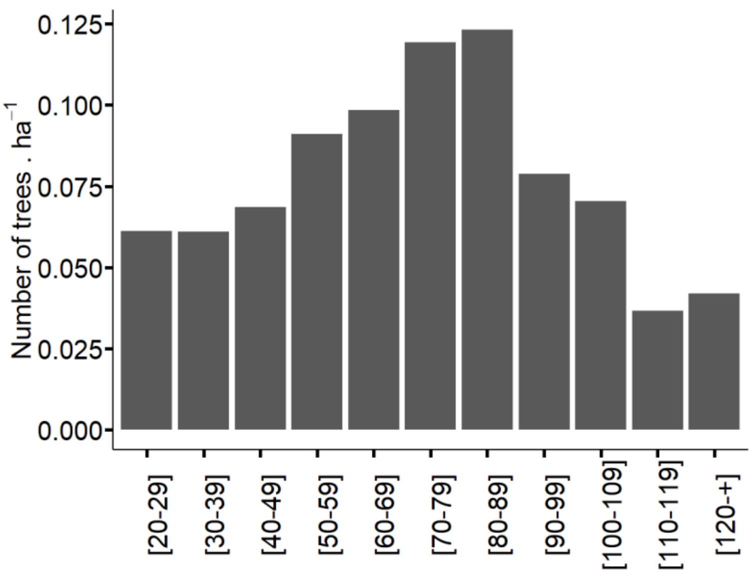

Figure 2. Population structure of *Erythrophleum ivorense* (Tali_ivo) defined using the number of trees per ha and per diameter class (from 20 cm of 27 logging concessions covering an area of 3 686 392.38 ha in Central Africa).

Since the mid-1900s, periodic tree monitoring and tree ring analyses have been carried out to study variability in tree growth across species in Central Africa (Durrieu de Madron, Nasi, et al., 2000; Ligot et al., 2019, 2022). We fitted growth models for each species using data from logged and unlogged areas of permanent tree plot monitoring from the DYNAFAC[17] network covering the five Central African countries. From the combined dataset, we identified 384 trees belonging to 2 sites in Cameroun (Ligot et al., 2022). The minimum and maximum sampled diameters ranged from 10 to 177 cm. The monitoring period ranged from 2011 to 2016. The mixed second-degree polynomial models (with a random site effect) were fitted for species monitored in several sites. The estimated coefficient from the mixed second-degree polynomial model has been used in the simulation in order to estimate the diameter growth (Table 2).

Table 2. Estimated coefficients (a, b, and c) of growth models between the increment (ac in cm $year^{-1}$) and the initial diameter (D in cm). The sample including the number of trees (n) and the number of sites (site) is also given. * significant (p-value < 0.05) and ^{ns} non-significant (p-value > 0.050)

species	n	site	model	a	b	c
Tali_ivo	384	2	ac ~ D + D^2 + (1|site)	0.832*	-0.007*	0.00002^{ns}

The transition probabilities of three parameters (mortality, growth, and recruitment rate) allowed making the harvested matrix. The logging operations have been modeled using the logging parameters (minimum cutting diameter, cutting and damage rate). The minimum cutting diameters were obtained from decrees of application of the forestry administrations (MCD_A) at the country level and the one used in the management plan (MCD_M, with $MCD_M \geq MCD_A$) at the logging company level. At the Central Africa level, we weighted the MCD_A and MCD_M values to the occupied area (**MCD_A = 55 cm and MCD_M = 75 cm**). The cutting rate (CA), which defines the proportion of harvested trees (trees with a diameter greater than MCD_A or MCD_M), was given by logging companies, and it was also weighted at the Central Africa level with a value of 66%. Given the current state of knowledge, it appears reasonable to use a fixed damage rate caused by logging of 7% of the initial population that disappears (Durrieu de Madron, Fontez, et al., 2000). The average cutting cycle (i.e. the period between two successive logging operations) is 28 years (FRMI, 2018), but we used 25 years to simplify computation of four simulations reaching 100 years (25, 50, 75 and 100 years), as requested by IUCN criterion A.

The Figure 3 shows the PPR in production forests for *Erythrophleum ivorense*. The reduction in the population of each species was then calculated as the difference between the initial numbers of mature individuals and the predicted numbers of mature individuals predicted after 100 years. The PPR in production forest was from **– 62.19% (MCD_A) to -56.97% (MCD_M)** for constant recruitment over 100 years.

[17] https://www.dynafac.org/en

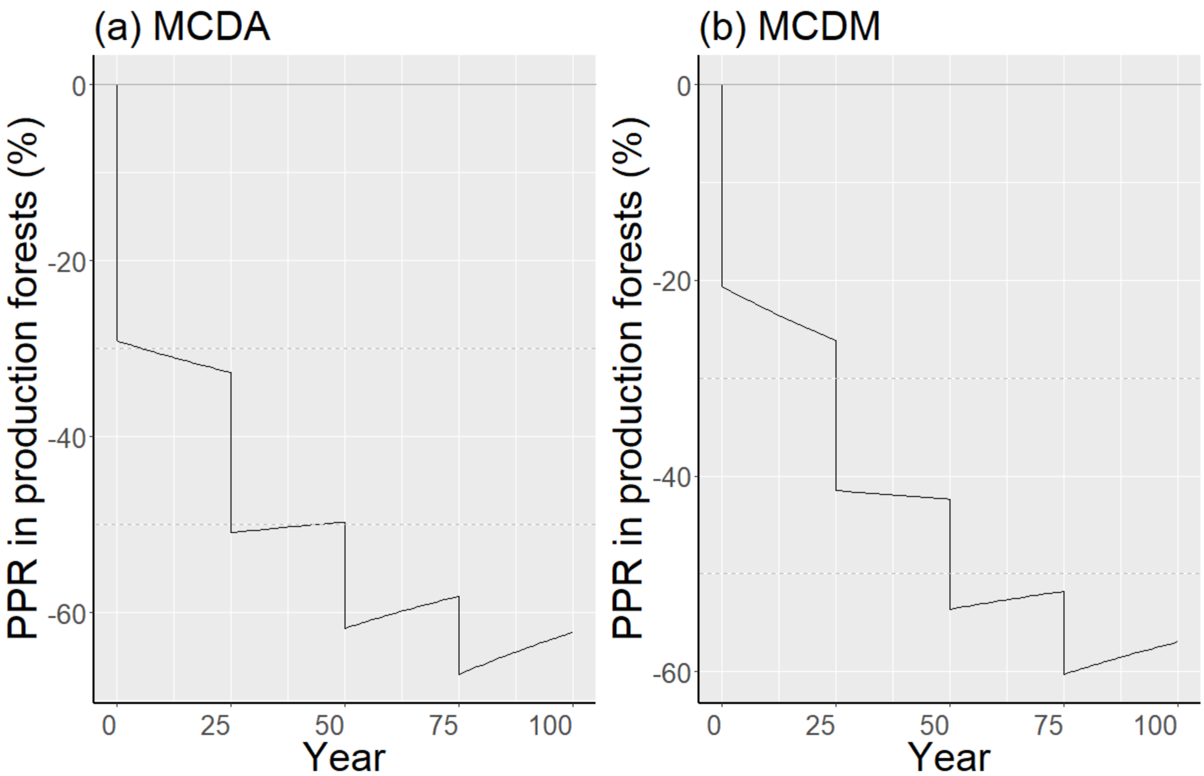

Figure 3. Simulations showing the projected population reduction (PPR) from the diameter of mature individuals (35 cm) in production forests for *Erythrophleum ivorense* for constant recruitment over 100 years.

PPR in the non-permanent forest domain

The major threats in the non-permanent domain are habitat loss due to the destruction of natural environments because of population growth and urbanization, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). The non-permanent domain area (9 592 553.818 ha) was considered as the area which was related to today's deforestation rate and illegal logging. Based on the large range of this species in Central Africa, the harvested volume from illegal logging and legal logging are 15% and 85%, respectively (FRMI 2018). In this condition, it was hypothesized that there is 85% of PPR from production forests and 15% of PPR from illegal logging in 100% PPR due to forest logging. Given that the PPR of production forests associated with its forest area was known, we deduced the PPR of illegal logging from those of the production forests. The deforestation rate was of 0.04% year^{-1} in the geographic range of this species (Eba'a et al., 2022). This is a conservative value since it will probably decrease in the future (Swamy et al., 2018).

The PPR in Central Africa by considering the PPR in production forest, protected area and non-permanent domain was from **– 49.36% (MCD_A) to -45.21% (MCD_M)** for constant recruitment over 100 years.

PPR in West Africa

In this region, forests are generally not managed in concessions, and the large part of the rainforest has been transformed in cultivated areas (Nix, 2019). Given the high degree of anthropization in this area, the main threats are the habitat loss due to the destruction of natural environments and illegal logging, and the trees are frequently felled in fields. Applying the deforestation rate related to agricultural production can be considered as a proxy for tree removal. Thus, the forest areas in West Africa (15 600 000 ha) were subject to a constant annual deforestation rate of 1.20% year^{-1} (Vancutsem et al., 2021). Taking this rate of deforestation as constant over the next 100 years, when it is expected to decline, is a reasonable precautionary measure incorporating illegal logging.

PPR global

We thus had two different PPR: PPR_C in Central Africa and PPR_W in West Africa. The global PPR was then computed after weighting the two values by their relative forest areas:

$$PPR = \frac{(S_C \times PPR_C) + (S_W \times PPR_W)}{S_C + S_W}$$

where S_C and S_W are forest areas in Central and West Africa, respectively.

The criterion A3 based on (c) a decline in area of occupancy (AOO), extent of occurrence (EOO) and/or habitat quality; and (d) potential levels of exploitation, has been computed as follow: (i) 30%≤PPR<50%, the species is considered as Vulnerable (VU); (ii) 50%≤PPR <80%, the species is considered as Endangered (EN), and PPR ≥ 80%, the species is considered as Critically endangered (CR).

The PPR global in distribution range of *Erythrophleum ivorense* was from **– 37.5% (MCD_A) to -40.9% (MCD_M)** for constant recruitment over 100 years. This PPR is > 30% and < 50%, suggesting that this species is threatened under the status of **Vulnerable (VU)** in its geographic area.

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10.10 Annexe 10. *Erythrophleum suaveolens* (Guill. & Perr.) Brenan

Draft

Erythrophleum suaveolens **(Guill. & Perr.) Brenan**

PLANTAE - TRACHEOPHYTA - MAGNOLIOPSIDA - FABALES - FABACEAE - Erythrophleum- suaveolens

Common Names: Ordeal tree (English), Tali (French)

Synonyms:

Red List Status
NT - Near Threatened, A3cd (IUCN version 3.1)

- **Red List Assessment**

- **Assessment Information**

Date of Assessment: 2022-09-01

Assessor(s): Monthe, F., Loubota, G., Ligot, G., Texier, N., Stévart, T. & Doucet, JL.

Reviewer(s):

Institution(s):

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Regions: Global

- **Identification Description**

Erythrophleum suaveolens is a large tree reaching 40 m in height and 1.5 m in diameter with buttresses or serrations. Its trunk is longer and straighter than that of the *Erythrophleum ivorense*. Its slice is reddish and let's escape a red sticky liquid, it has a smell of banana skin. Its leaves are compound, bipinnate, the 2 to 4 pairs of pinnae being composed of alternate leaflets (3.5-9 × 2-5 cm), subrounded and asymmetric at the base. The leaf blade, with a main vein that can be slightly hairy underneath, is greenish and dull when dry. The flowers of yellowish color to greenish white (until 7 mm) are pedunculated (1-1,5 mm) and grouped in compact ears. Its fruits are pods similar to those of the other species of tali but of a little bigger size (7-15 x 5-7 cm). They contain 5-11 hard black seeds, which are also a little larger (1.6-1.9 cm long).

Erythrophleum ivorense and *E. suaveolens* are very difficult to distinguish in the field. If there is any doubt, it is necessary to refer to their respective distribution. Genetic studies have indeed revealed that *E. ivorense* is coastal and *E. suaveolens* is continental (Duminil et al., 2013). There is also a widespread savanna species: *E. africanum* (Welw. ex Benth.) Harms.

Misidentifications are also possible with other Caesalpinioidea, especially *Pachyelasma tessmannii* (mekogho) and *Guibourtia pellegriniana*, *Guibourtia tessmannii* (bubinga), which sometimes have similar trunks. The first is distinguished by a rather orange slice without exudate and indented leaflets. The second has a different smelling slice and bifoliolate leaves in a half-moon shape.

- **Assessment Rationale**

Erythrophleum suaveolens is a widespread tall tree of tropical Africa semi-deciduous forest, long-lived, pioneer light demanding and usually non-gregarious species, native to semi-decidues rainforests and dry forests (Gorel et al., 2015). It is distributed from Senegal to Mozambique, Zimbabwe and Zambia (Gorel et al., 2015). Based on a 2 x 2 km cell size, the AOO of this species is estimated as 1788 km^2 with a minimum of 71 locations (number of forest management units of different logging companies in Central Africa). This species is not "Vulnerable" status under criterion B2. The EOO is calculated as 12 764 671 km^2, above the upper threshold for "Vulnerable" status under criterion B1.

E. suaveolens and *E. ivorense* are very difficult to distinguish in the field and are commonly known as Tali. Together, they are among the most exploited forest species in tropical Africa, sought after for the quality of its wood. The legal minimum cutting diameter "MCD" varies across its distribution range in Central Africa with 50 cm in Cameroon and Democratic Republic of Congo, 60 cm in Central Africa Republic and Republic of Congo, 70 cm in Gabon. The population structure showed a curve with a good representation of the small stems suggesting a good regeneration (see Supplementary Material). *E. suaveolens* has relatively high population densities of 0.49 stems.ha^{-1} (diameter at breast height, dbh ≥ 20 cm) and fairly fast growth rates of 0.47 ± 0.38 cm/year in Central Africa (see Supplementary Material). Given its stem density and the mean annual increment, we estimate the number of mature individuals over 10 000 across the distribution range, well above the threatened category under criteria C and D.

The most serious long-term threat is the conversion of the forest to agriculture and grazing, and illegal logging. However, the species is not considered severely fragmented as 580 known occurrences represent more than 50 localities. Considering the species' generation length of 141 years (see Supplementary Material), an inference of three generations in the past goes back to a period characterised by numerous activities in Central Africa, favouring the regeneration of light-demanding tropical species (Morin-Rivat et al., 2017). So, the species would certainly not be threatened according to the A2 and A1 criteria.

To model the recruitment, we used the hypothesis defined as the recruitment rate that would maintain a constant number of trees in the first diameter class. Based on simulations of the expected population reduction of *E.*

suaveolens in its distribution with constant recruitment, we estimated population reduction from 11.4-12.5 % in the next 100 years below the threshold to be considered threatened under criterion A3 (for further information about this methodology, see Supplementary Material). An assessment of the population reduction according to criterion A4 considering one to two generations back and one to two generations forward would likely introduce high levels of uncertainty due to the lack of data to efficiently model the reduction of population size in the past. No quantitative analysis of the probability of extinction in the wild was conducted, and therefore criterion E does not apply.
Considering (i) the population density, (ii) the reduction of population in the future across the distribution range, the species is assessed as near threatened NT, A3cd, and it can be threatened (VU) in future on the criterion A3 with a high level of exploitation.

Reasons for change

Reason(s) for Change in Red List Category from the Previous Assessment:

Erythrophleum suaveolens was previously assessed as "Least Concern" (https://www.iucnredlist.org/species/62025437/62025442) (Hills, 2019). During the last few years, important data have been produced on the self-ecology, population dynamics (growth, recruitment, mortality) of the species (DYNAFAC, 2022; Ligot et al., 2022). Moreover, a new version of the IUCN guidelines is available (from version 2.3 to 3.1). Given all these information, it was necessary to produce a new assessment of the species.

● Distribution

● Geographic Range

Erythrophleum suaveolens is a widespread species in tropical Africa with a distribution in West Africa, Central Africa and East Africa. It is widely distributed from Senegal to Mozambique, Zimbabwe and Zambia. The extent of occurrence (EOO) in native area is estimated at about 13 million km^2 across its distribution range.

● Area of Occupancy (AOO)

Estimated area of occupancy (AOO) - in km2	Justification
1788	The AOO has been estimated using ConR based on the 2 × 2 km cell size of 1011 occurrences from CJB (Conservatoire et Jardin botaniques de Genève) and RAINBIO

Continuing decline in area of occupancy (AOO)	Qualifier	Justification
Yes	Inferred	The species has suffered from reduction in area of occupancy, due to habitat degradation and deforestation in West Africa forest (more

	information here https://eros.usgs.gov/westafrica/land-cover/deforestation-upper-guinean-forest).

- Extent of Occurrence (EOO)

Estimated extent of occurrence (EOO)- in km2	EOO estimate calculated from Minimum Convex Polygon	Justification
12 764 671	true	Calculated using ConR based on 1456 known occurrences from CJBD and RAINBIO

Continuing decline in extent of occurrence (EOO)	Qualifier	Justification
Yes	Inferred	The species has certainly undergone Extent of Occurrence reduction in West; East and Central Africa, linked to the reduction in forest area (Vancutsem et al., 2021).

- Locations Information

Number of Locations	Justification
70-200	More than 71 localities. Based on the most serious plausible threat (conversion of its habitat) and illegal logging across the distribution range.

Continuing decline in number of locations	Qualifier	Justification
Yes	Inferred	The main threat remains the reduction of the forest area in tropical Africa.

Extreme fluctuations in the number of locations	Justification
No	

- Very restricted AOO or number of locations (triggers VU D2)

Very restricted in area of occupancy (AOO) and/or # of locations	Justification
No	-

- **Elevation / Depth / Depth Zones**

Elevation Lower Limit (in metres above sea level): 0

Elevation Upper Limit (in metres above sea level): 1100

- **Map Status**

Map Status	Use map from previous assessment	How the map was created, including data sources/methods used:	Please state reason for map not available:	Data Sensitive?	Justification	Geographic range this applies to:	Date restriction imposed:
Done	-	Qgis. The dataset was created from a compilation of Rainbio and CJB	-	-	-	-	-

- **Biogeographic Realms**

Biogeographic Realm: Afrotropical

- **Occurrence**

- **Countries of Occurrence**

Country	Presence	Origin	Formerly Bred	Seasonality
Benin	Extant	Native	-	Resident
Burkina Faso	Extant	Native	-	Resident
Cameroon	Extant	Native	-	Resident
Central African Republic	Extant	Native	-	Resident
Chad	Extant	Native	-	Resident
Congo	Extant	Native	-	Resident
Democratic Republic of the Congo	Extant	Native	-	Resident
Ivory Coast	Extant	Native	-	Resident
Equatorial Guinea	Extant	Native	-	Resident
Gabon	Extant	Native	-	Resident
Gambia	Extant	Native	-	Resident
Ghana	Extant	Native	-	Resident
Guinea	Extant	Native	-	Resident

Guinea-Bissau	Extant	Native	-	Resident
Kenya	Extant	Native	-	Resident
Liberia	Extant	Native	-	Resident
Malawi	Extant	Native	-	Resident
Mali	Extant	Native	-	Resident
Mozambique	Extant	Native	-	Resident
Nigeria	Extant	Native	-	Resident
Senegal	Extant	Native	-	Resident
Sierra Leone	Extant	Native	-	Resident
South Sudan	Extant	Native	-	Resident
Tanzania	Extant	Native	-	Resident
Togo	Extant	Native	-	Resident
Uganda	Extant	Native	-	Resident
Zambia	Extant	Native	-	Resident
Zimbabwe	Extant	Native	-	Resident

- **Population**

Erythrophleum suaveolens is a Guinean-Congolese and Zambezian endemism centers as well as Guinean-Congolese/Sudanese and Guinean-Congolese/Zambezian transition zones (Gorel et al., 2015). In West and East Africa, forests are generally not managed in concessions, and the large part of the rainforest has been transformed into cultivated areas (Nix, 2019). In Central Africa, the average density of *E. suaveolens* is 0.49 stems.ha^{-1} (dbh ≥ 20 cm) of forest commercial inventories (see Supplmentary Material). These Central African populations present contrasting tree densities (population density measured for dbh >30 cm), with the highest density found in Cameroon (1.72 stem.ha^{-1}), an intermediate density in Democratic Republic of Congo (0.68 stems.ha^{-1}) and the lowest density in Gabon (0.11 stem.ha^{-1}) (Duminil et al., 2016). The population density of harvestable trees (0.56 ± 0.056 stems.ha^{-1}, with dbh ≥ 60 cm) was higher than the population density of pre-harvestable trees (0.038 ± 0.009 stems.ha^{-1}, with dbh < 60 cm) in Cameroon (Noutcheu et al., 2016). This is in agreement with the population structure obtained at the regional level with the number of trees per ha according to diameter class (see Supplementary Material).

The average growth was 0.47 ± 0.38 cm/year in evergreen stands and in semi-deciduous forests (all diameters combined) in Central Africa (see Supplementary Material). The average growth of *E. suaveolens* within the growth monitoring plots is 0.45 ± 0.09 cm/year in Cameroon, 0.45 ± 0.41 cm/year in Central African Republic (Gorel et al. 2015). Tree ring measurements provide a value of 0.70 ± 0.13 cm/year in the Central African Republic (Durrieu de Madron et al., 2000), suggesting a growth overestimation due to a bad rings identification.

The legal minimum cutting diameter "MCD" varies across its distribution range, (50 cm in Cameroon and Democratic Republic of Congo, 60 cm in Central Africa Republic and Republic of Congo, 70 cm in Gabon). In the legal logging concession of central Africa, the MCD must be adapted to ensure sufficient recovery rates after each cutting cycle (MCD_M). At the Central Africa level, we weighted the MCD and MCD_M values to the occupied area with MCD = 65 cm and MCD_M = 75 cm (see Supplementary Material). These MCD are higher to the regular fruiting diameter (RFD), estimated at 60 cm (DYNAFAC, 2022). Situations that could affect the availability of seed trees and consequently the natural regeneration of the species though, the minimum fertility diameter was set at 35 cm in Central Africa (see Supplementary Material). In some concessions *E. suaveolens* is planted with a growth rate of 0.73 ± 0.164 cm/year in Cameroon (Doucet et al., 2016). However, illegal logging and local intense harvesting can occur. Efforts should be made to limit this illegal exploitation.

Using the Red List criterion A3, the projected population reduction (PPR) to be met in the future (100 years because the generation length of the species is 141 years) of the *E. suaveolens* population was assessed across its distribution range. Because *E. suaveolens* is a widespread species in West, East and Central Africa, the PPR was estimated for each region.

In Central Africa, three different PPR were thus estimated: PPRpa in protected areas, PPRpf in production forests and PPRnp in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas. First, protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). The population of the species in protected areas covering its range was kept stable in the future over 100 years, suggesting that the PPR in protected areas was 0%. Second, the evolution of the *E. suaveolens* population was simulated using an Usher matrix model to estimate the PPR of production forests (logging concessions, PPRpf). The simulations were initialised using the density (number of trees.ha-1) per diameter class (from 20 cm diameter, mature individuals) from forest management inventories of logging companies. The evolution of this initial population depended on several demographics (recruitment, mortality, and growth rate) and logging parameters (minimum cutting diameter, cutting and damage rate) that were adjusted using data of permanent tree plot monitoring. Thus, the density of *E. suaveolens* in 100 years was predicted with a logging event every 25 years, which corresponds to the average cutting cycle in Central Africa. PPRpf was then calculated as the difference between initial and final number of trees. Third, the major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Illegal logging and the habitat lost from deforestation rate have been both activities that allowed estimating the PPRnp in non-permanent domains.

In West and East Africa, the forest areas were subject to a constant annual deforestation rate of 1.20% year-1 and 1.53% year-1 respectively (Vancutsem et al., 2021). Taking this rate of deforestation as constant over the next 100 years, when it is expected to decline, is a reasonable precautionary measure. We thus had two different PPR: PPR in Central Africa, PPR in West Africa and PPR in East Africa.

The global PPR was then computed after weighting the three values by their relative forest areas. The global PPR result was found to be 11.4-14.5% (for further information about this methodology, see Supplementary Material).

- **Population Information**

Current Population Trend: Decreasing

Extreme fluctuations? (in # of mature individuals)	Justification
No	-

Severely fragmented?	Justification
No	-

Continuing decline in mature individuals?	Qualifier	Justification
Continuing decline % in mature individuals within 3 generations or 10 years, whichever is longer (up to max. of 100 years in the future)	**Qualifier**	**Justification**

Extreme fluctuations in the number of subpopulations	Justification
No	-

Continuing decline in number of subpopulations	Qualifier	Justification
No	-	-

All individuals in one subpopulation: No

Number of Subpopulations	Justification	Subpopulation Details	Subpopulation description	Number of mature individuals	Subpopulation trend	Qualifier	Location type	Number of Subpopulations	Location bounding box	Location coordinates	Notes
3	Genetic analyses Using nuclear microsatellites (nSSRs) and chloroplast non-coding sequences (pDNA) for 648 individuals sampled across the distribution range of the species	-	-	-	-	-	-	-	-	-	-

(Duminil et al., 2013)

- **Population Reduction - Past**

Percent Change in past	Reduction or Increase	Qualifier	Justification

Basis?

Reversible?

Understood?

Ceased?

- **Population Reduction - Future**

Percent Change in future	Reduction or Increase	Qualifier	Justification
11.4-14.5%	Reduction	Projected	Using the Red List criterion A3, the projected population reduction (PPR) to be met in the future (100 years because the generation length of the species is 141 years) of the *E. suaveolens* population was assessed across its distribution range. Because *E. suaveolens* is a widespread species in West, East and Central Africa, the PPR was estimated for each region. In Central Africa, three different PPR were thus estimated: PPRpa in protected areas, PPRpf in production forests and PPRnp in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas. First, protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the

	main agents of forest degradation across the region (Abernethy et al., 2016). The population of the species in protected areas covering its range was kept stable in the future over 100 years, suggesting that the PPR in protected areas was 0%. Second, the evolution of the *E. suaveolens* population was simulated using an Usher matrix model to estimate the PPR of production forests (logging concessions, PPRpf). The simulations were initialised using the density (number of trees.ha-1) per diameter class (from 20 cm diameter, mature individuals) from forest management inventories of logging companies. The evolution of this initial population depended on several demographics (recruitment, mortality, and growth rate) and logging parameters (minimum cutting diameter, cutting and damage rate) that were adjusted using data of permanent tree plot monitoring. Thus, the density of *E. suaveolens* in 100 years was predicted with a logging event every 25 years, which corresponds to the average cutting cycle in Central Africa. PPRpf was then calculated as the difference between initial and final number of trees. Third, the major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Illegal logging and the habitat lost from deforestation rate have been both activities that allowed estimating the PPRnp in non-permanent domains. In West and East Africa, the forest areas were subject to a constant annual deforestation rate of 1.20% year-1 and 1.53% year-1 respectively (Vancutsem et al., 2021). Taking this rate of deforestation as constant over the next 100 years, when it is expected to decline, is a reasonable precautionary measure. We thus had two different PPR: PPR in Central Africa, PPR in West Africa and PPR in East Africa. The global PPR was then computed after weighting the three values by their relative forest areas. The global PPR result was found to be 11.4-14.5%, lower than 30%. For further information about this methodology, see the attached Supplementary Information document.

Basis?

b) an index of abundance appropriate for the taxon, d) actual or potential levels of exploitation

- **Population Reduction - Ongoing**

Both: Percent Change over any 10 year or 3 generation period, whichever is longer, and must include both past and future, future can't go beyond 100 years	Reduction or Increase	Number of years for this period	Qualifier	Justification

Basis?

Reversible?
Yes

Understood?
Yes

Ceased?
No

Habitats and Ecology

Erythrophleum suaveolens is a large tree reaching 40 m in height and 1.5 m in diameter, long-lived, pioneer light demanding and usually non-gregarious species, found mostly in continental semi-deciduous forests and in gallery forests, widespread throughout tropical Africa. It is also indicative of secondary forests (Gorel et al., 2015). Saplings are briefly shade tolerant but quickly require light for further development (Hawthorne, 1995; Doucet, 2003; Meunier et al. 2015). Regeneration of *E. suaveolens* is best in open forest. The enrichment plantings of *E. suaveolens* has been performed on 44.4 ha in recently degraded forests to promote the regeneration of the logged species in the framework for certification (Doucet et al., 2016).

E. suaveolens bear hermaphrodite flowers. The species is deciduous and the defoliation starts during the great dry season, in December in the North of the climatic hinge such as in Cameroon and in July in the South such as in Gabon and South Africa (Gorel et al. 2015). Flowering has been noted to occur in January–April in West Africa, December–February in Kenya and in March–July in southern Africa. First flowers are observed at a minimum from 26 cm diameter in Central Africa Republic to 55 cm in northern Republic of Congo, becoming regular and abundant at 55 cm in northern Republic of Congo to 69 in Cameroon (Ouédraogo et al., 2018). Seeds are dispersed by opening the fruit (autochory) and by animals that consume the substance surrounding the seeds (zoochory) (Meunier et al., 2015). In Gabon, the fruiting period is respectively between March-June, and August – January in other Central Africa countries (Daïnou et al., 2021; Meunier et al., 2015).

- **IUCN Habitats Classification Scheme**

Habitat	Season	Suitability	Major Importance?
1.6. Forest -> Forest - Subtropical/Tropical Moist Lowland	Reside nt	Suitable	Yes

- **Continuing Decline in Habitat**

Continuing decline in area, extent and/or quality of habitat?	Qualifier	Justification
Yes	Observed	The annual deforestation rate of 0.35% in Central Africa, 1.20% in West Africa and 1.53% in East Africa (Vancutsem et al., 2021). The species can also colonise savannah and other open habitats.

- **Life History**

Generation Length	Justification	Data Quality
141	Minimum estimate of generation length for the species from the average growth rate, and the mean diameter of mature individuals (see Supplementary Material)	good

Age at maturity: female or unspecified
75 Years

Age at Maturity: Male
75 Years

Size at Maturity (in cms): Female
35

Size at Maturity (in cms): Male

35

Reproductive Periodicity
Annual

Annual Rate of Population Increase

Natural Mortality
1% (Ligot et al. 2022)

- **Systems**

System: Terrestrial

- **Plant / Fungi Specific**

Wild relative of a crop? No

Plant and Fungal Growth Forms
Tree - large

- **Use and Trade**

- **General Use and Trade Information**

Erythrophleum suaveolens are multipurpose trees characterised by high economic and socio-cultural values (Gorel et al. 2015). Together with *E. ivorense* is among the most exploited forest species in tropical Africa (Eba'a Atyi et al., 2022).

At industrial level, the wood, yellowish brown to reddish brown and darkens in the light, is quite hard and heavy, is suitable for joinery, flooring, railway sleepers, harbour and dock work, turnery, construction and bridges. It is durable with a resistance to fungi, dry wood insects and termites (Gorel et al. 2015). In 2005 the export of *Erythrophleum* ('tali') logs from Cameroon amounted to 37,500 m^3 and of sawn wood to 38,600 m^3, which made *Erythrophleum* the fourth most important timber of Cameroon. In 2010, Cameroon, the Republic of Congo and the Democratic Republic of the Congo exported 50 634, 13 324, and 2 349 m^3 respectively (ATIBT, 2010). In 2016, Central Africa, produce 454 153 m^3 (FRMi, 2018) and 432 407m^3 of log in 2018 (Eba'a Atyi et al., 2022).

The species of the *Erythrophleum* are known for the properties of their bark, wood and leaf extracts (Gorel et al. 2015). They contain a toxic agent called erythrophlein. Depending on the dosage, decoctions made from these organs can be therapeutic or toxic (Burkill, 1995). The use of bark grindings from *E. suaveolens* is often cited as a poison of ordeals (Hawthorne, 1995). Extracts from this species are also being tested as low environmental impact products for pathogen vector or plague control (Akinpelu et al., 2012). This species is mostly used in traditional pharmacopoeia by local populations. For example, the bark of *E. suaveolens* is indicated in the treatment of convulsions, pain, heart problems as well as edema caused by nematodes (Gorel et al. 2015).

Subsistence:	Rationale:	Local Commercial:	Further detail including information on economic value if available:
Yes	-	Yes	-

National Commercial Value: Yes

International Commercial Value: Yes

Is there harvest from captive/cultivated sources of this species? Yes

Trend in level of total offtake from wild sources: Stable

Trend in level of total offtake from domesticated sources: Unknown

- **Non- Consumptive Use**

Non-consumptive use of the species? true

- **Threats**

The main threats in the non-permanent domain across the species' distribution range, are mainly related to habitat loss due to the destruction of natural environments as a result of population explosion and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging and the abusive harvesting of plant parts requested as non-wood forest products (Bradshaw et al., 2009). In Central Africa, illegal logging accounts for nearly 46% of total log production, or over 650 000 m3 /year (FRMi, 2018). This production generally comes from unallocated forest areas (non-permanent forest domain).
In West and East Africa, forests are generally not managed in concessions, and the large part of the rainforest has been transformed into cultivated areas (Nix, 2019).

- **Threats Classification Scheme**

No past, ongoing, or future threats exist to this species. false

Threat	Timing	Scope	Severity	Impact Score
1.1. Residential & commercial development -> Housing & urban areas	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4
2.1.1. Agriculture & aquaculture -> Annual & perennial non-timber crops -> Shifting agriculture	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5

2.2.2. Agriculture & aquaculture -> Wood & pulp plantations -> Agro-industry plantations	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
2.3.2. Agriculture & aquaculture -> Livestock farming & ranching -> Small-holder grazing, ranching or farming	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4
3.2. Energy production & mining -> Mining & quarrying	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
4.1. Transportation & service corridors -> Roads & railroads	Ongoing	Minority (<50%)	Negligible declines	Past Impact
5.3.1. Biological resource use -> Logging & wood harvesting -> Intentional use: (subsistence/small scale) [harvest]	Ongoing	Minority (<50%)	Rapid Declines	Medium Impact: 6
5.3.2. Biological resource use -> Logging & wood harvesting -> Intentional use: (large scale) [harvest]	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 4
7.1.3. Natural system modifications -> Fire & fire suppression -> Trend Unknown/Unrecorded	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4

• Conservation

Erythrophleum suaveolens is recorded in 16 ex situ collections including seeds being banked at the Millennium Seed Bank, UK (BGCI 2022). This species has also been found in at least one protected area such as the Niokolo-Koba National Park (Senegal), Marahoué National Park (Côte d'Ivoire), and in many protected areas in Central Africa. The enrichment plantings of *E. suaveolens* has been performed on 44.4 ha in degraded forests (Doucet et al. 2016). In certified forest concessions where the species is exploited, trails and or permanent forest plots are usually installed. These plots provide important data for (i) quantifying population dynamics processes at the stand level: mortality, growth and recruitment; (ii) phenological studies to determine the regular fruiting diameter (RFD). These trails and plots are managed in collaboration with forest concessions grouped within the DYNAFAC collective (see here for more information https://www.dynafac.org/fr/p/130/installation-de-dispositifs-de-suivi-de-la-dynamique-forestiere). Compilation of these data provide important additional information for targeted silvicultural measures for the sustainable management of this species. First summaries have provided information on important parameters such as: mortality, growth, etc. (DYNAFAC, 2022; Ligot et al., 2022). Based on almost 40 years of monitoring forest dynamics in Central Africa, the DYNAFAC collective recommends a MCD of 80 cm in Central Africa to maintain optimal gene flow and optimal regeneration (DYNAFAC, 2022). DYNAFAC also recommends the preservation of additional seed trees or the implementation of regeneration support techniques to ensure the long-term maintenance of populations. *E. suaveolens* is also monitored in nurseries and planted in various forest concessions. Literature shows the abundance of light-demanding species in African rainforest and the history of

shifting cultivation on bushland are closely linked. The light-demanding pioneer species that dominate the canopy of many African forests are thought to have regenerated mainly towards the end of the 19th century, when farmers were abandoning their fields under fields under pressure from settlers (Daïnou et al., 2016; Morin-Rivat et al., 2017; Van Gemerden et al., 2003). Keeping the environment open would ensure good regeneration of the species.
Logging in Central Africa is subject to strict legislation, species can only be harvested above a certain diameter and measures must be taken to ensure the renewal of the resource (Fargeot et al., 2004). Indeed, management plans for tropical rainforests require the determination of a minimum cutting diameter (MCD) to ensure a minimum renewal rate at the end of a rotation period (duration between two cuts on the same cutting base), the minimum reconstitution rate (40-50% depending on the country) as well as the rotation duration, being imposed by forestry legislation (Durrieu de Madron and Forni, 1997).
E. suaveolens is a species of High Conservation Value" (Daïnou et al., 2016). However, as many other logged species, they suffer from illegal timber trade, therefore it is crucial to develop effective monitoring and prevention systems. In addition, it will also be necessary to :

- Ensure the implementation of the recommendations of the Dynafac collective, including the establishment of a system for monitoring the populations of commercial species in the different forest types defined in a consensual manner;
- Set up monitoring and support systems for the regeneration of commercial species, prioritising species with regeneration deficits;
- Set up programmes to guarantee the phenotypic quality of commercial species populations: seed banks, seed stands, plus trees, seed orchards, conservation plantations;
- Consider threatened species in the delimitation of conservation series and in the identification of High Conservation Values;
- Update conservation statuses on a five-yearly basis, in particular by setting up a system of "green statuses";
- Define red lists adapted to regional or national contexts;
- Evaluate the status of cryptic species or species close to commercial species evaluated during this workshop.

- **Conservation Actions In- Place**

Action Recovery Plan	Note
Yes	Reforestation within forest concessions and others in forest gaps, old parks, quarries, and large logging roads

Systematic monitoring scheme	Note
Yes	The species is monitored in permanent plots installed within forestry companies in Central Africa (see here for more information https://www.dynafac.org/fr)

Occur in at least one PA	Note
Yes	The species may appear in at least 100 protected areas considering it distribution range

Percentage of population protected by PAs (0-100)	Note
1-10	Considering protected area across species distribution range

Area based regional management plan	Note
Unknown	-

Invasive species control or prevention	Note
No	-

Harvest management plan	Note
Yes	In certified forest concessions, the species is exploited according to a management plan.

Subject to ex-situ conservation	Note
NO	-

Included in international legislation	Note
No	-

Subject to any international management/trade controls	Note
No	

- **Important Conservation Actions Needed**

Conservation Actions	Note
3.1.1. Species management -> Species management -> Harvest management	-
3.1.2. Species management -> Species management -> Trade management	-
3.4.2. Species management -> Ex-situ conservation -> Genome resource bank	-

- **Research Needed**

Research	Note
1.1. Research -> Taxonomy	-
1.2. Research -> Population size, distribution & trends	-
3.1. Monitoring -> Population trends	-
3.2. Monitoring -> Harvest level trends	-
3.3. Monitoring -> Trade trends	-

• Ecosystem Services

• Ecosystem Services Provided by the Species

	Importance:	Geographic range of benefit:
1. Water Quality	2 - Important	Global
3. Flood Control	2 - Important	Global
4. Climate Regulation	2 - Important	Global
5. Landscape	2 - Important	Global
6. Air Quality	2 - Important	Global
7. Nutrient Cycling	2 - Important	Global
8. Habitat Maintenance	2 - Important	Global

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Erythrophleum suaveolens (Guill. & Perr.) Brenan

IUCN status using criterion A3

We adopted the criterion A3 to assess the projected population reduction (PPR) to be met in the future (up to a maximum of 100 years) of *Erythrophleum suaveolens*. To quantify the projected population reduction, simulations must be performed on mature individuals and three generations with a maximum of 100 years according to **criterion A3**. We estimated mature individuals and generation length, as recommended by the IUCN guidelines.

A **mature individual** is an individual that can reproduce, able to bear flowers or seeds (fertile in plant kingdom). To quantify the mature individuals for each species, we used phenological data of DYNAFAC network[18] from a combined dataset of 445 trees belonging to eight sites in four countries (Cameroun, Central African Republic, Gabon, and Republic of Congo). Minimum and maximum sampled diameters ranged from 10 to 130 cm (median 65 cm). The monitoring period ranged from 2004 to 2021. We assumed that the monitoring period was long enough to capture at least one reproductive event per tree such that trees without observed flowering/fruiting events were considered non-reproductive (about 30 percent of all monitored trees were non-reproductive). We used the methodology for the size at reproduction of canopy tree species in Central Africa (Ouédraogo et al., 2018): the **diameter of a mature individual** was obtained after fitting logistic regressions and the level of 50% of the probability to produce the flower or fruit was adopted for this species. Using this approach, the diameter of a mature individual was obtained after setting the 50% probability to produce flowers or fruits. The minimum diameter of mature individuals for this species was **35 cm**.

The **generation length** was the report between the mean diameter of mature individuals considering population structure and the mean increment. Given that the minimum diameter of mature individuals was 35 cm, we weighted the total number of trees by their diameter from 35 cm to 125 cm (Figure 1) to compute the number of mature individuals. The mean diameter of mature individuals was **66 cm**. The **mean annual increment** of the species was **0.467 cm**, obtained from 1647 observations of from logged and unlogged forests of published data (Ligot et al., 2022) and unpublished data in Cameroon, Gabon, and Republic of Congo. Thus, the **generation length** was 66 cm / 0.467 cm = **141 years**. The age at maturity (**75 years**) has been estimated as the report between the **minimum diameter of mature individuals** (**35 cm**) and the **mean annual increment** (**0.467 cm)**.

Estimation of the projected population reduction (PPR)

We adopted the criterion A3 to assess the projected population reduction (PPR) to be met in the future (up to a maximum of 100 years) of *Erythrophleum suaveolens*. *Erythrophleum suaveolens* is present from Senegal to Kenya, from Mozambique to Zimbabwe (Gorel et al., 2015). The geographic range of species was in three regions (Central Africa, West Africa, and East Africa) characteristic of three biogeographical regions across the tropical African

[18] https://www.dynafac.org/en

forests (Fayolle et al., 2014). According to each region, different data (deforestation annual rate, growth, mortality, recruitment, forest inventory, etc.) have been used with logging data in Central Africa. Thus, the PPR was estimated for each region and the global PPR was then computed after weighting the three values by their relative forest areas.

PPR in Central Africa

In this region, forest management follows three different modalities: protected areas, production forests (logging concessions) and non-permanent forest domain. Based on occurrences, the natural range of this species includes all countries in Central Africa (Figure 1). The total natural area is estimated at 200 575 561.2 ha. Within this area, there are 34 097 872.5 ha (17.0%) for production forests, 33 599 497.5 ha (16.8%) for protected areas, and 132 878 191.2 ha (66.2%) for the non-permanent domain.

Three different PPR were thus estimated: PPR_{pa} in protected areas, PPR_{pf} in production forests and PPR_{np} in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas and then added to estimate the PPR_C in Central Africa.

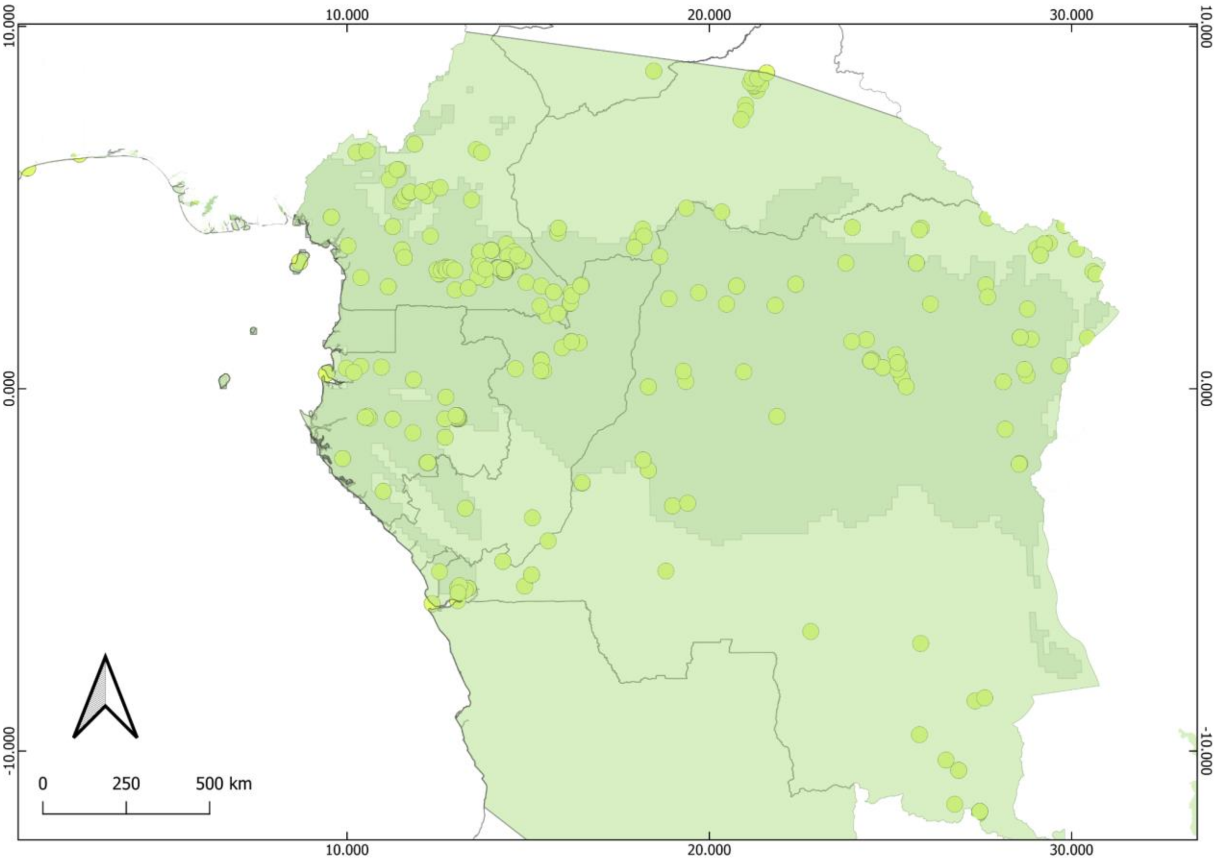

Figure 1. The range of *Erythrophleum suaveolens* in Central Africa estimated from RAINBIO and CJB data, validated in December 2022 during a workshop with a group of experts in Gabon.

PPR in protected areas

Central Africa countries have allocated a higher proportion of their land to conservation than any other tropical regions, with relatively higher conservation success (Laurance et al., 2012). Indeed, most protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that

have been the main agents of forest degradation across the region (Abernethy et al., 2016). They are currently representing a large part of forest and tree species conservation in Central Africa. Thus, the population of each species in protected areas (according to FRMI, 2018) covering its range was kept stable in the future over 100 years. **In these conditions, it was hypothesized that the PPR in protected areas for each species is 0%, suggesting no population reduction in the present and future.**

PPR in production forests

To quantify the evolution of the population of each timber species, matrix population models are widely used to study population dynamics (Picard & Liang, 2014). The population of this species was described at time t by a vector N_t corresponding to the density (number of trees ha^{-1}) in each diameter class (from 20 cm diameter to more than 120 cm). The density per diameter class was estimated using data from forest inventories that were carried out in 71 forest management units (FMU) of different logging companies in five countries (Cameroon, Central African Republic, Democratic Republic of the Congo, Gabon, and Republic of the Congo). Most logging companies followed a standardized inventory protocol (Réjou-Méchain et al., 2011). These forest inventory data covered about 17 million ha (Table 1), which are representative of 51% of Central Africa's production forests of this species. The number of trees sampled in Central Africa was 8 427 654 with a density of 0.49 tree ha^{-1}. Large-scale commercial inventories have already been found useful in the identification of large-scale patterns in Central Africa (Réjou-Méchain et al., 2011). Using large-scale data from commercial forest inventories, Réjou-Méchain et al. (2021) jointly model the distribution in the abundance of the most dominant tree species and produce continuous maps of the floristic and functional composition of central African forests.

Table 1. Forest management units (FMU) sampled in Central Africa (Cameroon, CAR: Central African Republic, DRC: Democratic Republic of the Congo, EG: Equatorial Guinea, Gabon, and RCongo: Republic of the Congo).

	Sampling	
Country	FMU	Area (ha)
Cameroon	10	857 994.77
CAR	7	2 165 837
DRC	15	4 348 051
EG	-	-
Gabon	31	5 915 846
RCongo	8	4 005 312
Total	71	17 293 040.77

The Usher matrix model was used to simulate the evolution of the recovery rate of all population and the exploitable stock of each species after logging in Central Africa. According to the Usher assumption, between t and t+1, an individual can either stay alive in the same class, stay alive and move up to the next class, or die; it cannot move up by more than one class or move backwards, i.e., the individual is free from diameter shrinkage (Picard et al., 2012). The Usher matrix model (U) considers three parameters (mortality, recruitment and growth rate that are constant in time) to estimate the transition probabilities:

$$U = \begin{pmatrix} q_1 + g_1 & g_2 & \cdots & \cdots & g_I \\ p_1 & q_2 & 0 & \cdots & 0 \\ 0 & \ddots & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & p_{I-1} & q_I \end{pmatrix}$$

where q_i is the probability for an individual to stay alive in class i between two consecutive time steps, p_i is the upgrowth transition rate (the probability for an individual to grow up from class i to class i +1), and g_i is the recruitment rate (Picard & Liang, 2014).

Tree mortality, recruitment, and growth are three central processes for predicting the dynamics of tropical rainforests, and estimating these three processes requires long-term monitoring in difficult field conditions (Picard & Gourlet-Fleury, 2008). These processes determine the evolution of the species population in the forest stand. The natural mortality is defined as the number of standing dead trees, and few studies have reported estimates of mortality rates in Central Africa. Data about tree mortality are still scarce and it does not allow for precisely model the mortality rate for each species and size class. Given the current state of knowledge, it appears reasonable to use a fixed mortality rate of 1% for all species and size classes, in agreement with the results of Ligot et al. (2022) on 21,180 trees belonging to 42 timber species of Central Africa annually monitored from one to seven years.
The recruitment integrates fruiting and seed dispersal from mother trees, and the survival of plant juveniles until they reach a size threshold where they are included in the stand. The recruitment term in the model is the average annual input of new individuals into the first size class from 20 cm. The recruitment events, like mortality events, are infrequent and thus difficult to model (Karsenty & Gourlet-Fleury, 2006). The population structure showed a single-mode curve with a good representation of the small stems suggesting a good regeneration (Figure 2). To model the recruitment, we used the hypothesis defined as the recruitment rate that would maintain a constant number of trees in the first diameter class. Claeys et al. (2019) projected the future forest dynamics up to the end of the century and they showed that projected mortality and recruitment rates in 2099 could not differ from the ones observed today. Thus, the hypothesis on the recruitment and the mortality rate is used in the future (up to 100 years) as they do today.

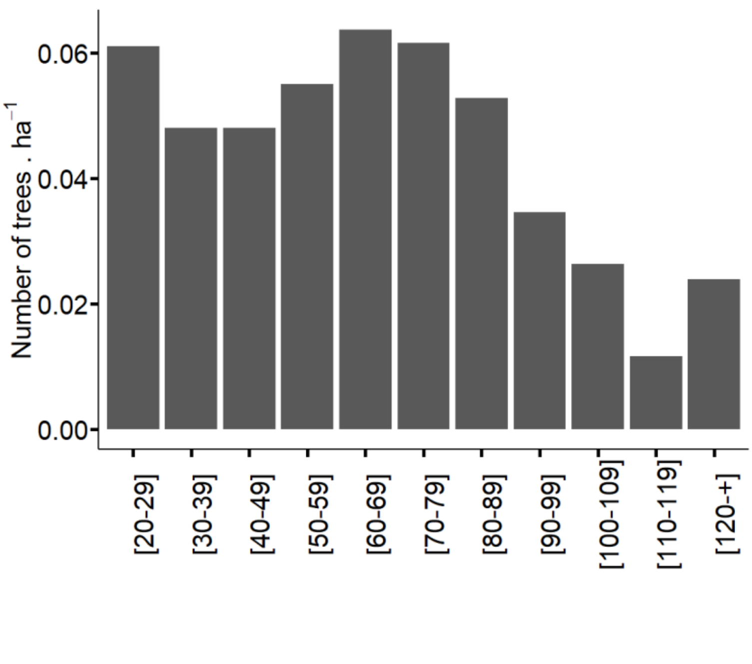

Figure 2. Population structure of *Erythrophleum suaveolens* (Tali_sua) defined using the number of trees per ha and per diameter class (from 20 cm of 71 logging concessions covering an area of 17 293 040.77 ha in Central Africa).

Since the mid-1900s, periodic tree monitoring and tree ring analyses have been carried out to study variability in tree growth across species in Central Africa (Durrieu de Madron, Nasi, et al., 2000; Ligot et al., 2019, 2022). We fitted growth models for each species using data from logged and unlogged areas of permanent tree plot monitoring from the DYNAFAC[19] network covering the five Central African countries. From the combined dataset, we identified 1647 trees belonging to 6 sites in three countries (Cameroun, Gabon, and Republic of Congo). The minimum and maximum sampled diameters ranged from 10 to 136 cm. The monitoring period ranged from 2005 to 2018. The mixed second-degree polynomial models (with a random site effect) were fitted for species monitored in several sites. The estimated coefficient from the mixed second-degree polynomial model has been used in the simulation in order to estimate the diameter growth (Table 2).

Table 2. Estimated coefficients (a, b, and c) of growth models between the increment (ac in cm year^{-1}) and the initial diameter (D in cm). The sample including the number of trees (n) and the number of sites (site) is also given. * significant (p-value < 0.05)

species	n	site	model	a	b	c
Tali_sua	1647	6	$ac \sim D + D^2 + (1\|site)$	0.517*	0.003*	-0.00006*

The transition probabilities of three parameters (mortality, growth, and recruitment rate) allowed making the harvested matrix. The logging operations have been modeled using the logging parameters (minimum cutting diameter, cutting and damage rate). The minimum cutting diameters were obtained from decrees of application of the forestry administrations (MCD_A) at the country level and the one used in the management plan (MCD_M, with $MCD_M \geq MCD_A$) at the logging company level. At the Central Africa level, we weighted the MCD_A and MCD_M values to the occupied area (**MCD_A = 65 cm and MCD_M = 75 cm**). The cutting rate (CA), which defines the proportion of harvested trees (trees with a diameter greater than MCD_A or MCD_M), was given by logging companies, and it was also weighted at the Central Africa level with a value of **60%**. Given the current state of knowledge, it appears reasonable to use a fixed damage rate caused by logging of **7%** of the initial population that disappears (Durrieu de Madron, Fontez, et al., 2000). The average cutting cycle (i.e. the period between two successive logging operations) is 28 years (FRMI, 2018), but we used 25 years to simplify computation of four simulations reaching 100 years (25, 50, 75 and 100 years), as requested by IUCN criterion A.
The Figure 3 shows the PPR in production forests for *Erythrophleum suaveolens*. The reduction in the population of each species was then calculated as the difference between the initial numbers of mature individuals and the

[19] https://www.dynafac.org/en

predicted numbers of mature individuals predicted after 100 years. **The PPR in production forests** was from **– 45.85% (MCD_A) to -41.86% (MCD_M)** for constant recruitment over 100 years.

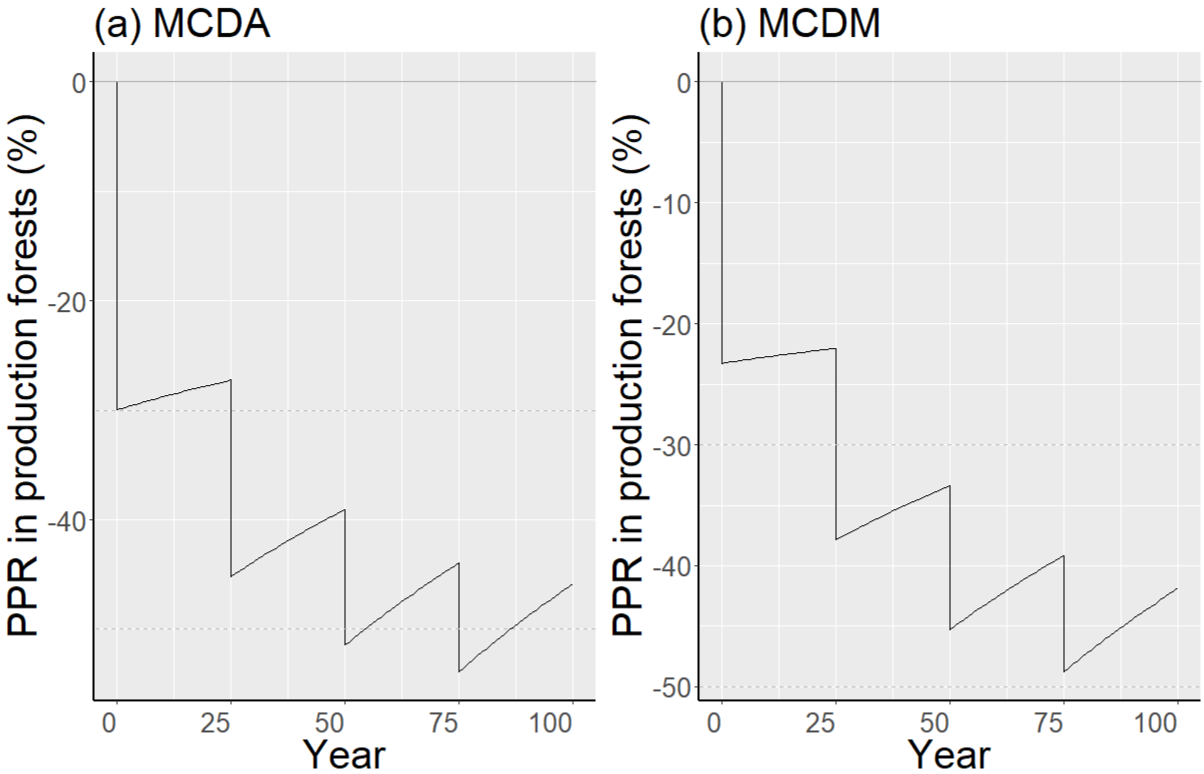

Figure 3. Simulations showing the projected population reduction (PPR) from diameter of mature individuals (35 cm) in production forests for the *Erythrophleum suaveolens* for constant recruitment over 100 years.

PPR in the non-permanent forest domain

The major threats in the non-permanent domain are habitat loss due to the destruction of natural environments because of population growth and urbanization, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Based on the large range of this species in Central Africa, the harvested volume from illegal logging and legal logging are 46% and 54%, respectively (FRMI 2018). In this condition, it was hypothesized that there is 54% of PPR from production forests and 46% of PPR from illegal logging in 100% PPR due to forest logging. Given that the PPR of production forests associated with its forest area was known, we deduced the PPR and forest area of illegal logging from those of the production forests. As a result, 29 046 335.9 ha were affected for the illegal logging for this species. The non-permanent domain area (132 878 191.2 ha) was considered as the area which was related to today's deforestation rate of 0.35% $year^{-1}$ in Central Africa (Vancutsem et al., 2021). This is a conservative value since it will probably decrease in the future (Swamy et al., 2018).

The PPR in Central Africa by considering the PPR in production forest, protected area, and non-permanent domain was from **– 15.7% (MCD_A) to -12.5% (MCD_M)** for the constant recruitment over 100 years.

PPR in West and East Africa

In these two regions, forests are generally not managed in concessions, and the large part of the rainforest has been transformed in cultivated areas (Nix, 2019). Given the high degree of anthropization in this area, the main threats are habitat loss due to the destruction of natural environments and illegal logging, and the trees are frequently felled in fields. Applying the deforestation rate related to agricultural production can be considered as a proxy for tree removal. Thus, the forest areas in West Africa (15 600 000 ha) and East Africa (6 400 000 ha) were subject to a constant annual deforestation rate of 1.20% $year^{-1}$ and 1.53% $year^{-1}$ respectively (Vancutsem et al., 2021). Taking this rate of deforestation as constant over the next 100 years, when it is expected to decline, is a reasonable precautionary measure incorporating illegal logging.

PPR global

We thus had three different PPR: PPR_C in Central Africa, PPR_W in West Africa, and PPR_E in East Africa. The global PPR was then computed after weighting the three values by their relative forest areas:

$$PPR = \frac{(S_C \times PPR_C) + (S_W \times PPR_W) + (S_E \times PPR_E)}{S_C + S_W + S_E}$$

where S_C, S_W, and S_E are forest areas in Central, West and East Africa, respectively.

The criterion A3 based on (c) a decline in area of occupancy (AOO), the extent of occurrence (EOO), and/or habitat quality; and (d) potential levels of exploitation, has been computed as follows: (i) 30%≤PPR<50%, the species is considered as Vulnerable (VU); (ii) 50%≤PPR <80%, the species is considered as Endangered (EN), and PPR ≥ 80%, the species is considered as Critically Endangered (CR).

The PPR global in the distribution range of *Erythrophleum suaveolens* was from **– 14.5% (MCD_A) to -11.4% (MCD_M)** for the constant recruitment over 100 years. This PPR is < 30%, suggesting that this species is not threatened in its geographic area.

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10.11 Annexe 11. *Lophira alata* - Banks ex C.F.Gaertn.

Draft

Lophira alata - Banks ex C.F.Gaertn.

PLANTAE - TRACHEOPHYTA - MAGNOLIOPSIDA - MALPIGHIALES - OCHNACEAE - Lophira - alata

Common Names: Azobe (English), Azobé (French)

Synonyms: *Lophira procera* A.Chev. (1935)

Red List Status
NT - Near Threatened, A3cd (IUCN version 3.1)

- **Red List Assessment**

- **Assessment Information**

Date of Assessment: 2022-09-01

Assessor(s): Monthe, F., Loubota, G., Ligot, G., Texier, N., Stévart, T. & Doucet, JL.

Reviewer(s):

Institution(s):

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Regions: Global

- **Identification Description**

Large tropical tree reaching 55 m height, *Lophira alata* presents large, sinuous, ascending branches bearing dark foliage grouped in clumps at the end of the branches. The trunk has a cylindrical base and develops thick serrations with age. Its reddish-brown bark is detached in elongated scales. In old trees it is covered with a layer of yellow powder. The large leaves (10-25(-45) x 4-12 cm) are simple, alternate, red when young, glabrous, leathery and marked with innumerable fine, tight, parallel secondary veins. The main vein is prominent on both sides. The top of the leaf blade is rounded to notched, the base is long attenuated. Its large white flowers are very fragrant and grouped in large inflorescences from 12 to 20 cm long. Its dry fruits, bright pink becoming light brown when ripe, have two wings of very unequal size (samaras). They are conical (3 x 1 cm), 8-15 cm long with the large wing, and contain a single ovoid seed (± 1.5 x 0.8 cm).
Recent genetic studies have revealed a well-differentiated genetic cluster endemic to Gabon, suggesting the presence of a cryptic species (Ewédjè et al., 2020) but until now, this probable new species couldn't be delimited through morphological characters.

- **Assessment Rationale**

Lophira alata is a widespread tall tree in African evergreen guineo-congolian forest, long-lived, usually gregarious pioneer species which forms large stands in the Atlantic evergreen rainforest of Central Africa. In semi-deciduous forests, the species is often found near large rivers or swampy clearings. It is distributed from Sierra Leone, Guinea Bissau to the lower Ogooué basin in Gabon and the Democratic Republic of Congo. Based on a 2 x 2 km cell size, the AOO of this species is estimated as 1 192 km^2 with a minimum of 69 locations (number of forest management units of different logging companies in Central Africa). This species is not "Vulnerable" status under criterion B2. The EOO is calculated as 4 439 584 km^2, above the upper threshold for "Vulnerable" status under criterion B1.
Commonly known as Azobe, it is one of the most exploited forest species in tropical Africa, sought after for the quality of its wood. The minimum cutting diameter (MCD) in Central Africa varies between 60 and 80 cm and is globally higher than the regular fruiting diameter (RFD) that varies between 50 and 60 cm diameter at breast height (DBH), ensuring optimal regeneration of the species. The population structure of this species showed a decreasing suggesting a good regeneration with a density of 0.40 stems.ha^{-1} (dbh ≥ 20 cm) in Central Africa (see Supplementary Material). Given its stem density and the mean annual increment of 0.49 ± 0.33 cm/year in Central Africa (see Supplementary Material), we estimate the number of mature individuals over 10 000 across the distribution range, well above the threatened category under criteria C and D.
The most serious long-term threat is the conversion of the forest to agriculture and grazing, and illegal logging. However, the species is not considered severely fragmented as the 1 034 specimens and observations represent 3 large sub-populations that are not isolated. Considering the species' generation length (129 years), an inference of three generations in the past goes back to around 1635, towards the end of the period characterised by high regeneration of light-demanding trees species, resulting from plantation activities of local populations in the forest, creating scattered large openings (Biwolé et al., 2015; Morin-Rivat et al., 2017), promoting light-demanding species. So, the species would certainly not be threatened according to the A2 and A1 criteria. Based on simulations of the expected population reduction in protected areas, non - permanent forest areas and production forest (logging concessions), we estimated population reduction between 18.0 to 19.6 % in the next 100 years below the threshold to be considered threatened under criterion A3 (see Supplementary Material). An assessment of the population reduction according to criterion A4 considering one to two generations back and one to two generations forward

would likely introduce high levels of uncertainty due to the lack of data to efficiently model the reduction of population size in the past. No quantitative analysis of the probability of extinction in the wild was conducted, and therefore criterion E does not apply.

Considering (i) the high population density, (ii) the good regeneration of the species, (iii) the good matching between MCD and RFD, and (iv) the reduction of population in the future across the distribution range, the species is assessed as near threatened NT, A3cd, and it can be threatened (VU) in future on the criterion A3 with a high level of exploitation.

Reasons for change

Reason(s) for Change in Red List Category from the Previous Assessment:

Lophira alata was previously assessed as "Vulnerable" (https://www.iucnredlist.org/species/33056/9745747) at the African Regional Workshop (Conservation & Sustainable Management of Trees, Zimbabwe, July 1996), 1998, following the A1cd criterion. During the last few years, important data have been produced on the self-ecology, population dynamics (growth, recruitment, mortality) of the species. Moreover, a new version of the IUCN guidelines is available (from version 2.3 to 3.1). Given all these information, it was necessary to produce a new assessment of the species.

• Distribution

• Geographic Range

Lophira alata is widely distributed from the Democratic Republic of the Congo to Sierra Leone, Guinea Bissau and the lower Ogooué basin in Gabon (Bamps, 1967). It is very common on the coast and less inland. In Democratic Republic of the Congo the species is found from the western borders to the central basin of the Congo River. The extent of occurrence (EOO) in native area is estimated at 4 439 584 km^2 across its distribution range.

• Area of Occupancy (AOO)

Estimated area of occupancy (AOO) - in km2	Justification
1 192	The AOO has been estimated using ConR based on the 2 × 2 km cell size of 1 034 occurrences from CJB (Conservatoire et Jardin botaniques de Genève) and RAINBIO

Continuing decline in area of occupancy (AOO)	Qualifier	Justification
Yes	Inferred	The species has suffered from reduction in Area of Occupancy, due to habitat degradation and deforestation in West and Central Africa forest (Vancutsem et al., 2021).

- **Extent of Occurrence (EOO)**

Estimated extent of occurrence (EOO)- in km2	EOO estimate calculated from Minimum Convex Polygon	Justification
4 439 584	true	Calculated using ConR based on 1 034 known occurrences from CJB (Conservatoire et Jardin botaniques de Genève) and RAINBIO

Continuing decline in extent of occurrence (EOO)	Qualifier	Justification
Yes	Inferred	The species has certainly undergone Extent of Occurrence reduction in West Africa, linked to the reduction in forest area (Vancutsem et al., 2021)

- **Locations Information**

Number of Locations	Justification
60-200	More than 69 localities. Based on the most serious plausible threat (conversion of its habitat) and illegal logging across the distribution range.

Continuing decline in number of locations	Qualifier	Justification
Yes	Inferred	The main threat remains the reduction of the forest area in West Africa.

Extreme fluctuations in the number of locations	Justification
No	

- **Very restricted AOO or number of locations (triggers VU D2)**

Very restricted in area of occupancy (AOO) and/or # of locations	Justification
No	-

- **Elevation / Depth / Depth Zones**

Elevation Lower Limit (in metres above sea level): 0

Elevation Upper Limit (in metres above sea level): 1600

- **Map Status**

Map Status	Use map from previous assessment	How the map was created, including data sources/methods used:	Please state reason for map not available:	Data Sensitive?	Justification	Geographic range this applies to:	Date restriction imposed:
Done	-	Qgis. The dataset was created from a compilation of Rainbio and CJB	-	-	-	-	-

- **Biogeographic Realms**

Biogeographic Realm: Afrotropical

- **Occurrence**

- **Countries of Occurrence**

Country	Presence	Origin	Formerly Bred	Seasonality
Cameroon	Extant	Native	-	Resident
Central African Republic	Extant	Native	-	Resident
Chad	Extant	Native	-	Resident
Congo	Extant	Native	-	Resident
Congo, The Democratic Republic of the	Extant	Native	-	Resident
Côte d'Ivoire	Extant	Native	-	Resident
Equatorial Guinea	Extant	Native	-	Resident
Equatorial Guinea -> Equatorial Guinea (mainland)	Extant	Native	-	Resident
Gabon	Extant	Native	-	Resident
Ghana	Extant	Native	-	Resident
Guinea	Extant	Native	-	Resident
Liberia	Extant	Native	-	Resident
Nigeria	Extant	Native	-	Resident
Sierra Leone	Extant	Native	-	Resident

Lophira alata is a guineo-congolian species, widely distributed from Democratic Republic of Congo to Sierra Leone and Guinea Bissau, as well as Cameroon. Its average density is 0.40 stems.ha-1 (dbh ≥ 20 cm) in Central Africa (see Supplementary Material). This density can locally reach 6 to 26 stems.ha^{-1} in some populations in Ivory Coast (Palla et al., 2002). Indeed, as for the vast majority of light-demanding species, population densities of *L. alata* vary according to forest type. They are generally lower mature forests (where the species has a "bell-shaped" diameter distribution) and higher in young secondary forests (where the diameter distribution is "decreasing exponential"). Misidentifications are sometimes observed by taxonomists particularly in the contact zone between forest and savannah with *L. lanceolata* (Ewédjè et al., 2020).

The average diameter growth is 0.49 ± 0.33 cm/year in evergreen stands and in semi-deciduous riverine forest in Central Africa (see Supplementary Material), a growth between 0.4 and 0.8 cm/year is observed in Sierra Leone, Ghana and Nigeria (Biwole, 2015; Doucet, 2003). A maximum growth rate of 2.25 cm/year was observed on a tree whose diameter had increased from 28.6 cm to 78.5 cm in 22 years in Ivory Coast (Doumenge and Séné, 2012).

The legal minimum cutting diameter "MCD" varies across its distribution range, (60 cm in Cameroon and Democratic Republic of Congo, 70 cm in Central Africa Republic and Republic of Congo, 80 cm in Gabon, 90 cm in Liberia and 110cm in Ghana). MCD is usually higher than the regular fruiting diameter (RFD), estimated at 50 cm (DYNAFAC, 2022), and the minimum fertility diameter estimated at 35 cm in Central Africa (see Supplementary Material). In some concessions *L. alata* is planted with a growth rate of 13.64 ± 1.15 mm/year and it takes 44 years to reach the MCD in Cameroon (Doucet et al., 2016).

Using the Red List criterion A3, the projected population reduction (PPR) to be met in the future (100 years because the generation length of the species is 129 years) of the *L. alata* population was assessed across its distribution range. Because *L. alata* is a widespread species in West and Central Africa, the PPR was estimated for each region.

In Central Africa, three different PPR were thus estimated: PPRpa in protected areas, PPRpf in production forests and PPRnp in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas. First, protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). The population of the species in protected areas covering its range was kept stable in the future over 100 years, suggesting that the PPR in protected areas was 0%. Second, the evolution of the *L. alata* population was simulated using an Usher matrix model to estimate the PPR of production forests (logging concessions, PPRpf). The simulations were initialised using the density (number of trees.ha-1) per diameter class (from 20 cm diameter, mature individuals) from forest management inventories of logging companies. The evolution of this initial population depended on several demographics (recruitment, mortality, and growth rate) and logging parameters (minimum cutting diameter, cutting and damage rate) that were adjusted using data of permanent tree plot monitoring. Thus, the density of *L. alata* in 100 years was predicted with a logging event every 25 years, which corresponds to the average cutting cycle in Central Africa. PPRpf was then calculated as the difference between initial and final number of trees. Third, the major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Illegal logging and the habitat lost from deforestation rate have been both activities that allowed estimating the PPRnp in non-permanent domains.

In West Africa, the forest areas were subject to a constant annual deforestation rate of 1.20% year-1 (Vancutsem et al., 2021). Taking this rate of deforestation as constant over the next 100 years, when it is expected to decline, is a reasonable precautionary measure.

We thus had two different PPR: PPRC in Central Africa and PPRW in West Africa. The global PPR was then computed after weighting the three values by their relative forest areas. The global PPR result was found to be between 18.0 to 19.6 %, lower than 30%.

For further information about this methodology, see the attached Supplementary Information document.

- **Population Information**

Current Population Trend: Decreasing

Extreme fluctuations? (in # of mature individuals)	Justification
No	-

Severely fragmented?	Justification
No	-

Continuing decline in mature individuals?	Qualifier	Justification

Continuing decline % in mature individuals within 3 generations or 10 years, whichever is longer (up to max. of 100 years in the future)	Qualifier	Justification

Extreme fluctuations in the number of subpopulations	Justification
No	-

Continuing decline in number of subpopulations	Qualifier	Justification
No	-	-

All individuals in one subpopulation: No

Number of Subpopulations	Justification	Subpopulation Details	Subpopulation description	Number of mature individuals	Subpopulation trend	Qualifier	Location type	Number of Subpopulations	Location bounding box	Location coordinates	Notes
3	Genetic analyses using 10 nuclear microsatellites for 433 individuals sampled across the distribution range of the species (Ewédjè et al., 2020).	-	-	-	-	-	-	-	-	-	-

- **Population Reduction - Past**

Percent Change in past	Reduction or Increase	Qualifier	Justification

Basis?

Reversible?

Understood?

Ceased?

- **Population Reduction - Future**

Percent Change in future	Reduction or Increase	Qualifier	Justification
18.0-19.6%	Reduction	Projected	Using the Red List criterion A3, the projected population reduction (PPR) to be met in the future (100 years because the generation length of the species is 129 years) of the *L. alata* population was assessed across its distribution range. Because *L. alata* is a

widespread species in West and Central Africa, the PPR was estimated for each region.

In Central Africa, three different PPR were thus estimated: PPRpa in protected areas, PPRpf in production forests and PPRnp in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas. First, protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). The population of the species in protected areas covering its range was kept stable in the future over 100 years, suggesting that the PPR in protected areas was 0%. Second, the evolution of the *L. alata* population was simulated using an Usher matrix model to estimate the PPR of production forests (logging concessions, PPRpf). The simulations were initialised using the density (number of trees.ha-1) per diameter class (from 20 cm diameter, mature individuals) from forest management inventories of logging companies. The evolution of this initial population depended on several demographics (recruitment, mortality, and growth rate) and logging parameters (minimum cutting diameter, cutting and damage rate) that were adjusted using data of permanent tree plot monitoring. Thus, the density of *L. alata* in 100 years was predicted with a logging event every 25 years, which corresponds to the average cutting cycle in Central Africa. PPRpf was then calculated as the difference between initial and final number of trees. Third, the major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Illegal logging and the habitat lost from deforestation rate have been both activities that allowed to estimate the PPRnp in non-permanent domain.

In West Africa, the forest areas were subject to a constant annual deforestation rate of 1.20% year-1 (Vancutsem et al., 2021). Taking this rate of deforestation as constant over the next 100 years, when it is expected to decline, is a reasonable precautionary measure.

We thus had two different PPR: PPRC in Central Africa and PPRW in West Africa. The global PPR was then computed after weighting

	the three values by their relative forest areas. The global PPR result was found to be 18.0 to 19.6 %, lower than 30%. For further information about this methodology, see the attached Supplementary Information document.

Basis?
b) an index of abundance appropriate for the taxon, d) actual or potential levels of exploitation

- **Population Reduction - Ongoing**

Both: Percent Change over any 10 year or 3 generation period, whichever is longer, and must include both past and future, future can't go beyond 100 years	Reduction or Increase	Number of years for this period	Qualifier	Justification

Basis?

Reversible?

Understood?

Ceased?

• Habitats and Ecology

Lophira alata is a large tree reaching 50 m in height and 1.8 m in diameter. It's a long-lived, gregarious light-demanding species that forms large stands in the Atlantic evergreen rainforests of West and Central Africa. In semi-deciduous forests, it is found on mountain slopes (high altitudes between 1200-1600 m), in the vicinity of large rivers or swampy clearings and in the transition zones between forest and savannah. The species is also found scattered in mixed forests on dry land from West Africa and Nigeria to north western Democratic Republic of Congo. Its stands are the result of former human activities (anthropophilic species) (Biwole, 2015). It is established in humid soils and forms root associations with arbuscular mycorrhizal fungi (Doumenge and Séné, 2012; Palla et al., 2002).

Lophira alata bears hermaphrodite flowers. In West Africa, the flowering takes place between October and November, and in December on the Cameroonian coast (Doumenge and Séné, 2012). First flowers are observed at a minimum 23 cm (Ma'an) diameter in Cameroon, 15 cm in Central Africa Republic and 28 cm in northern Republic of Congo (Ouédraogo et al., 2018; Yalibanda, 1999). It is a pterochorous species and its seeds are wind dispersed (Doucet, 2003). In Cameroon, Central Africa Republic and the Republic of Congo, the fruiting period is respectively between January-April, between January-March in Gabon and March-June in Guinea and Liberia (Daïnou et al., 2021; Meunier et al., 2015). In favourable conditions (high winds), the fruits can be transported up to 200 m from the tree (Biwole, 2015). Consequently, the seedlings preferentially settle in the direction of the prevailing winds. Its young stems are found in large openings on moist soils, not far from the parent plants. It is a social species that regenerates easily in open areas. However, this regeneration seems to require a total absence of competing species (Biwole et al., 2012). The species rejects stumps well but does not suckle. Nevertheless, as most light-demanding species in dense, undisturbed forests, it can have a diametric bell-shaped structure with a regeneration deficit. However in Central Africa, the global structure is balanced (see Supplementary Material).

The species is well suited to opened environments and colonises the savannahs of Cameroon and Gabon where it is often confused with *L. lanceolata* Tiegh. ex Keay (Ewédjè et al., 2020; Staquet, 2013). Locally, *L. alata* also benefits from the opening up of environments created by logging for its regeneration in natural environments (in large gaps and along roads) (Doucet, 2003; Palla et al., 2002).

- **IUCN Habitats Classification Scheme**

Habitat	Season	Suitability	Major Importance?
1.6. Forest -> Forest - Subtropical/Tropical Moist Lowland	Resident	Suitable	Yes

- **Continuing Decline in Habitat**

Continuing decline in area, extent and/or quality of habitat?	Qualifier	Justification
Yes	Observed	Despite the annual deforestation rate of 0.35%, 1.2% and 1.53% in Central, West and East Africa respectively (Vancutsem et al., 2021), the species can also colonised savannah and other open habitats.

- **Life History**

Generation Length	Justification	Data Quality

129	Minimum estimate of generation length for the species from the average growth rate, and the mean diameter of mature individuals (see Supplementary Material)	good

Age at maturity: female or unspecified
71 Years

Age at Maturity: Male
71 Years

Size at Maturity (in cms): Female
35

Size at Maturity (in cms): Male
35

Reproductive Periodicity
Annual

Annual Rate of Population Increase

Natural Mortality
1% (Ligot et al. 2022)

- **Systems**

System: Terrestrial

- **Plant / Fungi Specific**

Wild relative of a crop? No

Plant and Fungal Growth Forms
Tree - large

● **General Use and Trade Information**

Lophira alata is one of the most exploited forest species in tropical Africa. The earliest record of its export dates back to the 16th century when it was sold by Ghana to the United Kingdom for the manufacture of keels for shipbuilding (Doumenge and Séné, 2012).

At industrial level, *L. alata* is considered as non-impregnable wood (impregnability class: 4) according to NF EN 350-2 (European standard on the durability of wood and wood products). It is appreciated for installations in exposed areas such as harbours, hydraulic constructions, railway sleepers and wagon bottoms. It is used for the manufacture of sills, supports, water jets and for certain elements of timber-framed houses. It is suitable for the manufacture of parquet and stairs for industrial applications (Biwole et al., 2012). As early as 1914, *L. alata* was used in Cameroon for the construction of wharves and pontoons, with regular exports to Europe beginning in the aftermath of the First World War. In 2016, *L. alata* ranked 5th in the list of timber harvested in Cameroon with 5% of the total volume of timber harvested, representing almost 286 084 m^3/year. In Gabon and Equatorial Guinea, *L. alata* is an important export timber, but far behind okoumé (*Aucoumea klaineana* Pierre), with 37,700 m^3 destined for sawmills in 2007 (compared to 931,500 m^3 for okoumé). In the first four months of 2010, ITTO reported an increase in the price of several tropical woods, including *L. alata*, due to strong demand from China. In 2010, Liberia exported species logs at a price of US$ 253 per m^3.

At a local level, although there is recurrent confusion in use with *L. lanceolata*, the oil extracted from the seeds would be the only part of the tree used for food in Cameroon. Edible caterpillars (*Imbrasia obscura* Butler, 1878), whose main host tree is *Piptadeniastrum africana* Hook.f. (Dabema), are thought to be present on *L. alata* in the Democratic Republic of the Congo. The bark is used in the treatment of various diseases (dental caries, visceral pain, yellow fever, heartache, etc.). Harvested from the trunk, it is said to be an analgesic and anti-inflammatory. Mixed with the bark of *Afzelia africana* Sm. ex Pers. It is said to be used to combat mental disorders. The leaves, roots and seeds are said to combat malaria. The young leaves are used against respiratory disorders. The adult leaves, used as mulch, are said to be used to fight termites. Thus, *L. alata*, which does not seem to have much economic value as a non-wood product, is mainly sought after at the traditional level for its medicinal virtues.

Subsistence:	Rationale:	Local Commercial:	Further detail including information on economic value if available:
Yes	-	Yes	-

National Commercial Value: Yes

International Commercial Value: Yes

Is there harvest from captive/cultivated sources of this species? Yes

Trend in level of total offtake from wild sources: Stable

Trend in level of total offtake from domesticated sources: Unknown

- **Non- Consumptive Use**

Non-consumptive use of the species? true

- **Threats**

The main threats in the non-permanent domain across the species' distribution range, are mainly related to habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging and the abusive harvesting of plant parts requested as non-wood forest products (Bradshaw et al., 2009). In Central Africa, illegal logging accounts for nearly 46% of total log production (FRMi, 2018). This production generally comes from unallocated forest areas (non-permanent forest domain). However, illegal logging and local intense harvesting can occur. It is the case in southern Cameroon where the species is among the most exploited for the local market (Babe et al., 2020). In such areas, efforts should be made to limit this illegal exploitation.
Lophira alata is exploited in Central Africa. In West and East Africa, forests are generally not managed in concessions, and the large part of the rainforest has been transformed into cultivated areas (Nix, 2019).

- **Threats Classification Scheme**

No past, ongoing, or future threats exist to this species. false

Threat	Timing	Scope	Severity	Impact Score
1.1. Residential & commercial development -> Housing & urban areas	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4
2.1.1. Agriculture & aquaculture -> Annual & perennial non-timber crops -> Shifting agriculture	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
2.2.2. Agriculture & aquaculture -> Wood & pulp plantations -> Agro-industry plantations	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
2.3.2. Agriculture & aquaculture -> Livestock farming & ranching -> Small-holder grazing, ranching or farming	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4
3.2. Energy production & mining -> Mining & quarrying	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
4.1. Transportation & service corridors -> Roads & railroads	Ongoing	Minority (<50%)	Negligible declines	Past Impact

5.3.1. Biological resource use -> Logging & wood harvesting -> Intentional use: (subsistence/small scale) [harvest]	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 4
5.3.2. Biological resource use -> Logging & wood harvesting -> Intentional use: (large scale) [harvest]	Ongoing	Minority (<50%)	Slow, Significant Declines	Medium Impact: 6
7.1.3. Natural system modifications -> Fire & fire suppression -> Trend Unknown/Unrecorded	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4

- **Conservation**

Lophira alata is known to occur in at least 3 *ex situ* collections (BGCI, 2022), and may occur in many protected areas considering its distribution range. In certified forest concessions where the species is exploited, permanent forest plots are usually installed. These plots provide important data for (i) quantifying population dynamics processes at the stand level: mortality, growth and recruitment; (ii) phenological studies to determine the regular fruiting diameter (RFD). These trails and plots are managed in collaboration with forest concessions grouped within the DYNAFAC collective (see https://www.dynafac.org/fr/p/130/installation-de-dispositifs-de-suivi-de-la-dynamique-forestiere). Compilation of these data provide important additional information for targeted silvicultural measures for the sustainable management of this species. First summaries have provided information on important parameters such as: mortality, growth, etc. (DYNAFAC, 2022; Ligot et al., 2022). Based on almost 40 years of monitoring forest dynamics in Central Africa, the DYNAFAC collective recommends a MCD of 70 cm in Central Africa to maintain optimal gene flow and optimal regeneration (DYNAFAC, 2022). *L. alata* is also monitored in nurseries and planted in various forest concessions. It also colonises savannahs and open areas in general. Literature shows that the extent of past human disturbance in the forests of the Congo Basin has a positive impact on the abundance of pioneer species such as *L. alata* (Daïnou et al., 2016; Morin-Rivat et al., 2017; Van Gemerden et al., 2003). Keeping the environment open would ensure good regeneration of the species.
Genetic studies have revealed a well-differentiated genetic cluster endemic to Gabon, suggesting the presence of a cryptic species (Ewédjè et al., 2020). It would be important to finalise the taxonomical characterisation of this species.

Logging in Central Africa is subject to strict legislation, species can only be harvested above a certain diameter and measures must be taken to ensure the renewal of the resource (Fargeot et al., 2004). Indeed, management plans for tropical rainforests require the determination of a minimum cutting diameter (MCD) to ensure a minimum renewal rate at the end of a rotation period (duration between two cuts on the same cutting base), the minimum reconstitution rate (40-50% depending on the country) as well as the rotation duration, being imposed by forestry legislation (Durrieu de Madron and Forni, 1997).

In addition, it will also be necessary to :

- Ensure the implementation of the recommendations of the Dynafac collective, including the establishment of a system for monitoring the populations of commercial species in the different forest types defined in a consensual manner;
- Set up monitoring and support systems for the regeneration of commercial species, prioritising species with regeneration deficits;
- Set up programmes to guarantee the phenotypic quality of commercial species populations: seed banks, seed stands, plus trees, seed orchards, conservation plantations;
- Consider threatened species in the delimitation of conservation series and in the identification of High Conservation Values;
- Update conservation statuses on a five-yearly basis, in particular by setting up a system of "green statuses";
- Define red lists adapted to regional or national contexts;
- Evaluate the status of cryptic species or species close to commercial species evaluated during this workshop.

- **Conservation Actions In- Place**

Action Recovery Plan	Note
Yes	Reforestation within forest concessions and others in forest gaps, old parks, quarries, and large logging roads

Systematic monitoring scheme	Note
Yes	The species is monitored in permanent plots installed within forestry companies in Central Africa (see here for more information https://www.dynafac.org/fr)

Occur in at least one PA	Note
Yes	The species may appear in at least 100 protected areas considering it distribution range

Percentage of population protected by PAs (0-100)	Note
1-10	Considering protected area across species distribution range

Area based regional management plan	Note
Unknown	-

Invasive species control or prevention	Note
No	-

Harvest management plan	Note
Yes	In certified forest concessions, the species is exploited according to a management plan.

Subject to ex-situ conservation	Note
NO	-

Included in international legislation	Note
No	-

Subject to any international management/trade controls	Note
No	

- **Important Conservation Actions Needed**

Conservation Actions	Note
3.1.1. Species management -> Species management -> Harvest management	-
3.1.2. Species management -> Species management -> Trade management	-
3.4.2. Species management -> Ex-situ conservation -> Genome resource bank	-

- **Research Needed**

Research	Note
1.1. Research -> Taxonomy	-
1.2. Research -> Population size, distribution & trends	-
3.1. Monitoring -> Population trends	-
3.2. Monitoring -> Harvest level trends	-
3.3. Monitoring -> Trade trends	-

- **Ecosystem Services**

- **Ecosystem Services Provided by the Species**

	Importance:	Geographic range of benefit:
1. Water Quality	2 - Important	Global
3. Flood Control	2 - Important	Global
4. Climate Regulation	2 - Important	Global
5. Landscape	2 - Important	Global
6. Air Quality	2 - Important	Global
7. Nutrient Cycling	2 - Important	Global
8. Habitat Maintenance	2 - Important	Global

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• SUPPLEMENTARY MATERIAL

Lophira alata - Banks ex C.F.Gaertn.

• IUCN status using criterion A3

We adopted the criterion A3 to assess the projected population reduction (PPR) to be met in the future (up to a maximum of 100 years) of *Lophira alata*. To quantify the projected population reduction, simulations must be performed on mature individuals and three generations with maximum 100 years according to **criterion A3**. We estimated mature individuals and generation length, as recommended by the IUCN guidelines.

A **mature individual** is an individual that can reproduce, able to bear flowers or seeds (fertile in plant kingdom). To quantify the mature individuals for each species, we used phenological data of DYNAFAC network[20] from a combined dataset of 410 trees belonging to three sites in two countries (Cameroun, and Republic of Congo). Minimum and maximum sampled diameter ranged from 10 to 130 cm (median 50 cm). The monitoring period ranged from 23 to 76 months (Ouédraogo et al., 2018). We assumed that the monitoring period was long enough to capture at least one reproductive event per tree such that trees without observed flowering/fruiting events were considered non-reproductive (36 percent of all monitored trees were non-reproductive). We used the methodology for the size at reproduction of canopy tree species in Central Africa (Ouédraogo et al., 2018): the **diameter of a mature individual** was obtained after fitting logistic regressions and the level of 50% of the probability to produce the flower or fruit was adopted for this species. Using this approach, the diameter of a mature individual was obtained after setting the 50% probability to produce flowers or fruits. Thus, the minimum diameter of mature individuals for this species was **35 cm**.

The **generation length** was the report between the mean diameter of mature individuals considering population structure and the mean increment. Given that the minimum diameter of mature individuals was 35 cm, we weighted the total number of trees by their diameter from 35 cm to 125 cm (Figure 1) to compute the number of mature individuals. The mean diameter of mature individuals was **63 cm**. The **mean increment** of the species was **0.49 cm**, obtained from 882 observations of Ligot et al. (2022) and unpublished data in Cameroon, Gabon, and Republic of Congo. Thus, the **generation length** was 63 cm / 0.49 cm = **129 years**. The age at maturity (**71 years**) has been estimated as the report between the **minimum diameter of mature individuals** (**35 cm**) and the **mean annual increment** (**0.49 cm**).

• Estimation of the projected population reduction (PPR)

We adopted the criterion A3 to assess the projected population reduction (PPR) to be met in the future (up to a maximum of 100 years). *Lophira alata* (Azobe), is found in Guineo–Congolian rainforest species, widely distributed

[20] https://www.dynafac.org/en

mainly from Guinea-Bissau to Democratic Republic of Congo (Biwole et al., 2012). The geographic range of species was in two regions (Central Africa and West Africa) characteristic of two biogeographical regions across the tropical African forests (Fayolle et al., 2014). According to each region, different data (deforestation annual rate, growth, mortality, recruitment, forest inventory, etc.) have been used with logging data in Central Africa. Thus, the PPR was estimated for each region and the global PPR was then computed after weighting the two values by their relative forest areas.

- **PPR in Central Africa**

In this region, forest management follows three different modalities: protected areas, production forests (logging concessions) and non-permanent forest domain. Based on occurrences, the natural range of this species includes all countries in Central Africa (Figure 1). The total natural area is estimated at 193 051 369.6 ha. Within this area, there are 42 161 206.4 ha (21.8%) for production forests, 15 478 333.4 ha (8.0%) for protected areas, and 135 411 829.8 ha (70.2%) for the non-permanent domain.

Three different PPR were thus estimated: PPR_{pa} in protected areas, PPR_{pf} in production forests and PPR_{np} in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas and then added to estimate the PPR_C in Central Africa.

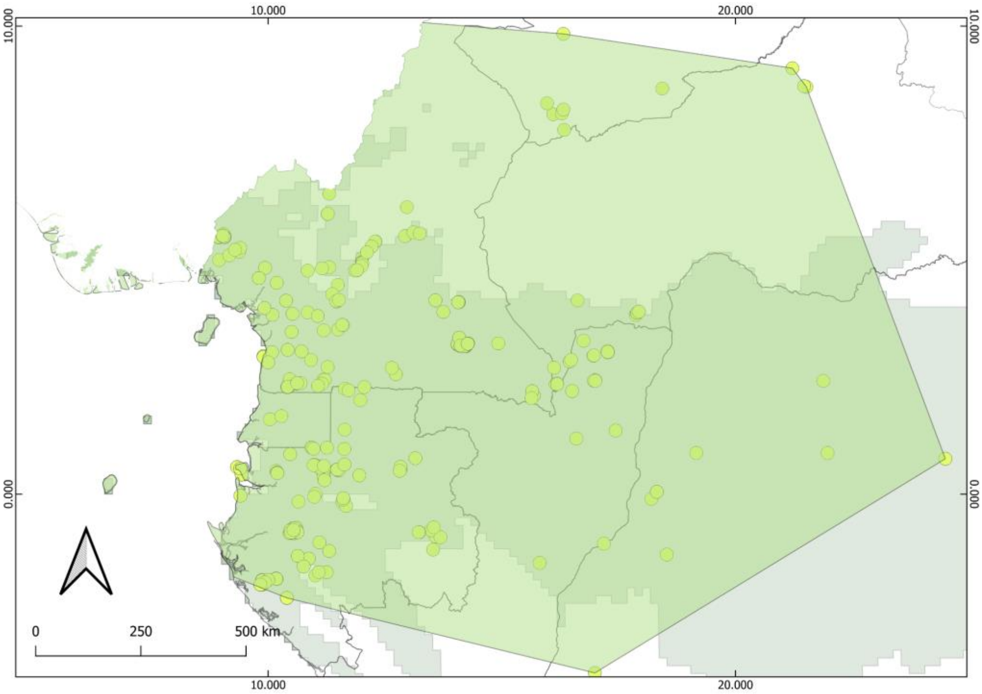

Figure 1. The range of *Tieghemella africana* in Central Africa estimated from RAINBIO and CJB data, validated in December 2022 during a workshop with a group of experts in Gabon.

- **PPR in protected areas**

Central Africa countries have allocated a higher proportion of their land to conservation than any other tropical regions, with relatively higher conservation success (Laurance et al., 2012). Indeed, most protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). They are currently representing a large part of forest and tree species conservation in Central Africa. Thus, the population of each species in protected areas (according to FRMI, 2018) covering its range was kept stable in the future over 100 years. **In these conditions, it was hypothesized that the PPR in protected areas for each species is 0%, suggesting no population reduction in the present and future.**

- **PPR in production forests**

To quantify the evolution of the population of each timber species, matrix population models are widely used to study population dynamics (Picard & Liang, 2014). The population of this species was described at time t by a vector N_t corresponding to the density (number of trees ha^{-1}) in each diameter class (from 20 cm diameter to more than 120 cm). The density per diameter class was estimated using data from forest inventories that were carried out in 69 forest management units (FMU) of different logging companies in five countries (Cameroon, Central African Republic, Democratic Republic of Congo, Gabon, and Republic of the Congo). Most logging companies followed a standardized inventory protocol (Réjou-Méchain et al., 2011). These forest inventory data covered about 15 million ha (Table 1), that are representative of 36% of Central Africa's production forests of this species. The number of trees sampled in Central Africa was 6 042 810 with a density of 0.40 tree ha^{-1}. Large-scale commercial inventories have already been found useful in the identification of large-scale patterns in Central Africa (Réjou-Méchain et al., 2011). Using large-scale data from commercial forest inventories, Réjou-Méchain et al. (2021) jointly model the distribution in the abundance of the most dominant tree species and produce continuous maps of the floristic and functional composition of central African forests.

Table 1. Forest management units (FMU) sampled in Central Africa (Cameroon, CAR: Central African Republic, DRC: Democratic Republic of the Congo, EG: Equatorial Guinea, Gabon and RCongo: Republic of the Congo).

	Sampling	
Country	FMU	Area (ha)
Cameroon	15	1 397 488.77
CAR	7	2 165 837
DRC	1	217 928
EG	-	-
Gabon	38	7 211 294
RCongo	8	4 005 312
Total	69	14 997 859.77

The Usher matrix model was used to simulate the evolution of the recovery rate of all population and the exploitable stock of each species after logging in Central Africa. According to the Usher assumption, between t and t+1, an individual can either stay alive in the same class, stay alive and move up to the next class, or die; it cannot move up by more than one class or move backwards, i.e., the individual is free from diameter shrinkage (Picard et al.,

2012). The Usher matrix model (U) considers three parameters (mortality, recruitment and growth rate that are constant in time) to estimate the transition probabilities:

$$U = \begin{pmatrix} q_1 + g_1 & g_2 & \cdots & \cdots & g_I \\ p_1 & q_2 & 0 & \cdots & 0 \\ 0 & \ddots & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & p_{I-1} & q_I \end{pmatrix}$$

where q_i is the probability for an individual to stay alive in class i between two consecutive time steps, p_i is the upgrowth transition rate (the probability for an individual to grow up from class i to class i +1), and g_i is the recruitment rate (Picard & Liang, 2014).

Tree mortality, recruitment and growth are three central processes for predicting the dynamics of tropical rainforests and estimating these three processes requires long-term monitoring in difficult field conditions (Picard & Gourlet-Fleury, 2008). These processes determine the evolution of the species population in the forest stand. The natural mortality is defined as the number of standing dead trees, and few studies have reported estimates of mortality rates in Central Africa. Data about tree mortality are still scarce and it does not allow to precisely model the mortality rate for each species and size class. Given the current state of knowledge, it appears reasonable to use a fixed mortality rate of 1% for all species and size classes, in agreement with the results of Ligot et al. (2022) on 21,180 trees belonging to 42 timber species of Central Africa annually monitored from one to seven years.

The recruitment integrates fruiting and seed dispersal from mother trees, and the survival of plant juveniles until they reach a size threshold where they are included in the stand. The recruitment term in the model is the average annual input of new individuals into the first size class from 20 cm. The recruitment events, like mortality events, are infrequent and thus difficult to model (Karsenty & Gourlet-Fleury, 2006). The population structure showed a curve in "decreasing exponential" suggesting a good regeneration (Figure 2). To model the recruitment, we used the hypothesis defined as the recruitment rate that would maintain a constant number of trees in the first diameter class. Claeys et al. (2019) projected the future forest dynamics up to the end of the century and they showed that projected mortality and recruitment rates in 2099 could not differ from the ones observed today. Thus, the hypothesis on the recruitment and the mortality rate is used in the future (up to 100 years) as they do today.

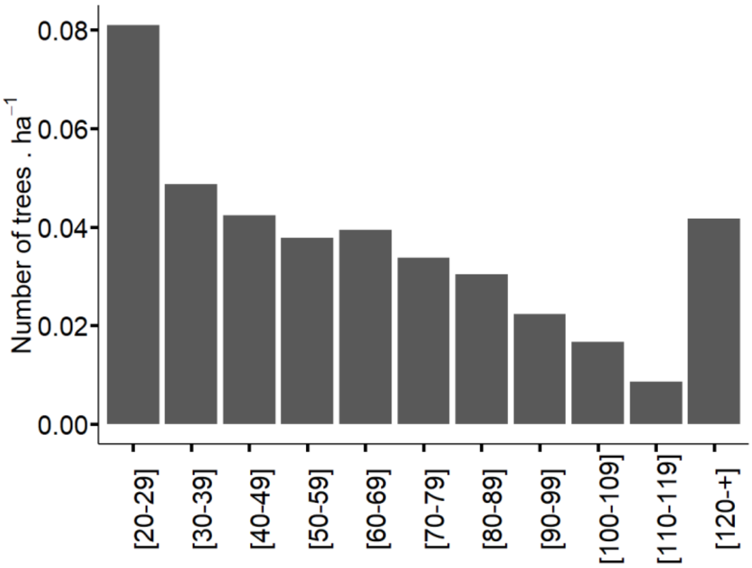

Figure 2. Population structure of *Lophira alata* (Azobe) defined using the number of trees per ha and per diameter class (from 20 cm of 69 logging concessions covering an area of 14 997 859.77 ha in Central Africa).

Since the mid-1900s, periodic tree monitoring and tree ring analyses have been carried out to study variability in tree growth across species in Central Africa (Durrieu de Madron, Nasi, et al., 2000; Ligot et al., 2019, 2022). We fitted growth models for each species using data from logged and unlogged areas of permanent tree plot monitoring from the DYNAFAC[21] network covering the five Central African countries. From the combined dataset, we identified 882 trees belonging to 8 sites in three countries (Cameroun, Central African Republic, and Republic of Congo). Minimum and maximum sampled diameters ranged from 10 to 150 cm. The monitoring period ranged from 1984 to 2017. The mixed second-degree polynomial models (with a random site effect) were fitted for species monitored in several sites. The estimated coefficient from mixed second-degree polynomial model has been used in the simulation to estimate the diameter growth (Table 2).

Table 2. Estimated coefficients (a, b and c) of growth models between the increment (ac in cm year^{-1}) and the initial diameter (D in cm). The sample including the number of trees (n) and the number of sites (site) are also given. * significant (p-value < 0.05) and ^{ns} non-significant (p-value > 0.050)

species	n	site	model	a	b	c
Azobe	1179	6	$ac \sim D + D^2 + (1\|site)$	0.035^{ns}	0.017*	-0.0001*

The transition probabilities of three parameters (mortality, growth, and recruitment rate) allowed making the harvested matrix. The logging operations have been modeled using the logging parameters (minimum cutting diameter, cutting and damage rate). The minimum cutting diameters were obtained from decrees of application of

[21] https://www.dynafac.org/en

the forestry administrations (MCD_A) at the country level and the one used in the management plan (MCD_M, with $MCD_M \geq MCD_A$) at the logging company level. At the Central Africa level, we weighted the MCD_A and MCD_M values to the occupied area (**MCD_A = 75 cm** and **MCD_M = 85 cm**). The cutting rate (CA), which defines the proportion of harvested trees (trees with a diameter greater than MCD_A or MCD_M), was given by logging companies, and it was also weighted at the Central Africa level with a value of 63%. Given the current state of knowledge, it appears reasonable to use a fixed damage rate caused by logging of 7% of the initial population that disappears (Durrieu de Madron, Fontez, et al., 2000). The average cutting cycle (i.e. the period between two successive logging operations) is 28 years (FRMI, 2018), but we used 25 years to simplify computation of four simulations reaching 100 years (25, 50, 75 and 100 years), as requested by IUCN criterion A.
The Figure 3 shows the PPR in production forests for the *Lophira alata*. The reduction in the population of each species was then calculated as the difference between the initial numbers of mature individuals and the predicted numbers of mature individuals predicted after 100 years. The PPR in production forest was from **– 49.44 % (MCD_A) to -45.45% (MCD_M)** for constant recruitment over 100 years.

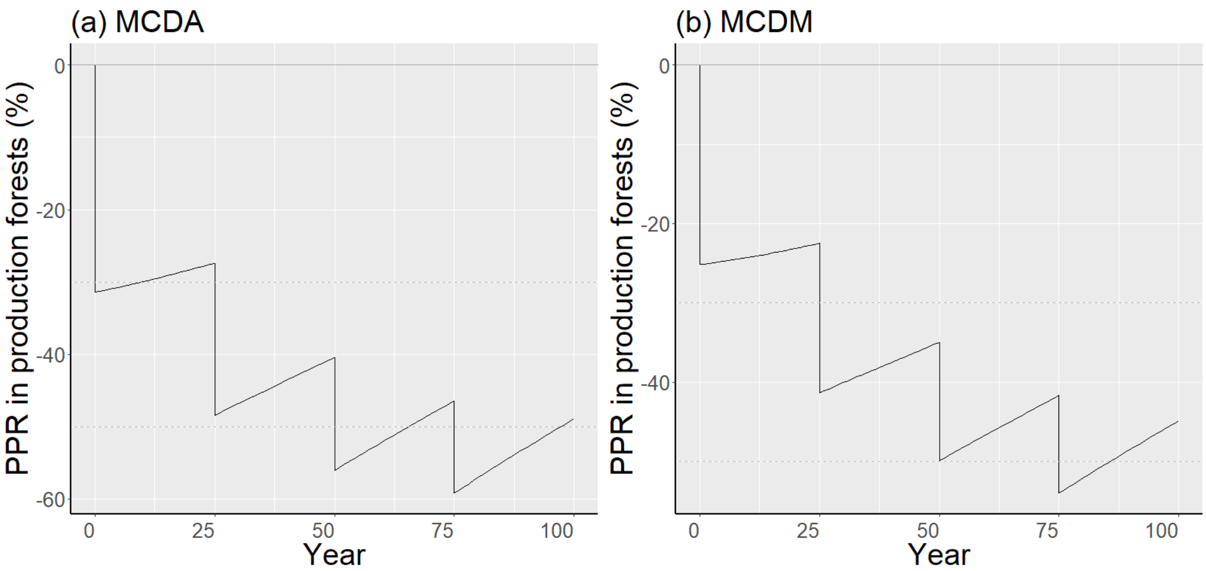

Figure 3. Simulations showing the projected population reduction (PPR) from diameter of mature individuals (35 cm) in production forests for the *Lophira alata* for constant recruitment over 100 years.

- **PPR in the non-permanent forest domain**

The major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanization, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Based on the large range of this species in Central Africa, the harvested volume from illegal logging and legal logging are 46% and 54%, respectively (FRMI 2018). In this condition, it was hypothesized that there is 54% of PPR from production forests and 46% of PPR from illegal logging in 100% PPR due to forest logging. Given that the PPR of production forests associated with its forest area was known, we deduced the PPR and forest area of illegal logging from those of the production forests. As a result, 35 915 101.7 ha were affected for the illegal logging for this species. The non-permanent domain area (135

411 829.8 ha) was considered as the area which was related to today's deforestation rate of 0.35% $year^{-1}$ in Central Africa (Vancutsem et al., 2021). This is a conservative value since it will probably decrease in the future (Swamy et al., 2018).

The PPR in Central Africa by considering the PPR in production forest, protected area and non-permanent domain was from **– 21.08% (MCD_A) to -19.40% (MCD_M)** for constant recruitment over 100 years.

- **PPR in West Africa**

In this region, forests are generally not managed in concessions, and the large part of the rainforest has been transformed in cultivated areas (Nix, 2019). Given the high degree of anthropization in this area, the main threats are habitat loss due to the destruction of natural environments and illegal logging, and the trees are frequently felled in fields. Applying the deforestation rate related to agricultural production can be considered as a proxy for tree removal. Thus, the forest areas in West Africa (15 600 000 ha) were subject to a constant annual deforestation rate of 1.20% $year^{-1}$ (Vancutsem et al., 2021). Taking this rate of deforestation as constant over the next 100 years, when it is expected to decline, is a reasonable precautionary measure incorporating illegal logging.

- **PPR global**

We thus had two different PPR: PPR_C in Central Africa and PPR_W in West Africa. The global PPR was then computed after weighting the two values by their relative forest areas:

$$PPR = \frac{(S_C \times PPR_C) + (S_W \times PPR_W)}{S_C + S_W}$$

where S_C and S_W are forest areas in Central and West Africa, respectively.

The criterion A3 based on (c) a decline in area of occupancy (AOO), extent of occurrence (EOO) and/or habitat quality; and (d) potential levels of exploitation, has been computed as follow: (i) 30%≤PPR<50%, the species is considered as Vulnerable (VU); (ii) 50%≤PPR <80%, the species is considered as Endangered (EN), and PPR ≥ 80%, the species is considered as Critically endangered (CR).

The PPR global in distribution range of the *Lophira alata* was from **– 19.6 % (MCD_A) to -18.0% (MCD_M)** for the constant recruitment over 100 years. This PPR is < 30%, suggesting that this species is not threatened in its geographic area.

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10.12 Annexe 12. *Microberlinia bisulcata* - A.Chev.

Draft

Microberlinia bisulcata - A.Chev.

PLANTAE - TRACHEOPHYTA - MAGNOLIOPSIDA - FABALES - FABACEAE - Microberlinia - bisulcata

Common Names: Zebrawood (English), Allen Élé, Zebrano, Zingana

Synonyms:

Red List Status
CR - Critically Endangered, (IUCN version 3.1)

Red List Assessment

Assessment Information

Date of Assessment: 2022-09-01

Assessor(s): Monthe, F., Loubota, G., Ligot, G., Texier, N., Stévart, T. & Doucet, JL.

Reviewer(s):

Institution(s):

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Regions: Global

Identification Description

Microberlinia bisulcata is a large tree that can reach 40 m in height and exceed 1.5 m in diameter, with a spreading domed crown and dense foliage. The trunk is cylindrical and develops winged and sinuous buttresses with characteristic horizontal reliefs, which spread out sharply in the case of the largest trees. The reddish-brown to blackish bark, which is covered with mosses and lichens, is smooth to rough with orange lenticels, becoming more or less scaly. The fibrous, hard edge is wet, pinkish to orange inwards, the sapwood creamy white. The old marks on the trunk are brown, from which a gum may flow. The leaves are compound paripinnate with small, opposite, stalkless leaflets with more or less emarginate tops. Composed of (12-18 pairs of leaflets of 1.5-3.5 x 0.8-1 cm). The rachis is rather short (8-15 cm) and reddish with long deciduous golden hairs (under a magnifying glass). The inflorescences are terminal with fragrant white flowers. Fruits are oblong flattened woody pods (16-18 × 4-5 cm), with a single raised rib running along the thickened suture, releasing 3-6 flattened black elliptic seeds (2 × 1.4 cm).

Microberlinia bisulcata is very similar to *Microberlinia brazzavillensis* it mainly by its distribution range. *M. bisulcata* is endemic to Cameroon while *M. brazzavillensis* is distributed in Gabon and Congo.

Assessment Rationale

Microberlinia bisulcata is a large tree to 45 m high and 75 cm in diameter, known from Atlantic evergreen forest, gregarious species, which forms root associations with ectomycorrhizal fungi. The species is endemic to Cameroon with 21 known occurrences from CJB (Conservatoire et Jardin botaniques de Genève) and RAINBIO. Based on a 2 x 2 km cell size, the AOO of this species is estimated as 52 km^2, below the upper threshold for "Endangered" status under criterion B2. The EOO is calculated as 19 961 km^2, below the upper threshold for "Vulnerable" status under criterion B1.

Commonly known as Zingana or Zebrawood, it is a valuable timber species, with high wood demand due to its unique colour, texture and hardness. However, the species is distributed in relatively low density and poor regeneration (Sépulchre et al., 2008) .We estimated the number of mature individuals below 10 00 across the distribution range, below the threatened category under criteria C and D. Little information are available on its ecology and its ability to respond to logging. However, minimum cutting diameter (MCD) is set at 80 cm in Cameroon (Sépulchre et al., 2008). Population data are also not available for the species, so criterion A does not apply. No quantitative analysis of the probability of extinction in the wild was conducted, and therefore criterion E does not apply.

Considering that, (i) its distribution is restricted to western Cameroon, and the anthropic pressures including logging over the species distribution range, the species is assessed as Critically Endangered (CR), B2ab.

Reasons for change

Reason(s) for Change in Red List Category from the Previous Assessment:

Distribution

Geographic Range

Microberlinia bisulcata is a species endemic to Cameroon. Known only from four subpopulations including Mount Cameroon, Loum Forest Reserve, Korup National Park, and more recently in the Ebo Forest (Nana et al., 2021). The extent of occurrence (EOO) in native area is estimated at 19 961 km^2 in Cameroon.

Area of Occupancy (AOO)

Estimated area of occupancy (AOO) - in km2	Justification
52	The AOO has been estimated using ConR based on the 2 × 2 km cell size of 21 occurrences from CJB (Conservatoire et Jardin botaniques de Genève) and RAINBIO

Continuing decline in area of occupancy (AOO)	Qualifier	Justification
Yes	Inferred	The species has suffered from reduction in Area of Occupancy, due to habitat degradation and deforestation in West and Central Africa forest (Vancutsem et al., 2021).

Extent of Occurrence (EOO)

Estimated extent of occurrence (EOO)- in km2	EOO estimate calculated from Minimum Convex Polygon	Justification
19 961	true	Calculated using ConR based on 21 known occurrences from CJB (Conservatoire et Jardin botaniques de Genève) and RAINBIO

Continuing decline in extent of occurrence (EOO)	Qualifier	Justification
Yes	Inferred	The species has certainly undergone Extent of Occurrence reduction in Central Africa, linked to the reduction in forest area (Vancutsem et al., 2021)

Locations Information

Number of Locations	Justification
5-10	More than 5 localities. Based on the most serious plausible threat (conversion of its habitat) and logging.

Continuing decline in number of locations	Qualifier	Justification
Yes	Inferred	The main threat remains the reduction of the forest area in Central Africa.

Extreme fluctuations in the number of locations	Justification
No	

Very restricted AOO or number of locations (triggers VU D2)

Very restricted in area of occupancy (AOO) and/or # of locations	Justification
No	-

Elevation / Depth / Depth Zones

Elevation Lower Limit (in metres above sea level):

Elevation Upper Limit (in metres above sea level):

Map Status

Map Status	Use map from previous assessment	How the map was created, including data sources/methods used:	Please state reason for map not available:	Data Sensitive?	Justification	Geographic range this applies to:	Date restriction imposed:
Done	-	The dataset was created from a compilation of Rainbio, Tropicos, and CJB with specimen by specimen verification (csv file).	-	-	-	-	-

Biogeographic Realms

Biogeographic Realm: Afrotropical

Occurrence

Countries of Occurrence

Country	Presence	Origin	Formerly Bred	Seasonality
Cameroon	Extant	Native	-	-

Population

Microberlinia bisulcata is a lower guinea species, endemic to Cameroon. The legal minimum cutting diameter “MCD” is 80 cm in Cameroon. The growth rate of *M. bisulcata* has been poorly studied, initially it would be relatively fast (Norghauer, 2020). No quantitative population data are available for the species.

Population Information

Current Population Trend: Decreasing

Extreme fluctuations? (in # of mature individuals)	Justification

No	-

Severely fragmented?	Justification
Yes	The occurrences of *M. bisulcata* in Cameroon are located in the same area. Some populations are located in areas proposed for logging.

Continuing decline in mature individuals?	Qualifier	Justification
Unknown		

Continuing decline % in mature individuals within 3 generations or 10 years, whichever is longer (up to max. of 100 years in the future)	Qualifier	Justification

Extreme fluctuations in the number of subpopulations	Justification
No	-

Continuing decline in number of subpopulations	Qualifier	Justification
No	-	-

All individuals in one subpopulation: No

Number of Subpopulations	Justification	Subpopulation	Subpopulation description	Number of mature	Subpopulation trend	Qualifier	Location type	Number of Subpopulations	Location bounding box	Location coordinates	Notes
3-4	Last estimation form the IUCN Species Survival Commission , quarterly Report December 2021										-

Population Reduction - Past

Percent Change in past	Reduction or Increase	Qualifier	Justification

Basis?

Reversible?

Understood?

Ceased?

Population Reduction - Future

Percent Change in future	Reduction or Increase	Qualifier	Justification

Basis?

Population Reduction - Ongoing

Both: Percent Change over any 10 year or 3 generation period, whichever is longer, and must include both past and future, future can't go beyond 100 years	Reduction or Increase	Number of years for this period	Qualifier	Justification

Basis?

Reversible?

Understood?

Ceased?

Habitats and Ecology

Microberlinia bisulcata is a very large, buttressed, canopy-emergent tree species which characteristically forms large groves of approx. 0.5–1 km^2 in area (Newbery and Van Der Burgt, 2004). The species occurs in lowland rainforest areas, usually on sandy soils in flat areas and has ectomycorrhizal properties (Chuyong et al., 2000; Newbery et al., 2006). It is codominant with two other, less-abundant, ectomycorrhizal trees species, *Tetraberlinia bifoliolata* (Harms) Hauman and *T. korupensis Wieringa* in southern Korup, and occurs occasionally in the surrounding region. *M. bisulcata* is a leaf-exchanging species, the newly flushing (pinnate) leaves in the dry season (Chuyong et al., 2000).

Pollination is carried out by insects (mainly bees). *M. bisulcata* is a ballochore species. According to Newbery and Van Der Burgt (2004) *M. bisulcata* becomes adult at 50 cm in dbh. Poor regeneration of the species was observed in groves in Korup. The species is highly susceptible to leaf loss when illuminated and opportunities for seedling release are thus very low (Green and Newbery, 2001; Newbery and Van Der Burgt, 2004). The seeds are dispersed, not far from the mother tree.

IUCN Habitats Classification Scheme

Habitat	Season	Suitability	Major Importance?
1.6. Forest -> Forest - Subtropical/Tropical Moist Lowland	Resident	Suitable	Yes

1.9. Forest - Subtropical/Tropical Moist Montane	Reside nt	Suitable	Yes	

Continuing Decline in Habitat

Continuing decline in area, extent and/or quality of habitat?	Qualifier	Justification
Yes	Observed	Despite the annual deforestation rate of 0.35%, in Central (Vancutsem et al., 2021).

Life History

Generation Length	Justification	Data Quality
144	Mean estimate of generation length for 19 Central Africa timber species.	good

Age at maturity: female or unspecified

Age at Maturity: Male

Size at Maturity (in cms): Female

Size at Maturity (in cms): Male

Reproductive Periodicity
Annual

Annual Rate of Population Increase

Natural Mortality
1% (Ligot et al., 2022)

Systems

System: Terrestrial

Plant / Fungi Specific

Wild relative of a crop? No

Plant and Fungal Growth Forms
Tree - large

Use and Trade

Microberlinia bisulcata, is sourced for its high valuable timber that is durable and resistant to tunnelling insects and wood-rotting fungi. The wood is suitable for furniture-making; with common objects like tool handles, panelling and veneers frequently produced from this wood.

General Use and Trade Information

Subsistence:	Rationale:	Local Commercial:	Further detail including information on economic value if available:
Yes	-	Yes	-

National Commercial Value: Yes

International Commercial Value: Yes

Is there harvest from captive/cultivated sources of this species? Yes

Trend in level of total offtake from wild sources: Stable

Trend in level of total offtake from domesticated sources: Unknown

Non- Consumptive Use

Non-consumptive use of the species? true

Threats

The main threats in the non-permanent domain across distribution range, are mainly related to habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging and the abusive harvesting of plant parts requested as non-wood forest products (Bradshaw et al., 2009). In Central Africa, illegal logging accounts for nearly 46% of total log production (FRMi, 2018). This production generally comes from unallocated forest areas (non-permanent forest domain). Illegal logging has recently increased as Chinese traders buy a cubic metre of tree at almost double the price on the black market (USD 600/m^3) (IUCN, 2021; Nana et al., 2021). This has caused the local people to cut down the African zebrawood trees below the fructification diameter (i.e., immature trees) (Nana et al., 2021).

Threats Classification Scheme

No past, ongoing, or future threats exist to this species. false

Threat	Timing	Scope	Severity	Impact Score
1.1. Residential & commercial development -> Housing & urban areas	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4
2.1.1. Agriculture & aquaculture -> Annual & perennial non-timber crops -> Shifting agriculture	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
2.2.2. Agriculture & aquaculture -> Wood & pulp plantations -> Agro-industry plantations	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
2.3.2. Agriculture & aquaculture -> Livestock farming & ranching -> Small-holder grazing, ranching or farming	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4
3.2. Energy production & mining -> Mining & quarrying	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5

4.1. Transportation & service corridors -> Roads & railroads	Past, Likely to Return	Minority (<50%)	Slow, Significant Declines	Low Impact: 4
5.3.1. Biological resource use -> Logging & wood harvesting -> Intentional use: (subsistence/small scale) [harvest]	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 4
5.3.2. Biological resource use -> Logging & wood harvesting -> Intentional use: (large scale) [harvest]	Ongoing	Minority (<50%)	Slow, Significant Declines	Medium Impact: 6
7.1.3. Natural system modifications -> Fire & fire suppression -> Trend Unknown/Unrecorded	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4

Conservation

Microberlinia bisulcata does not occur in *ex situ* collections (BGCI, 2022), and may occur in many protected areas such Korup or Ebo forest in Cameroon. The species should be added or permanent forest plots installed in some logging legal forest concessions. These plots provide important data for (i) quantifying population dynamics processes at the stand level: mortality, growth and recruitment; (ii) phenological studies to determine the regular fruiting diameter (RFD). These plots are managed in collaboration with forest concessions grouped within the DYNAFAC collective (see here for more information https://www.dynafac.org/fr/p/130/installation-de-dispositifs-de-suivi-de-la-dynamique-forestiere).

Logging in Central Africa is subject to strict legislation, species can only be harvested above a certain diameter and measures must be taken to ensure the renewal of the resource (Fargeot et al., 2004). Indeed, management plans for tropical rainforests require the determination of a minimum cutting diameter (MCD) to ensure a minimum renewal rate at the end of a rotation period (duration between two cuts on the same cutting base), the minimum reconstitution rate (40-50% depending on the country) as well as the rotation duration, being imposed by forestry legislation (Durrieu de Madron and Forni, 1997). This should be done for the species.

Conservation Actions In- Place

Action Recovery Plan	Note
Unknown	

Systematic monitoring scheme	Note

Unknown

Occur in at least one PA	Note
Yes	The species may appear in at least 2 protected areas considering it distribution range

Percentage of population protected by PAs (0-100)	Note
1-10	Considering protected area across species distribution range

Area based regional management plan	Note
Unknown	-

Invasive species control or prevention	Note
No	-

Harvest management plan	Note
Yes	In certified forest concessions, the species is exploited according to a management plan.

Subject to ex-situ conservation	Note
NO	-

Included in international legislation	Note
No	-

Subject to any international management/trade controls	Note

No

Important Conservation Actions Needed

Conservation Actions	Note
3.1.1. Species management -> Species management -> Harvest management	-
3.1.2. Species management -> Species management -> Trade management	-
3.4.2. Species management -> Ex-situ conservation -> Genome resource bank	-

Research Needed

Research	Note
1.2. Research -> Population size, distribution & trends	-
3.1. Monitoring -> Population trends	-
3.2. Monitoring -> Harvest level trends	-
3.3. Monitoring -> Trade trends	-

Ecosystem Services

Ecosystem Services Provided by the Species

	Importance:	Geographic range of benefit:
1. Water Quality	2 - Important	Global
3. Flood Control	2 - Important	Global
4. Climate Regulation	2 - Important	Global
5. Landscape	2 - Important	Global
6. Air Quality	2 - Important	Global
7. Nutrient Cycling	2 - Important	Global
8. Habitat Maintenance	2 - Important	Global

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10.13 Annexe 13. *Microberlinia brazzavillensis* - A.Chev.

Draft

Microberlinia brazzavillensis **- A.Chev.**

PLANTAE - TRACHEOPHYTA - MAGNOLIOPSIDA - FABALES - FABACEAE - Microberlinia - brazzavillensis

Common Names: Zebrawood (English), Allen Élé, Zebrano, Zingana
Synonyms: *Berlinia brazzavillensis* (A.Chev.) Troupin

Red List Status
EN - Endangered, (IUCN version 3.1)

Red List Assessment

Assessment Information

Date of Assessment: 2022-09-01

Assessor(s): Monthe, F., Loubota, G., Ligot, G., Texier, N., Stévart, T. & Doucet, JL.

Reviewer(s):

Institution(s):

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Regions: Global

Identification Description

Microberlinia brazzavillensis is a large tree that can reach 40 m in height and exceed 1.5 m in diameter, with a spreading domed crown and dense foliage. The trunk is cylindrical and develops winged and sinuous buttresses with characteristic horizontal reliefs, which spread out sharply in the case of the largest trees. The reddish-brown to blackish bark, which is covered with mosses and lichens, is smooth to rough with orange lenticels, becoming more or less scaly. The fibrous, hard edge is wet, pinkish to orange inwards, the sapwood creamy white. The old marks on the trunk are brown, from which a gum may flow. The leaves are compound paripinnate with small, opposite, stalkless leaflets with more or less emarginate tops. Composed of 7-14 pairs of leaflets (1-1.6 x 0.5-0.7 cm) with rounded or barely emarginate apexes, and shorter rachis (6-7 cm), more winged and glabrous.

The inflorescences are terminal with fragrant white flowers. Fruits are oblong flattened woody pods (16-18 × 4-5 cm), with a single raised rib running along the thickened suture, releasing 3-6 flattened black elliptic seeds (2 × 1.4 cm).

Microberlinia brazzavillensis differs from *Microberlinia bisulcata* mainly by its distribution range. *M. brazzavillensis* is distributed in Gabon and Congo while *M. bisulcata* is endemic to Cameroon.

Assessment Rationale

Microberlinia brazzavillensis is a tall tree in African dense moist evergreen lower guinea forest, long-lived gregarious species, which forms root associations with ectomycorrhizal fungi. It is distributed in Gabon and Republic of Congo with 43 known occurrences from CJB (Conservatoire et Jardin botaniques de Genève) and RAINBIO. Based on a 2 x 2 km cell size, the AOO of this species is estimated as 64 km^2, below the upper threshold for "Endangered" status under criterion B2. The EOO is calculated as 167 717 km^2, over the upper threshold for "Vulnerable" status under criterion B1.

Commonly known as Zingana or Zebrawood, it is a valuable timber species, with high wood demand due to its unique colour, texture and hardness. However, little information are available on the international market of the species. The species has low population densities of 0.02 stems.ha^{-1} (dbh ≥ 20 cm) in Central Africa. There is a lack of data to reliably quantify the population structure in Central Africa. However, young stems would not be rare throughout the range (see Supplementary Material). Given this density and species distribution, we estimate the number of mature individuals over 10,000 across the distribution range, well above the threatened category under criteria C and D. The minimum cutting diameter (MCD) in Central Africa varies is 70 and 80 cm respectively in Gabon and Republic of Congo. No information are available on the regular fruiting diameter (RFD) for the species in the two countries. No population data are available for the species, so criterion A does not apply. No quantitative analysis of the probability of extinction in the wild was conducted, and therefore criterion E does not apply.

Considering that, the low species density and the anthropic pressures including logging over the species distribution range, the species is assessed as Endangered (EN), B2ab

Reasons for change

Reason(s) for Change in Red List Category from the Previous Assessment: *Microberlinia brazzavillensis* was previously assessed as "Vulnerable" https://www.iucnredlist.org/species/33184/9758268 at the African Regional Workshop (Conservation & Sustainable Management of Trees, Zimbabwe, July 1996), 1998. During the last years, data have been produced on species distribution and a new version of the IUCN guidelines is available (from version 2.3 to 3.1). Given all these information, it was necessary to produce a new assessment of the species.

Distribution

Geographic Range

Microberlinia brazzavillensis is an lower guinea species distributed in Gabon and the Republic of Congo. It is very common on forest margins, along rivers and on sandy soils on the edges of lagoons, usually as single trees or small stands, but sometimes in almost pure stands. The extent of occurrence (EOO) in native area is estimated at 167 717 km^2 in.

Area of Occupancy (AOO)

Estimated area of occupancy (AOO) - in km2	Justification
64	The AOO has been estimated using ConR based on the 2 × 2 km cell size of 43 occurrences from CJB (Conservatoire et Jardin botaniques de Genève) and RAINBIO

Continuing decline in area of occupancy (AOO)	Qualifier	Justification
Yes	Inferred	The species has suffered from reduction in Area of Occupancy, due to habitat degradation and deforestation in West and Central Africa forest (Vancutsem et al., 2021).

Extent of Occurrence (EOO)

Estimated extent of occurrence (EOO)- in km2	EOO estimate calculated from Minimum Convex Polygon	Justification
167 717	true	Calculated using ConR based on 43 known occurrences from CJB (Conservatoire et Jardin botaniques de Genève) and RAINBIO

Continuing decline in extent of occurrence (EOO)	Qualifier	Justification
Yes	Inferred	The species has certainly undergone Extent of Occurrence reduction in Central Africa, linked to the reduction in forest area (Vancutsem et al., 2021)

Locations Information

Number of Locations	Justification
5-10	More than 5 localities. Based on the most serious plausible threat (conversion of its habitat) and logging.

Continuing decline in number of locations	Qualifier	Justification
Yes	Inferred	The main threat remains the reduction of the forest area in Central Africa.

Extreme fluctuations in the number of locations	Justification
No	

Very restricted AOO or number of locations (triggers VU D2)

Very restricted in area of occupancy (AOO) and/or # of locations	Justification
No	-

Elevation / Depth / Depth Zones

Elevation Lower Limit (in metres above sea level):

Elevation Upper Limit (in metres above sea level):

Map Status

Map Status	Use map from previous assessment	How the map was created, including data sources/methods used:	Please state reason for map not available:	Data Sensitive?	Justification	Geographic range this applies to:	Date restriction imposed:
Done	-	The dataset was created from a compilation of Rainbio, Tropicos, and CJB with specimen by specimen verification (csv file).	-	-	-	-	-

Biogeographic Realms

Biogeographic Realm: Afrotropical

Occurrence

Countries of Occurrence

Country	Presence	Origin	Formerly Bred	Seasonality
Cameroon				
Gabon	Extant	Native	-	-
Republic of Cong	Extant	Native	-	-

Population

Microberlinia brazzavillensis is an lower guinea species, mainly distributed in Gabon and Republic of Congo. The legal minimum cutting diameter “MCD varies form 70 cm to 80 cm in Gabon and Republic of Congo respectively. Population dynamics of *M. brazzavillensis* is poorly studied. No quantitative population data are available for the species.

Population Information

Current Population Trend: Decreasing

Extreme fluctuations? (in # of mature individuals)	Justification
No	-

Severely fragmented?	Justification
Unknown	

Continuing decline in mature individuals?	Qualifier	Justification
Unknown		

Continuing decline % in mature individuals within 3 generations or 10 years, whichever is longer (up to max. of 100 years in the future)	Qualifier	Justification

Extreme fluctuations in the number of subpopulations	Justification
No	-

Continuing decline in number of subpopulations	Qualifier	Justification
No	-	-

All individuals in one subpopulation: No

Number of Subpopulations	Justification	Subpopulation	Subpopulation description	Number of mature	Subpopulation trend	Qualifier	Location type	Number of Subpopulations	Location bounding box	Location coordinates	Notes
											-

Population Reduction - Past

Percent Change in past	Reduction or Increase	Qualifier	Justification

Basis?

Reversible?

Understood?

Ceased?

Population Reduction - Future

Percent Change in future	Reduction or Increase	Qualifier	Justification

Basis?

Population Reduction - Ongoing

Both: Percent Change over any 10 year or 3 generation period, whichever is longer, and must include both past and future, future can't go beyond 100 years	Reduction or Increase	Number of years for this period	Qualifier	Justification

Basis?

Reversible?

Understood?

Ceased?

Habitats and Ecology

Microberlinia brazzavillensis occurs in savanna areas, forest margins, along rivers, and on lagoon sides on sandy soil, usually as isolated trees or in small stands, but sometimes in nearly pure stands. It is also found on the Batékés plateaux in savannah areas, as far as. Its regeneration appears to be rare, occurring in forest gaps. *M. brazzavillensis* is a ballochore species, seeds are dispersed by bursting the pod (self-pollination), not far from the mother tree.

IUCN Habitats Classification Scheme

Habitat	Season	Suitability	Major Importance?
1.6. Forest -> Forest - Subtropical/Tropical Moist Lowland	Resident	Suitable	Yes

Continuing Decline in Habitat

Continuing decline in area, extent and/or quality of habitat?	Qualifier	Justification
Yes	Observed	Despite the annual deforestation rate of 0.35%, in Central (Vancutsem et al., 2021), the species can also colonise savannah and other open habitats.

Life History

Generation Length	Justification	Data Quality
144	Mean estimate of generation length for 19 Central Africa timber species.	good

Age at maturity: female or unspecified

Age at Maturity: Male

Size at Maturity (in cms): Female

Size at Maturity (in cms): Male

Reproductive Periodicity
Annual

Annual Rate of Population Increase

Natural Mortality
1% (Ligot et al., 2022)

Systems

System: Terrestrial

Plant / Fungi Specific

Wild relative of a crop? No

Plant and Fungal Growth Forms
Tree - large

Use and Trade

Microberlinia brazzavillensis, is mainly used for decorative furniture, turnery, sliced veneer and faces of plywood. It is also used for flooring and musical instruments such as guitars and drums, and it has been used for ski manufacture. It is suitable for construction, joinery, interior trim, mine props, ship building, vehicle bodies, railway sleepers, sporting goods, toys, novelties, tool handles and pulpwood. In Gabon it is used as firewood.

In traditional medicine in the Republic of Congo the pounded leaves are rubbed on the body for the treatment of rheumatism and oedema of the legs. In the 1960s Gabon exported an average 230 m^3/year of *M. brazzavillensis* sawn wood; this production was about 15,000 m^3 in 2009 (Brink, 2012).

General Use and Trade Information

Subsistence:	Rationale:	Local Commercial:	Further detail including information on economic value if available:
Yes	-	Yes	-

National Commercial Value: Yes

International Commercial Value: Yes

Is there harvest from captive/cultivated sources of this species? Yes

Trend in level of total offtake from wild sources: Stable

Trend in level of total offtake from domesticated sources: Unknown

Non- Consumptive Use

Non-consumptive use of the species? true

Threats

The main threats in the non-permanent domain across distribution range, are mainly related to habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging and the abusive harvesting of plant parts requested as non-wood forest products (Bradshaw et al., 2009). In Central Africa, illegal logging accounts for nearly 46% of total log production (FRMi, 2018). This production generally comes from unallocated forest areas (non-permanent forest domain).

Threats Classification Scheme

No past, ongoing, or future threats exist to this species. false

Threat	Timing	Scope	Severity	Impact Score
1.1. Residential & commercial development -> Housing & urban areas	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4
2.1.1. Agriculture & aquaculture -> Annual & perennial non-timber crops -> Shifting agriculture	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
2.2.2. Agriculture & aquaculture -> Wood & pulp plantations -> Agro-industry plantations	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
2.3.2. Agriculture & aquaculture -> Livestock farming & ranching -> Small-holder grazing, ranching or farming	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4
3.2. Energy production & mining -> Mining & quarrying	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
4.1. Transportation & service corridors -> Roads & railroads	Past, Likely to Return	Minority (<50%)	Slow, Significant Declines	Low Impact: 4
5.3.1. Biological resource use -> Logging & wood harvesting -> Intentional use: (subsistence/small scale) [harvest]	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 4
5.3.2. Biological resource use -> Logging & wood harvesting -> Intentional use: (large scale) [harvest]	Ongoing	Minority (<50%)	Slow, Significant Declines	Medium Impact: 6
7.1.3. Natural system modifications -> Fire & fire suppression -> Trend Unknown/Unrecorded	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4

Conservation

Microberlinia brazzavillensis does not occur in *ex situ* collections (BGCI, 2022), and may occur in many protected areas across its distribution range. The species should be added to trails and or permanent forest plots installed in some logging legal forest concessions. These plots provide important data for (i) quantifying population dynamics processes at the stand level: mortality, growth and recruitment; (ii) phenological studies to determine the regular fruiting diameter (RFD). These trails and plots are managed in collaboration with forest concessions grouped within the DYNAFAC collective (see here for more information https://www.dynafac.org/fr/p/130/installation-de-dispositifs-de-suivi-de-la-dynamique-forestiere).

Logging in Central Africa is subject to strict legislation, species can only be harvested above a certain diameter and measures must be taken to ensure the renewal of the resource (Fargeot et al., 2004). Indeed, management plans for tropical rainforests require the determination of a minimum cutting diameter (MCD) to ensure a minimum renewal rate at the end of a rotation period (duration between two cuts on the same cutting base), the minimum reconstitution rate (40-50% depending on the country) as well as the rotation duration, being imposed by forestry legislation (Durrieu de Madron and Forni, 1997). This should be done for the species.

Conservation Actions In- Place

Action Recovery Plan	Note
Unknown	

Systematic monitoring scheme	Note
Unknown	

Occur in at least one PA	Note
Yes	The species may appear in at least 2 protected areas considering it distribution range

Percentage of population protected by PAs (0-100)	Note
1-10	Considering protected area across species distribution range

Area based regional management plan	Note

Unknown	-

Invasive species control or prevention	Note
No	-

Harvest management plan	Note
Yes	In certified forest concessions, the species is exploited according to a management plan.

Subject to ex-situ conservation	Note
NO	-

Included in international legislation	Note
No	-

Subject to any international management/trade controls	Note
No	

Important Conservation Actions Needed

Conservation Actions	Note
3.1.1. Species management -> Species management -> Harvest management	-
3.1.2. Species management -> Species management -> Trade management	-
3.4.2. Species management -> Ex-situ conservation -> Genome resource bank	-

Research Needed

Research	Note
1.2. Research -> Population size, distribution & trends	-

3.1. Monitoring -> Population trends	-
3.2. Monitoring -> Harvest level trends	-
3.3. Monitoring -> Trade trends	-

Ecosystem Services

Ecosystem Services Provided by the Species

	Importance:	Geographic range of benefit:
1. Water Quality	2 - Important	Global
3. Flood Control	2 - Important	Global
4. Climate Regulation	2 - Important	Global
5. Landscape	2 - Important	Global
6. Air Quality	2 - Important	Global
7. Nutrient Cycling	2 - Important	Global
8. Habitat Maintenance	2 - Important	Global

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Microberlinia brazzavillensis A. Chev.

The density per diameter class was estimated using data from forest inventories that were carried out in 2 forest management units (FMU) of different logging companies in Gabon. The forest inventory data covered about 245 660 ha, and the number of trees sampled was 6 264 with a density of 0.0255 tree ha^{-1} in Gabon. The population structure showed a curve with a low number of young stems and no trees in diameter classes from 70 cm to 120 cm (Figure 1). A deficit in young stems leads thus to difficulties in regeneration.

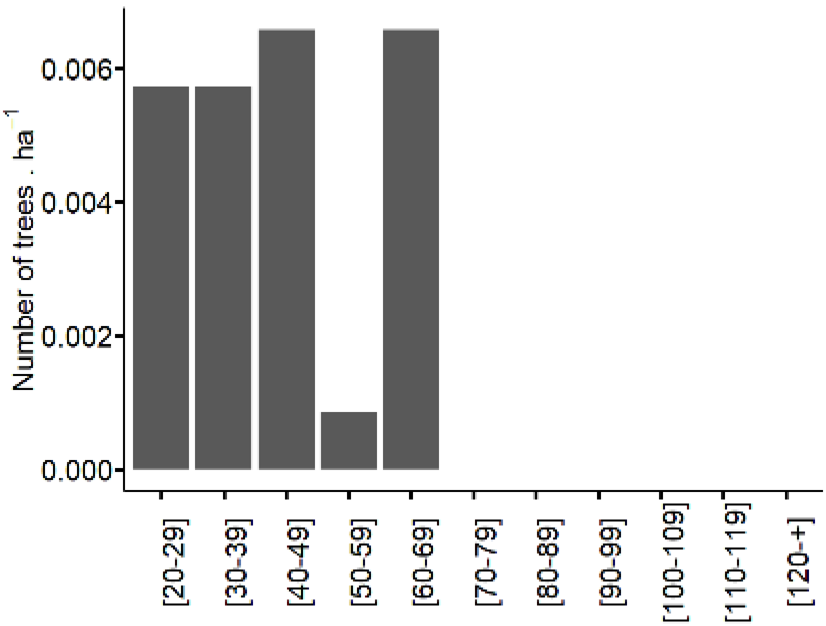

Figure 4. Population structure of *Microberlinia brazzavillensis* defined using the number of trees per ha and per diameter class (from 20 cm of 2 logging concessions in Gabon covering an area of 245 660 ha).

10.14 Annexe 14. *Milicia excelsa* (Welw.) C.C. Berg

Draft

Milicia excelsa **(Welw.) C.C. Berg**

PLANTAE - TRACHEOPHYTA - MAGNOLIOPSIDA - ROSALES - MORACEAE - Milicia- excelsa

Common Names: Iroko-rock elm-African teak-African oak (English), Iroko-chêne d'Afrique-teck d'Afrique-teck kambala (French), Câmbala-amoreira-moreira-teca africana-tumbiro-magundo (Portuguese), Mvule (Swahili)

Synonyms: *Maclura excelsa* (Welw.) Bureau (1873),
Chlorophora excelsa (Welw.) Benth. (1880)

Red List Status
LC - Least Concern, A3Ccd (IUCN version 3.1)

- **Red List Assessment**

- **Assessment Information**

Date of Assessment: 2022-09-01

Assessor(s): Monthe, F., Loubota, G., Ligot, G., Texier, N., Stévart, T. & Doucet, J.L.

Reviewer(s):

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Regions: Global

- **Identification Description**

Milicia excelsa is a large tree up to 50 m tall and exceeding 1.5 m in diameter. Its foliage is dark and sparsely scattered, borne on large, sinuous, ascending branches. It usually has thick, rounded serifs at the base. Its cylindrical trunk has aligned orange-yellow lenticels and rough grey to blackish-brown bark that peels off with age in angular scales. Its yellowish edge is brittle and very hard with orange granules. It quickly leaks a white latex that hardens in the air, and may give off a slight soap-like odour. Its large leaves (10-25 x 7-15 cm) are broadly elliptical, with wavy margins and often cordate at the base, with a long (3-6 cm) very thick petiole. The underside of the leaf blade has a very thick, prominent main vein and about 15 prominent secondary veins. The male flowers are greenish-white, the female flowers greenish, and are grouped in ± elongated, dense spikes (± 0.5 cm diameter). Its infructescences are green, caterpillar-shaped, elongated and fleshy (3-5 x 1.5 cm), sweet, and contain many tiny seeds ± 2 mm long.

- **Assessment Rationale**

Milicia excelsa is a widespread tall tree of tropical Africa, and a long-lived, pioneer, and usually non-gregarious species, native to semi-deciduous and evergreen rainforests (Daïnou et al., 2012).

It has a wide distribution on the African continent, from Guinea-Bissau to Ethiopia and from Angola to Zimbabwe (Daïnou et al., 2012). Based on a 2 x 2 km cell size, the AOO of this species is estimated as 2 076 km^2 with a minimum of 86 locations (number of forest management units of different logging companies in Central Africa). This species is not "Vulnerable" status under criterion B2. The EOO is calculated as 13 280 136 km^2, above the upper threshold for "Vulnerable" status under criterion B1.

The wood of *M. excelsa* and *Milicia regia* (A.Chev.) C.C.Berg are not distinguished in the timber trade, and are traded under the trade name 'iroko'. In Central Africa, the timber of *M. excelsa* was in the top 10 of the most exploited species in Central African Republic (36 276 m^3) and Republic of Congo (24 562 m^3) between 2017 and 2018 (Eba'a Atyi et al., 2022). The legal minimum cutting diameter "MCD" of *M. excelsa* varies across its distribution range in Central Africa with 70 cm in Central Africa Republic and Republic of Congo, 80 cm in Gabon and Democratic Republic of Congo, and 100 cm in Cameroon. MCD is higher than the regular fruiting diameter (RFD), estimated at 55 cm in Cameroon (Daïnou et al., 2021) and the minimum fertility diameter estimated at 20 cm in Central Africa (see Supplementary Material). The population structure showed a curve in "decreasing exponential" suggesting a good regeneration (see Supplementary Material). *M. excelsa* has relatively high population densities of 0.15 stems.ha^{-1} (diameter at breast height, dbh ≥ 20 cm) and fairly fast growth rates of 0.52 ± 0.37 cm/year in Central Africa (see Supplementary Material). Given its stem density and the mean annual increment, we estimate the number of mature individuals (dbh ≥ 20 cm, see Supplementary Material) over 10 000 across the distribution range, well above the threatened category under criteria C and D.

The most serious long-term threat is the conversion of the forest to agriculture and grazing, and illegal logging. However, the species is not considered severely fragmented as 682 known occurrences represent more than 50 localities (sensu Comité des normes et des pétitions de l'UICN, 2019). Considering the species' generation length of 111 years (see Supplementary Material), an inference of population reduction for three generations in the past is impossible following A1 and A2 criteria.

To model the recruitment, we used the hypothesis defined as the recruitment rate that would maintain a constant number of trees in the first diameter class. Based on simulations with constant recruitment on its distribution range, we estimated a population increase of **5.86-6.99**% in the next 100 years under criterion A3 (see Supplementary Material). An assessment of the population reduction according to criterion A4 considering one to two generations back and one to two generations forward would likely introduce high levels of uncertainty due to the lack of data to efficiently model the reduction of population size in the past. No quantitative analysis of the probability of extinction in the wild was conducted, and therefore criterion E does not apply.

Considering (i) the population density and the natural regeneration, (ii) the increase of population in the future across the distribution range, the species is assessed as Least Concern (LC), A3cd.

Reasons for change

Reason(s) for Change in Red List Category from the Previous Assessment:

Milicia excelsa was previously assessed as "Near Threatened" in 1998 (https://www.iucnredlist.org/species/33903/9817388) at the African Regional Workshop (Conservation & Sustainable Management of Trees, Zimbabwe, July 1996). During the last few years, important data have been produced on the self-ecology, population dynamics (growth, recruitment, mortality) of the species (DYNAFAC, 2022; Ligot et al., 2022). Moreover, a new version of the IUCN guidelines is available (from version 2.3 to 3.1). Given all these information, it was necessary to produce a new assessment of the species.

● Distribution

● Geographic Range

Milicia excelsa is a very widespread species in Tropical Africa with a distribution in West Africa, Central Africa and East Africa (Daïnou et al., 2012). It has a wide distribution on the African continent, from Guinea Bissau to Ethiopia and from Angola to Zimbabwe in the south direction. The extent of occurrence (EOO) in native area is estimated at about 13 280 136 km^2 across its distribution range.

● Area of Occupancy (AOO)

Estimated area of occupancy (AOO) - in km2	Justification
2 076	The AOO has been estimated using ConR based on the 2 × 2 km cell size of 1 011 occurrences from CJB (Conservatoire et Jardin botaniques de Genève) and RAINBIO.

Continuing decline in area of occupancy (AOO)	Qualifier	Justification
Yes	Inferred	The species has suffered from reduction in area of occupancy, due to habitat degradation and deforestation in Central, East and West Africa (Vancutsem et al., 2021).

- **Extent of Occurrence (EOO)**

Estimated extent of occurrence (EOO)- in km2	EOO estimate calculated from Minimum Convex Polygon	Justification
13 280 136	true	Calculated using ConR based on 1011 known occurrences from CJB and RAINBIO

Continuing decline in extent of occurrence (EOO)	Qualifier	Justification
Yes	Inferred	The species has certainly undergone an extent of occurrence reduction in Central, East and West Africa (Vancutsem et al., 2021).

- **Locations Information**

Number of Locations	Justification
80-200	More than 86 localities. Based on the most serious plausible threat (conversion of its habitat) and illegal logging across the distribution range.

Continuing decline in number of locations	Qualifier	Justification
Yes	Inferred	The main threat remains the reduction of the forest area in tropical Africa.

Extreme fluctuations in the number of locations	Justification
No	

- **Very restricted AOO or number of locations (triggers VU D2)**

Very restricted in area of occupancy (AOO) and/or # of locations	Justification
No	-

- **Elevation / Depth / Depth Zones**

Elevation Lower Limit (in metres above sea level): 0

Elevation Upper Limit (in metres above sea level): 1600

- **Map Status**

Map Status	Use map from previous assessment	How the map was created, including data sources/methods used:	Please state reason for map not available:	Data Sensitive?	Justification	Geographic range this applies to:	Date restriction imposed:
Done	-	Qgis. The dataset was created from a compilation of Rainbio and CJB	-	-	-	-	-

- **Biogeographic Realms**

Biogeographic Realm: Afrotropical

- **Occurrence**

- **Countries of Occurrence**

Country	Presence	Origin	Formerly Bred	Seasonality
Angola	Extant	Native	-	Resident
Benin	Extant	Native	-	Resident
Burkina Faso	Extant	Native	-	Resident
Burundi	Extant	Native	-	Resident
Cameroon	Extant	Native	-	Resident
Central African Republic	Extant	Native	-	Resident
Chad	Extant	Native	-	Resident
Congo	Extant	Native	-	Resident
Congo, The Democratic Republic of the	Extant	Native	-	Resident
Ivory Coast	Extant	Native	-	Resident
Equatorial Guinea	Extant	Native	-	Resident
Ethiopia	Extant	Native	-	Resident
Gabon	Extant	Native	-	Resident
Gambia	Extant	Native	-	Resident
Ghana	Extant	Native	-	Resident
Guinea	Extant	Native	-	Resident
Guinea-Bissau	Extant	Native	-	Resident
Kenya	Extant	Native	-	Resident

Liberia	Extant	Native	-	Resident
Malawi	Extant	Native	-	Resident
Mali	Extant	Native	-	Resident
Mozambique	Extant	Native	-	Resident
Nigeria	Extant	Native	-	Resident
Rwanda	Extant	Native	-	Resident
Sierra Leone	Extant	Native	-	Resident
South Sudan	Extant	Native	-	Resident
Tanzania	Extant	Native	-	Resident
Togo	Extant	Native	-	Resident
Uganda	Extant	Native	-	Resident
Zambia	Extant	Native	-	Resident
Zimbabwe	Extant	Native	-	Resident

- **Population**

Milicia excelsa is a guineo-congolian species, widely distributed from Guinea Bissau to Ethiopia as well as Angola and Zimbabwe (Daïnou, 2012). In Central Africa, the average density of *M. excelsa* is 0.15 stems.ha^{-1} (dbh ≥ 20 cm) from forest commercial inventories (see Supplementary Material). In West Africa, *M. excelsa* appeared sparsely distributed from 1 to 4 stems/ha in agroforestry systems (Atindehou et al., 2022) and other forest systems (Ouinsavi and Sokpon, 2008).

M. excelsa is a deciduous and long-lived pioneer species from African dense humid evergreen and semi-deciduous forests where juvenile plants are briefly shade tolerant but quickly require light for further development (Doucet, 2003; Hawthorne, 1995; Meunier et al., 2015). The average growth was 0.52 ± 0.37 cm/year in evergreen stands and in semi-deciduous riverine forest (all diameters combined) in Central Africa (see Supplementary Material). In contrast, there is more abundant growth data from experimental plantations (Daïnou, 2012). The average growth from plantation was from 0.2 to 0.9 cm/year in Central Africa (Zaou et al., 1998), and from 0.3 to 1.4 cm/year in West Africa (Dupuy & Mille 1991; Bosu et al. 2006). The average diameter growth commonly used for *M. excelsa* is about 5 mm per year, a value confirmed by growth ring studies in Central African forests (Durrieu de Madron and Daumerie, 2004).

The legal minimum cutting diameter “MCD” of *M. excelsa* varies across its distribution range, (70 cm in Central Africa Republic and Republic of Congo, 80 cm in Gabon and Democratic Republic of Congo, and 100 cm in Cameroon). MCD is higher than the regular fruiting diameter (RFD), estimated at 55 cm in Cameroon (Daïnou et al., 2021) and the minimum fertility diameter estimated at 20 cm in Central Africa (see Supplementary Material). At the Central Africa level, we weighted the MCD and MCDM values to the occupied area with MCD = 80 cm (see Supplementary Material). In some concessions *M. excelsa* is planted with a growth rate of 1.67 ± 1.34 mm/year and it takes 600 years to reach the MCD in Cameroon (Doucet et al., 2016). Illegal logging and local intense harvesting can occur. Efforts should be made to limit this illegal exploitation.

Using the Red List criterion A3, the projected population reduction (PPR) to be met in the future (100 years because the generation length of the species is 111 years) of the population was assessed across its distribution range. Because *M. excelsa* is a widespread species in Central, West and East Africa, the PPR was estimated for each region. In Central Africa, three different PPR were thus estimated: PPRpa in protected areas, PPRpf in production forests and PPRnp in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas. First, protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). The population of the species in protected areas covering its range was kept stable in the future over 100 years, suggesting that the PPR in protected areas was 0%. Second, the evolution of the *M. excelsa* population was simulated using an Usher matrix model to estimate the PPR of production forests (logging concessions, PPRpf). The simulations were initialised using the density (number of trees.ha-1) per diameter class (from 20 cm diameter, mature individuals) from forest management inventories of logging companies. The evolution of this initial population depended on several demographics (recruitment, mortality, and growth rate) and logging parameters (minimum cutting diameter, cutting and damage rate) that were adjusted using data of permanent tree plot monitoring. Thus, the density of *M. excelsa* in 100 years was predicted with a logging event every 25 years, which corresponds to the average cutting cycle in Central Africa. PPRpf was then calculated as the difference between initial and final number of trees. Third, the major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Illegal logging and the habitat lost from deforestation rate have been both activities that allowed estimating the PPRnp in non-permanent domains. In West and East Africa, the forest areas were subject to a constant annual deforestation rate of 1.20% year-1 and 1.53 year-1, respectively (Vancutsem et al., 2021). Taking this rate of deforestation as constant over the next 100 years, when it is expected to decline, is a reasonable precautionary measure. We thus had three different PPR: PPR in Central Africa, PPR in West Africa and PPR in East Africa. The global PPR was then computed after weighting the three values by their relative forest areas.

The global PPR was then computed after weighting the three values by their relative forest areas. We estimated a population increase of **5.86-6.99**% in the next 100 years under criterion A3 (for further information about this methodology, see Supplementary Material).

- **Population Information**

Current Population Trend: Incresing

Extreme fluctuations? (in # of mature individuals)	Justification
No	-

Severely fragmented?	Justification

No	-

Continuing decline in mature individuals?	Qualifier	Justification

Continuing decline % in mature individuals within 3 generations or 10 years, whichever is longer (up to max. of 100 years in the future)	Qualifier	Justification

Extreme fluctuations in the number of subpopulations	Justification
No	-

Continuing decline in number of subpopulations	Qualifier	Justification
No	-	-

All individuals in one subpopulation: No

Number of Subpopulations	Justification	Subpopulation Details	Subpopulation description	Number of mature individuals	Subpopulation trend	Qualifier	Location type	Number of Subpopulations	Location bounding box	Location coordinates	Notes
4	Genetic analyses using nuclear microsatellites (nSSRs), nuclear and plastid DNA sequences for 849 individuals sampled across the distribution range of the species (Daïnou et al., 2014)	-	-	-	-	-	-	-	-	-	-

- Population Reduction - Past

Percent Change in past	Reduction or Increase	Qualifier	Justification

Basis?

Reversible?

Understood?

Ceased?

- **Population Reduction - Future**

Percent Change in future	Reduction or Increase	Qualifier	Justification
5.86-6.99%	Increase	Projected	Using the Red List criterion A3, the projected population reduction (PPR) to be met in the future (100 years because the generation length of the species is 111 years) of the population was assessed across its distribution range. Because *M. excelsa* is a widespread species in Central, West and East Africa, the PPR was estimated for each region. In Central Africa, three different PPR were thus estimated: PPRpa in protected areas, PPRpf in production forests and PPRnp in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas. First, protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). The population of the species in protected areas covering its range was kept stable in the future over 100 years, suggesting that the PPR in protected areas was 0%. Second, the evolution of the *M. excelsa* population was simulated using an Usher matrix model to estimate the PPR of production forests (logging concessions, PPRpf). The simulations were initialised using the density (number of trees.ha-1) per diameter class (from 20 cm diameter, mature individuals) from forest management inventories of logging companies. The evolution of this initial population depended on several demographics (recruitment, mortality, and growth rate) and logging parameters (minimum cutting diameter, cutting and damage rate) that were adjusted using data of permanent tree plot monitoring. Thus, the density of *M. excelsa* in 100 years was predicted with a logging event every 25 years, which corresponds to

	the average cutting cycle in Central Africa. PPRpf was then calculated as the difference between initial and final number of trees. Third, the major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Illegal logging and the habitat lost from deforestation rate have been both activities that allowed estimating the PPRnp in non-permanent domains. In West and East Africa, the forest areas were subject to a constant annual deforestation rate of 1.20% year-1 and 1.53 year-1, respectively (Vancutsem et al., 2021). Taking this rate of deforestation as constant over the next 100 years, when it is expected to decline, is a reasonable precautionary measure. The global PPR was then computed after weighting the three values by their relative forest areas. We estimated a population increase of **5.86-6.99**% in the next 100 years under criterion A3 (for further information about this methodology, see Supplementary Material).

Basis?
b) an index of abundance appropriate for the taxon, d) actual or potential levels of exploitation

- **Population Reduction - Ongoing**

Both: Percent Change over any 10 year or 3 generation period, whichever is longer, and must include both past and future, future can't go beyond 100 years	Reduction or Increase	Number of years for this period	Qualifier	Justification

Basis?
b) an index of abundance appropriate for the taxon, c) a decline in area of occupancy, extent of occurrence and/or quality of habitat, d) actual or potential levels of exploitation

Reversible?
Yes

Understood?
Yes

Ceased?
No

● Habitats and Ecology

Milicia excelsa is a large tree that can reach 55 m in height and exceed 1.5 m in diameter, it forms root associations with arbuscular mycorrhizal fungi, it grows well in soils rich in exchangeable bases not far from rivers. Its presence and persistence in a wide variety of habitats is evidence of a relatively broad ecological preference. It is considered a pioneer species, demanding intense light and unable to stand deep shade. In the young secondary forest, for example, it cannot compete with climbers and shrubs. Due to the lack of regeneration of commercial light-demanding species, enrichment plantings have been performed on 44.4 ha in recently degraded forests to promote the regeneration of the logged species in the framework for certification (Doucet et al., 2016).

M. excelsa bears dioecious with white male and greenish female flowers grouped in spikes. From West Africa to Sudan, *M. excelsa* flowers from December to March, generally male flowers bloom and ripen several days before the females (Nyong'o et al., 1994; Ofori, 2007). First flowers are observed at a minimum of 21 and 37 cm diameter in Cameroon and Central Africa Republic, becoming regular and abundant at 44 cm (Ouédraogo et al., 2018). It is a zoochorous species, fruits are dispersed by birds, bats and squirrels (Daîinou, 2012; Ofori et al., 2004). In Cameroon, Central Africa Republic and the Republic of the Congo, fruiting occurs from February to April as well as in West Africa and from August to September in Democratic Republic of Congo (Daïnou et al., 2021). Fruits are regularly observed at 55 cm diameter (Daïnou et al., 2021).

● IUCN Habitats Classification Scheme

Habitat	Season	Suitability	Major Importance?
1.6. Forest -> Forest - Subtropical/Tropical Moist Lowland	Resident	Suitable	Yes

● Continuing Decline in Habitat

Continuing decline in area, extent and/or quality of habitat?	Qualifier	Justification
Yes	Observed	The annual deforestation rate of 0.35% in Central Africa, 1.20% in West Africa and 1.53% in East Africa (Vancutsem et al., 2021).

- **Life History**

Generation Length	Justification	Data Quality
111	Minimum estimate of generation length for the species from the average growth rate, and the mean diameter of mature individuals (see Supplementary Material)	good

Age at maturity: female or unspecified
38 Years

Age at Maturity: Male
38 Years

Size at Maturity (in cms): Female
20

Size at Maturity (in cms): Male
20

Reproductive Periodicity
Annual

Annual Rate of Population Increase

Natural Mortality
1% (Ligot et al. 2022)

- **Systems**

System: Terrestrial

- **Plant / Fungi Specific**

Wild relative of a crop? No

Plant and Fungal Growth Forms
Tree - large

• Use and Trade

• General Use and Trade Information

M. excelsa is multipurpose trees characterised by high economic and socio-cultural values (Dainou et al. 2012). It is widely used in African traditional medicine. For example, preparations from the bark are taken to treat cough, general fatigue, asthma, heart trouble, etc (Ofori, 2017). On the other hand, a multitude of remedies, beverages and food products are derived from different parts of the tree (Daïnou et al. 2012). The fruits are used in human food (Ofori 2007), and the barks are used in the treatment of sterility in women.

It is among the most exploited forest species in tropical Africa. The wood of *M. excelsa* and the closely related *Milicia regia* (A.Chev.) C.C.Berg are not distinguished in the timber trade, and are traded under the trade name 'iroko'. It has long been traded and exported. It is frequently used in interior and exterior joinery, in cabinet making, and it can also be used for the parquet manufacture, staircases, light frameworks, etc (Meunier et al. 2015). In West Africa, Iroko is a major timber in international trade; during the 1960s Côte d'Ivoire exported about 55,000 m^3 of iroko logs and 6000 m^3 of iroko sawnwood per year, and Ghana 28,000 m^3 of sawnwood (Ofori, 2017). *M. excelsa* was in the top 10 of the most exploited species in Central African Republic (36276 m^3) and Republic of Congo (24562 m^3) between 2017 and 2018 (Eba'a Atyi et al., 2022). In the past Tanzania and Uganda were major suppliers of iroko, and small volumes are still exported from East Africa (Ofori, 2017). In order to reduce the threat on long-term population, some countries have taken measures to limit the production of iroko wood: (i) a special permit is required for its exploitation in Ghana, Tanzania, Côte d'Ivoire and Mozambique; (ii) it has recently been officially banned in Uganda; (iii) it has been banned in Kenya by presidential decree; (iv) countries such as Ghana, Tanzania, Côte d'Ivoire, Gabon and Cameroon prohibit the export of logs; only sawn timber is allowed for this purpose (Ofori, 2007).

Subsistence:	Rationale:	Local Commercial:	Further detail including information on economic value if available:
Yes	-	Yes	-

National Commercial Value: Yes

International Commercial Value: Yes

Is there harvest from captive/cultivated sources of this species? Yes

Trend in level of total offtake from wild sources: Stable

Trend in level of total offtake from domesticated sources: Unknown

• Non- Consumptive Use

Non-consumptive use of the species? true

• Threats

The main threats in the non-permanent domain across the species' distribution range, are mainly related to habitat loss due to the destruction of natural environments because of population explosion and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging and the abusive harvesting of plant parts requested as non-wood forest products (Bradshaw et al., 2009). In Central Africa, illegal logging accounts for nearly 46% of total log production (FRMi, 2018). This production generally comes from unallocated forest areas (non-permanent forest domain).
In West and East Africa, forests are generally not managed in concessions, and the large part of the rainforest has been transformed into cultivated areas (Nix, 2019).

- **Threats Classification Scheme**

No past, ongoing, or future threats exist to this species. false

Threat	Timing	Scope	Severity	Impact Score
1.1. Residential & commercial development -> Housing & urban areas	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4
2.1.1. Agriculture & aquaculture -> Annual & perennial non-timber crops -> Shifting agriculture	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
2.2.2. Agriculture & aquaculture -> Wood & pulp plantations -> Agro-industry plantations	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
2.3.2. Agriculture & aquaculture -> Livestock farming & ranching -> Small-holder grazing, ranching or farming	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4
3.2. Energy production & mining -> Mining & quarrying	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
4.1. Transportation & service corridors -> Roads & railroads	Ongoing	Minority (<50%)	Negligible declines	Past Impact
5.3.1. Biological resource use -> Logging & wood harvesting -> Intentional use: (subsistence/small scale) [harvest]	Ongoing	Minority (<50%)	Rapid Declines	Medium Impact: 6
5.3.2. Biological resource use -> Logging & wood harvesting -> Intentional use: (large scale) [harvest]	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 4
7.1.3. Natural system modifications -> Fire & fire suppression -> Trend Unknown/Unrecorded	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4

- **Conservation**

Milicia excelsa is known to occur in at least 22 *ex situ* collections (BGCI, 2022), and may occur in many protected areas considering its distribution range. In certified forest concessions where the species is exploited, trails and or permanent forest plots are usually installed. These plots provide important data for (i) quantifying population dynamics processes at the stand level: mortality, growth and recruitment; (ii) phenological studies to determine the regular fruiting diameter (RFD). These trails and plots are managed in collaboration with forest concessions grouped within the DYNAFAC collective (see here for more information https://www.dynafac.org/fr/p/130/installation-de-dispositifs-de-suivi-de-la-dynamique-forestiere). Compilation of these data provide important additional information for targeted silvicultural measures for the sustainable management of this species. First summaries have provided information on important parameters such as: mortality, growth, etc. (DYNAFAC, 2022; Ligot et al., 2022). Based on almost 40 years of monitoring forest dynamics in Central Africa, the DYNAFAC collective recommends a MCD of 70 cm in Central Africa to maintain optimal gene flow and optimal regeneration (DYNAFAC, 2022). DYNAFAC also recommends the preservation of additional seed trees or the implementation of regeneration support techniques to ensure the long-term maintenance of populations. *M. excelsa* is also monitored in nurseries and planted in various forest concessions (Doucet et al., 2016).

Logging in Central Africa is subject to strict legislation, species can only be harvested above a certain diameter and measures must be taken to ensure the renewal of the resource (Fargeot et al., 2004). Indeed, management plans for tropical rainforests require the determination of a minimum cutting diameter (MCD) to ensure a minimum renewal rate at the end of a rotation period (duration between two cuts on the same cutting base), the minimum reconstitution rate (40-50% depending on the country) as well as the rotation duration, being imposed by forestry legislation (Durrieu de Madron and Forni, 1997).

In addition, it will also be necessary to :

- Ensure the implementation of the recommendations of the Dynafac collective, including the establishment of a system for monitoring the populations of commercial species in the different forest types defined in a consensual manner;
- Set up monitoring and support systems for the regeneration of commercial species, prioritising species with regeneration deficits;
- Set up programmes to guarantee the phenotypic quality of commercial species populations: seed banks, seed stands, plus trees, seed orchards, conservation plantations;
- Consider threatened species in the delimitation of conservation series and in the identification of High Conservation Values;
- Update conservation statuses on a five-yearly basis, in particular by setting up a system of "green statuses";
- Define red lists adapted to regional or national contexts;
- Evaluate the status of cryptic species or species close to commercial species evaluated during this workshop.

- **Conservation Actions In- Place**

Action Recovery Plan	Note

Yes	Reforestation within forest concessions and others in forest gaps, old parks, quarries, and large logging roads

Systematic monitoring scheme	Note
Yes	The species is monitored in permanent plots installed within forestry companies in Central Africa (see here for more information https://www.dynafac.org/fr)

Occur in at least one PA	Note
Yes	The species may appear in at least 100 protected areas considering it distribution range

Percentage of population protected by PAs (0-100)	Note
1-10	Considering protected area across species distribution range

Area based regional management plan	Note
Unknown	-

Invasive species control or prevention	Note
No	-

Harvest management plan	Note
Yes	In certified forest concessions, the species is exploited according to a management plan.

Subject to ex-situ conservation	Note
NO	-

Included in international legislation	Note
No	-

Subject to any international management/trade controls	Note
No	

- **Important Conservation Actions Needed**

Conservation Actions	Note
3.1.1. Species management -> Species management -> Harvest management	-
3.1.2. Species management -> Species management -> Trade management	-
3.4.2. Species management -> Ex-situ conservation -> Genome resource bank	-

- **Research Needed**

Research	Note
1.1. Research -> Taxonomy	-
1.2. Research -> Population size, distribution & trends	-
3.1. Monitoring -> Population trends	-
3.2. Monitoring -> Harvest level trends	-
3.3. Monitoring -> Trade trends	-

Ecosystem Services

- **Ecosystem Services Provided by the Species**

	Importance:	Geographic range of benefit:
1. Water Quality	2 - Important	Global
3. Flood Control	2 - Important	Global
4. Climate Regulation	2 - Important	Global
5. Landscape	2 - Important	Global
6. Air Quality	2 - Important	Global
7. Nutrient Cycling	2 - Important	Global
8. Habitat Maintenance	2 - Important	Global

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Milicia excelsa (Welw.) C.C. Berg

IUCN status using criterion A3

We adopted the criterion A3 to assess the projected population reduction (PPR) to be met in the future (up to a maximum of 100 years) of *Milicia excelsa*. To quantify the projected population reduction, simulations must be performed on mature individuals and three generations with maximum 100 years according to **criterion A3**. We estimated mature individuals and generation length, as recommended by the IUCN guidelines.

A **mature individual** is an individual that can reproduce, able to bear flowers or seeds (fertile in plant kingdom). To quantify the mature individuals for each species, we used phenological data of DYNAFAC network[22] from a combined dataset of 152 trees belonging to four sites in three countries (Cameroun, Central African Republic, and Gabon). Minimum and maximum sampled diameters ranged from 10 to 160 cm (median 55 cm). The monitoring period ranged from 2004 to 2021, and every year monitored had at least one recorded reproductive event. We assumed that the monitoring period was long enough to capture at least one reproductive event per tree such that trees without observed flowering/fruiting events were considered non-reproductive (20 percent of all monitored trees were non-reproductive). We used the methodology for the size at reproduction of canopy tree species in Central Africa (Ouédraogo et al., 2018): the **diameter of a mature individual** was obtained after fitting logistic regressions and the level of 50% of the probability to produce the flower or fruit was adopted for this species. Using this approach, the diameter of a mature individual was obtained after setting the 50% probability to produce flowers or fruits. Thus, the minimum diameter of mature individuals for this species was **20 cm**.

The **generation length** was the report between the mean diameter of mature individuals considering population structure and the mean increment. Given that the diameter of mature individuals was 20 cm, we weighted the total number of trees by their diameter from 20 cm to 125 cm to compute the number of mature individuals. The mean of mature individuals was **58 cm** as the report between the number of mature individuals and total number of trees. The **mean increment** of the species was **0.52 cm**, obtained from 53 observations of published data (Ligot et al., 2022) and unpublished data in two countries (Cameroon, and Republic of Congo). Thus, the **generation length** was 58 cm / 0.52 cm = **111 years**.

Estimation of the projected population reduction (PPR)

We adopted the criterion A3 to assess the projected population reduction (PPR) to be met in the future (up to a maximum of 100 years) of *Milicia excelsa*. *Milicia excelsa* is a very widespread species in Tropical Africa with a distribution in West Africa, Central Africa and East Africa - (Daïnou et al., 2012). The geographic range of species

[22] https://www.dynafac.org/en

was in three regions (Central Africa, West Africa, and East Africa) characteristic of three biogeographical regions across the tropical African forests (Fayolle et al., 2014). According to each region, different data (deforestation annual rate, growth, mortality, recruitment, forest inventory, etc.) have been used with logging data in Central Africa. Thus, the PPR was estimated for each region and the global PPR was then computed after weighting the three values by their relative forest areas.

PPR in Central Africa

In this region, forest management follows three different modalities: protected areas, production forests (logging concessions) and non-permanent forest domain. Based on occurrences, the natural range of this species includes countries in Central Africa (Figure 1). The total natural area is estimated at 200 358 861.6 ha. Within this area, there are 56 483 244.9 ha (28.2%) for production forests, 34 807 650.6 ha (17.4%) for protected areas, and 109 067 966 ha (54.4%) for the non-permanent domain.

Three different PPR are thus estimated: PPR_{pa} in protected areas, PPR_{pf} in production forests and PPR_{np} in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas and then added to estimate the PPR_C in Central Africa.

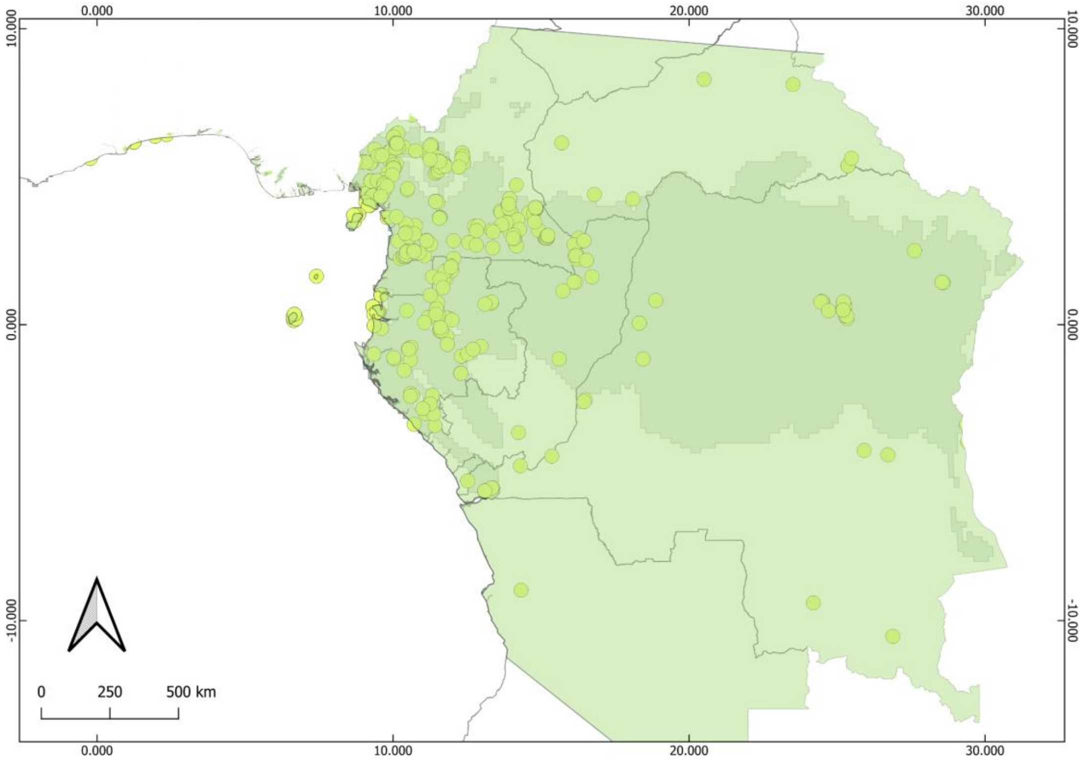

Figure 1. The range of *Tieghemella africana* in Central Africa estimated from RAINBIO and CJB data, validated in December 2022 during a workshop with a group of experts in Gabon.

PPR in protected areas

Central Africa countries have allocated a higher proportion of their land to conservation than any other tropical regions, with relatively higher conservation success (Laurance et al., 2012). Indeed, most protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that

have been the main agents of forest degradation across the region (Abernethy et al., 2016). They are currently representing a large part of forest and tree species conservation in Central Africa. Thus, the population of each species in protected areas (according to FRMI, 2018) covering its range was kept stable in the future over 100 years. **In these conditions, it was hypothesized that the PPR in protected areas for each species is 0%, suggesting no population reduction in the present and future.**

PPR in production forests

To quantify the evolution of the population of each timber species, matrix population models are widely used to study population dynamics (Picard & Liang, 2014). The population of this species was described at time *t* by a vector N_t corresponding to the density (number of trees ha^{-1}) in each diameter class (from 20 cm diameter to more than 120 cm). The density per diameter class was estimated using data from forest inventories that were carried out in 86 forest management units (FMU) of different logging companies in five countries (Cameroon, Central African Republic, Democratic Republic of the Congo, Gabon, and Republic of the Congo). Most logging companies followed a standardized inventory protocol (Réjou-Méchain et al., 2011). These forest inventory data covered about 18 million ha (Table 1), that are representative of 33% of Central Africa's production forests of this species. The number of trees sampled in Central Africa was 2 830 375 with a density of 0.154 tree ha^{-1}. Large-scale commercial inventories have already been found useful in the identification of large-scale patterns in Central Africa (Réjou-Méchain et al., 2011). Using large-scale data from commercial forest inventories, Réjou-Méchain et al. (2021) jointly model the distribution in abundance of the most dominant tree species and produce continuous maps of the floristic and functional composition of central African forests.

Table 1. Forest management units (FMU) sampled, and areas affected to different management modalities in Central Africa (Cameroon, CAR: Central African Republic, DRC: Democratic Republic of the Congo, EG: Equatorial Guinea, Gabon and RCongo: Republic of the Congo). The relative proportion (value in %) for the sampled area is also given according to the areas of production forest of each country.

	Sampling	
Country	FMU	Area (ha)
Cameroon	22	2 148 948.78
CAR	5	1 018 129
DRC	15	4 348 051
EG	-	-
Gabon	36	6 848 912
RCongo	8	4 005 312
Total	76	18 369 352.78

The Usher matrix model was used to simulate the evolution of the recovery rate of all population and the exploitable stock of each species after logging in Central Africa. According to the Usher assumption, between *t* and *t*+1, an individual can either stay alive in the same class, stay alive and move up to the next class, or die; it cannot move up by more than one class or move backwards, i.e., the individual is free from diameter shrinkage (Picard et al.,

2012). The Usher matrix model (U) considers three parameters (mortality, recruitment and growth rate that are constant in time) to estimate the transition probabilities:

$$U = \begin{pmatrix} q_1 + g_1 & g_2 & \cdots & \cdots & g_I \\ p_1 & q_2 & 0 & \cdots & 0 \\ 0 & \ddots & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & p_{I-1} & q_I \end{pmatrix}$$

where q_i is the probability for an individual to stay alive in class i between two consecutive time steps, p_i is the upgrowth transition rate (the probability for an individual to grow up from class i to class i +1), and g_i is the recruitment rate (Picard & Liang, 2014).

Tree mortality, recruitment and growth are three central processes for predicting the dynamics of tropical rainforests and estimating these three processes requires long-term monitoring in difficult field conditions (Picard & Gourlet-Fleury, 2008). These processes determine the evolution of the species population in the forest stand. The natural mortality is defined as the number of standing dead trees, and few studies have reported estimates of mortality rates in Central Africa. Data about tree mortality are still scarce and it does not allow to precisely be modelling the mortality rate for each species and size class. Given the current state of knowledge, it appears reasonable to use a fixed mortality rate of 1% for all species and size classes, in agreement with the results of Ligot et al. (2022) on 21,180 trees belonging to 42 timber species of Central Africa annually monitored from one to seven years.

The recruitment integrates fruiting and seed dispersal from mother trees, and the survival of plant juveniles until they reach a size threshold where they are included in the stand. The recruitment term in the model is the average annual input of new individuals into the first size class from 20 cm. The recruitment events, like mortality events, are infrequent and thus difficult to model (Karsenty & Gourlet-Fleury, 2006). The population structure showed a curve in "decreasing exponential" suggesting a good regeneration (Figure 2). To model the recruitment, we used the hypothesis defined as the recruitment rate that would maintain a constant number of trees in the first diameter class. Claeys et al. (2019) projected the future forest dynamics up to the end of the century and they showed that projected mortality and recruitment rates in 2099 could not differ from the ones observed today. Thus, the hypothesis on the recruitment and the mortality rate is used in the future (up to 100 years) as they do today.

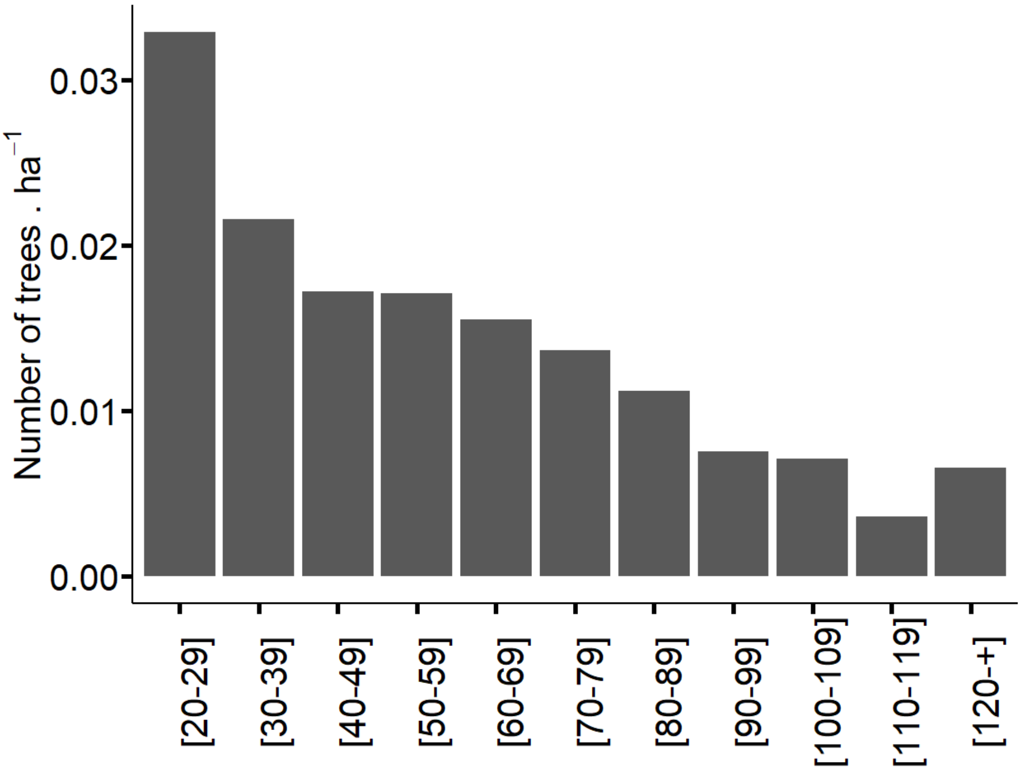

Figure 2. Population structure of *Milicia excelsa* (Iroko) defined using the number of trees per ha and per diameter class (from 20 cm of 86 logging concessions covering an area of 18 369 352.78 ha in Central Africa).

Since the mid-1900s, periodic tree monitoring and tree ring analyses have been carried out to study variability in tree growth across species in Central Africa (Durrieu de Madron, Nasi, et al., 2000; Ligot et al., 2019, 2022). We fitted growth models for each species using data from logged and unlogged areas of permanent tree plot monitoring from the DYNAFAC[23] network covering the five Central African countries. From the combined dataset, we identified 477 trees belonging to 7 sites in three countries (Cameroun, Gabon, and Republic of Congo). Minimum and maximum sampled diameter ranged from 10 to 124 cm. The monitoring period ranged from 2005 to 2017. The mixed second-degree polynomial models (with a random site effect) were fitted for this species monitored in several sites. The estimated coefficient from the mixed second-degree polynomial model has been used in the simulation in order to estimate the diameter growth (Table 2).

Table 2. Estimated coefficients (a, b and c) of growth models between the increment (ac in cm year^{-1}) and the initial diameter (D in cm). The sample including the number of trees (n) and the number of sites (site) are also given. * significant (p-value < 0.05)

species	n	site	model	a	b	c
Iroko	54	4	ac ~ D + D^2 + (1|site)	1.33*	-0.02*	0.00009*

[23] https://www.dynafac.org/en

The transition probabilities of three parameters (mortality, growth, and recruitment rate) allowed making the harvested matrix. The logging operations have been modeled using the logging parameters (minimum cutting diameter, cutting and damage rate). The minimum cutting diameters were obtained from decrees of application of the forestry administrations (MCD_A) at the country level and the one used in the management plan (MCD_M, with $MCD_M \geq MCD_A$) at the logging company level. At the Central Africa level, we weighted the MCD_A and MCD_M values to the occupied area with **MCD_A = 80 cm and MCD_M = 85 cm**. The cutting rate (CA), which defines the proportion of harvested trees (trees with a diameter greater than MCD_A or MCD_M), was given by logging companies, and it was also weighted at the Central Africa level with a value of **79%**. Given the current state of knowledge, it appears reasonable to use a fixed damage rate caused by logging of 7% of the initial population that disappears (Durrieu de Madron, Fontez, et al., 2000). The average cutting cycle (i.e. the period between two successive logging operations) is 28 years (FRMI, 2018), but we used 25 years to simplify computation of four simulations reaching 100 years (25, 50, 75 and 100 years), as requested by IUCN criterion A.
The Figure 2 shows the PPR in production forests for the *Milicia excelsa*. The reduction in the population of each species was then calculated as the difference between the initial numbers of mature individuals and the predicted numbers of mature individuals predicted after 100 years. **The simulations in production forest showed a population increase of 33.15% (MCD_A) to 39.21% (MCD_M) over 100 years.**

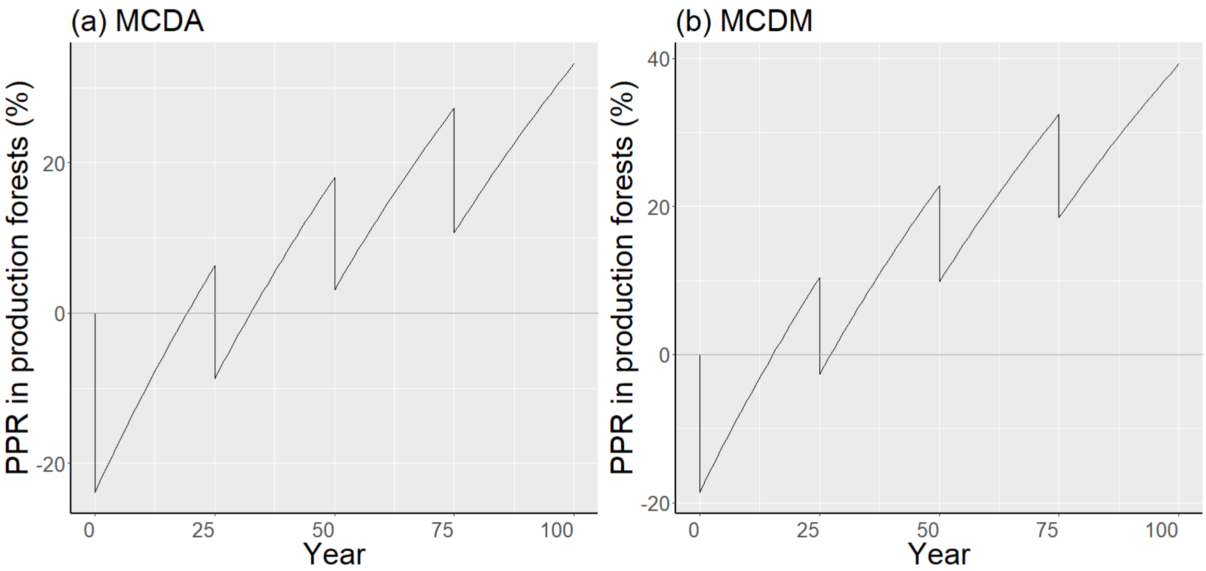

Figure 2. Simulations showing the projected population reduction (PPR) from diameter of mature individuals (20 cm) in production forests for the *Milicia excelsa* for constant recruitment over 100 years.

PPR in the non-permanent forest domain

The major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanization, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Based on the large range of this species in Central Africa, the harvested volume from illegal logging and legal logging are 46% and 54%, respectively (FRMI 2018). In this condition, it was hypothesized that there is 54% of PPR from production forests and 46% of PPR from illegal logging in 100% PPR due to forest logging. Given that the PPR of production forests associated with its forest area was known, we deduced the PPR and forest area of illegal logging from those of the production forests. As a result, 48 115 356.8 ha were affected for the illegal logging for this species. The non-permanent domain area (109 067 966 ha) was considered as the area which was related to today's deforestation rate of 0.35% year^{-1} in Central Africa (Vancutsem et al., 2021). This is a conservative value since it will probably decrease in the future (Swamy et al., 2018).

The simulations in production forest, protected area and non-permanent domain showed a population increase of 6.18% (MCD_A) and 7.36% (MCD_M) over 100 years.

PPR in West and East Africa

In these two regions, forests are generally not managed in concessions, and the large part of the rainforest has been transformed in cultivated areas (Nix, 2019). Given the high degree of anthropization in this area, the main threats are the habitat loss due to the destruction of natural environments and illegal logging, and the trees are frequently felled in fields. Applying the deforestation rate related to agricultural production can be considered as a proxy for tree removal. Thus, the forest areas in West Africa (15 600 000 ha) and East Africa (6 400 000 ha) were subject to a constant annual deforestation rate of 1.20% year^{-1} and 1.53% year^{-1} respectively (Vancutsem et al., 2021). Taking this rate of deforestation as constant over the next 100 years, when it is expected to decline, is a reasonable precautionary measure incorporating illegal logging.

PPR global

We thus had three different PPR: PPR_C in Central Africa, PPR_W in West Africa, and PPR_E in East Africa. The global PPR was then computed after weighting the three values by their relative forest areas:

$$PPR = \frac{(S_C \times PPR_C) + (S_W \times PPR_W) + (S_E \times PPR_E)}{S_C + S_W + S_E}$$

where S_C, S_W, and S_E are forest areas in Central, West and East Africa, respectively.

The global PPR was then computed after weighting the three values by their relative forest areas. Based on the distribution range of *Milicia excelsa*, we estimated a population increase of **5.86% (MCD_A) and 7.36% (MCD_M)** in the next 100 years under criterion A3. This population increase is due to the high number of mature individuals since the minimum diameter of the individuals is 20 cm, the constant recruitment that would maintain a constant number of trees in the first diameter class at each cycle of 25 years, and the minimum cutting diameter which is high (80 and 85 cm).

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10.15 Annexe 15. *Millettia laurentii* - De Wild.

Draft

Millettia laurentii **- De Wild.**

PLANTAE - TRACHEOPHYTA - MAGNOLIOPSIDA - FABALES - FABACEAE - Millettia - laurentii

Common Names: Wenge

Synonyms: No Synonyms

Red List Status
NT - Near Threatened, A3cd (IUCN version 3.1)

- **Red List Assessment**

- **Assessment Information**

Date of Assessment: 2022-09-01

Assessor(s): Monthe, F., Loubota, G., Ligot, G., Texier, N., Stévart, T. & Doucet, JL

Reviewer(s):

Institution(s):

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Regions: Global

- **Identification Description**

Millettia laurentii is a medium-sized, often low-branched tree, reaching 30 m high (rarely 50 m) and 1 m in diameter, with dense foliage, spreading and drooping branches, and a fluted or slightly serrated base. Its trunk is grayish, smooth in appearance and covered with lenticels. Its yellowish slice is marked with small whitish spots and lets out a red exudate as well as a strong smell reminiscent of cucumber. Its leaves are imparipinnate, composed of 6 to 7 pairs of opposite leaflets and a broader terminal abruptly acuminated and yellow on the ground. Its long inflorescences (20-40 cm) are composed of very visible purplish flowers. Its fruits are woody pods reaching nearly 30 x 5 cm, straight, flattened with very fine oblique stripes, and brown at maturity. They release from 2 to 4 round and flattened seeds (± 2 cm in diameter), with brown to the purplish shiny tegument.

There are many related species, mainly in the genus *Millettia*. They are usually small trees in secondary forests or on the banks of streams, except for *M. drastica* Welw, commonly known as Wenge distinguished by its very abruptly acuminate leaflets.

- **Assessment Rationale**

Millettia laurentii is a widespread tree endemic of the centro-guineocongolese dense humid evergreen and semi-deciduous forest, long-lived, cryptopioneer usually gregarious species, common in forests resulting from the colonisation of savannahs, in open Marantaceae forests and in forest galleries. It is distributed from Southern Cameroon to Western Democratic Republic of Congo. Based on a 2 x 2 km cell size, the AOO of this species is estimated as 192 km^2 with a minimum of 46 locations (number of forest management units of different logging companies in Central Africa). This species is not "Vulnerable" status under criterion B2. The EOO is calculated as 1 257 533 km^2, above the upper threshold for "Vulnerable" status under criterion B1.

Commonly known as Wengé, it is a timber species in Central Africa. The minimum cutting diameter (MCD) in Central Africa varies between 50 and 70 cm is higher than the regular fruiting diameter (RFD) estimated at 45 cm in Republic of Congo (Ouédraogo et al., 2018), ensuring good availability of seed trees for natural regeneration. The species has relatively high population densities of 1.02 $stems.ha^{-1}$ (diameter at breast height, dbh ≥ 20 cm), good regeneration (see population structure), and relatively low growth rates of 0.26 ± 0.21 cm/year in Central Africa (see Supplementary Material). Given its stem density and the mean annual increment, we estimate the number of mature individuals (dbh ≥ 35 cm, see Supplementary Material) over 10 000 across the distribution range, well above the threatened category under criteria C and D.

The most serious long-term threat is the conversion of the forest to agriculture and grazing, and illegal logging. Considering the species' generation length (211 years), an inference of population reduction for three generations in the past is impossible following A1 and A2 criteria.

To model the recruitment, we used the hypothesis defined as the recruitment rate that would maintain a constant number of trees in the first diameter class. Based on simulations of the expected population reduction in its distribution range including protected areas, non - permanent forest areas, and production forest (logging concessions), we estimated population reduction of 23.4-26.8% % in the next 100 years below the threshold to be considered threatened under criterion A3 (for further information about this methodology, see Supplementary Material). An assessment of the population reduction according to criterion A4 considering one to two generations back and one to two generations forward would likely introduce high levels of uncertainty due to the lack of data to efficiently model the reduction of population size in the past. No quantitative analysis of the probability of extinction in the wild was conducted, and therefore criterion E does not apply.

Considering (i) the population density, (ii) the reduction of population in the future across the distribution range,the species is assessed as near threatened NT, A3cd, and it can be threatened (VU) in future on the criterion A3 with a high level of exploitation.

Reasons for change

Reason(s) for Change in Red List Category from the Previous Assessment:

Millettia laurentii was previously assessed as "Endangered" by the IUCN (https://www.iucnredlist.org/species/33219/9767710) at the African Regional Workshop (Conservation & Sustainable Management of Trees, Zimbabwe, July 1996), 1998, following the A1cd criterion. During the last few years, important data have been produced on the self-ecology, population dynamics (growth, recruitment, mortality) of the species (DYNAFAC, 2022; Ligot et al., 2022). Moreover, a new version of the IUCN guidelines is available (from version 2.3 to 3.1). Given all these information, it was necessary to produce a new assessment of the species.

• Distribution

• Geographic Range

Millettia laurentii is a lower guinean species, distributed in Central Africa (Primarily Cameroon, Democratic Republic of Congo, Equatorial Guinea, Gabon, and the Republic of Congo). In Democratic Republic of Congo, *M. laurentii* is more frequent in vegetation areas subject to strong seasonality, and it is found in abundance on the Batéké plateau on the periphery of Kinshasa (Tchinda, 2008). The extent of occurrence (EOO) is estimated at 1 257 533 km^2 across its distribution range.

• Area of Occupancy (AOO)

Estimated area of occupancy (AOO) - in km2	Justification
192	The AOO has been estimated using ConR based on the 2 × 2 km cell size of 1034 occurrences from CJB (Conservatoire et Jardin botaniques de Genève) and RAINBIO

Continuing decline in area of occupancy (AOO)	Qualifier	Justification
Yes	Inferred	The species has suffered from reduction in area of occupancy, due to habitat degradation and deforestation in Central Africa forest (Vancutsem et al., 2021)

• Extent of Occurrence (EOO)

Estimated extent of occurrence (EOO)- in km2	EOO estimate calculated from Minimum Convex Polygon	Justification
1 257 533	true	Calculated using ConR based on 1034 known occurrences from CJB (Conservatoire et Jardin botaniques de Genève) and RAINBIO

Continuing decline in extent of occurrence (EOO)	Qualifier	Justification
Yes	Observed	The species has certainly undergone extent of occurrence reduction in Central Africa, linked to the reduction in forest area (Vancutsem et al., 2021)

- **Locations Information**

Number of Locations	Justification
40-100	More than 46 localities. Based on the most serious plausible threat (conversion of its habitat) and illegal logging across the distribution range.

Continuing decline in number of locations	Qualifier	Justification
Yes	Inferred	The main threat remains the reduction of the forest area in Central Africa.

Extreme fluctuations in the number of locations	Justification
No	Habitat degradation is the main threat.

- **Very restricted AOO or number of locations (triggers VU D2)**

Very restricted in area of occupancy (AOO) and/or # of locations	Justification
No	-

- **Elevation / Depth / Depth Zones**

Elevation Lower Limit (in metres above sea level):

Elevation Upper Limit (in metres above sea level):

- **Map Status**

Map Status	Use map from previous assessment	How the map was created, including data sources/methods used:	Please state reason for map not available:	Data Sensitive?	Justification	Geographic range this applies to:	Date restriction imposed:
Done	-	Qgis. The dataset was created from a compilation of Rainbio and CJB	-	-	-	-	-

- **Biogeographic Realms**

Biogeographic Realm: Afrotropical

- **Occurrence**

- **Countries of Occurrence**

Country	Presence	Origin	Formerly Bred	Seasonality
Cameroon	Extant	Native	-	Resident
Central African Republic	Extant	Native	-	Resident
Republic of Congo	Extant	Native	-	Resident
Democratic Republic of the Congo	Extant	Native	-	Resident
Equatorial Guinea	Extant	Native	-	Resident
Gabon	Extant	Native	-	Resident

- **Population**

Millettia laurentii is a centro-guineo-gongolian species, widely distributed from southern Cameroon to the Democratic Republic of Congo. Its average density is 1.02 stems.ha-1 (dbh ≥ 20 cm) in Central Africa (see Supplementary Material). This density can be very abundant in forests resulting from the colonization of savannahs, in open forests with Marantaceae and forest galleries on hydromorphic soils (Meunier et al., 2015). It regenerates in the open, not far from the producing trees. The oldest stems can then be overgrown by neighboring trees

In nurseries, the average germination rate is 55% (40-75%), seeds can be stored for several years, but the conditions are not well known (Daïnou et al., 2021). The average growth is 0.26 ± 0.21 cm/year in evergreen stands and in semi-deciduous riverine forest (all diameters combined) in Central Africa (see Supplementary Material).

The legal minimum cutting diameter "MCD" varies across its distribution range, (50 cm in Cameroon, 60 cm in Gabon, Republic of Congo and Democratic Republic of Congo, and 70 cm in Central Africa Republic). In the legal logging concession of central Africa, the MCD must be adapted to ensure sufficient recovery rates after each cutting cycle (MCD_M). At the Central Africa level, we weighted the MCD and MCD_M values to the occupied area with MCD = 60 cm and MCD_M = 65 cm (see Supplementary Material). Across the distribution range, MCD is higher than the regular fruiting diameter (RFD), estimated at 45 cm in the Republic of Congo (Ouedraogo et al., 2018) and Democratic Republic of Congo (Daïnou et al., 2021). The minimum fertility diameter is estimated at 35 cm in Central Africa (see Supplementary Material), ensuring a good availability of seed trees and the natural regeneration of the species.

Using the Red List criterion A3, the projected population reduction (PPR) to be met in the future (100 years because the generation length of the species is 211 years) of the *M. laurentii* population was assessed across its distribution range. Because *M. laurentii* is a widespread species in Central Africa, the PPR was estimated for the region. Three different PPR were thus estimated: PPRpa in protected areas, PPRpf in production forests and PPRnp in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas. First, protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). The population of the species in protected areas covering its range was kept stable in the future over 100 years, suggesting that the PPR in protected areas was 0%. Second, the evolution of the *M. laurentii* population was simulated using an Usher matrix model to estimate the PPR of production forests (logging concessions, PPRpf). The simulations were initialised using the density (number of trees.ha-1) per diameter class (from 20 cm diameter, mature individuals) from forest management inventories of logging companies. The evolution of this initial population depended on several demographics (recruitment, mortality, and growth rate) and logging parameters (minimum cutting diameter, cutting and damage rate) that were adjusted using data of permanent tree plot monitoring. Thus, the density of *M. laurentii* in 100 years was predicted with a logging event every 25 years, which corresponds to the average cutting cycle in Central Africa. PPRpf was then calculated as the difference between initial and final number of trees. Third, the major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Illegal logging and the habitat lost from deforestation rate have been both activities that allowed estimating the PPRnp in non-permanent domains. The global PPR was then computed after weighting the three values (protected area, production forest and non-permanent domain) by their relative forest areas. The global PPR result was found to be 23.4-26.8% (for further information about this methodology, see Supplementary Material).

- **Population Information**

Current Population Trend: Decreasing

Extreme fluctuations? (in # of mature individuals)	Justification
No	-

Severely fragmented?	Justification
No	-

Continuing decline in mature individuals?	Qualifier	Justification

Continuing decline % in mature individuals within 3 generations or 10 years, whichever is longer (up to max. of 100 years in the future)	Qualifier	Justification

Extreme fluctuations in the number of subpopulations	Justification
No	-

Continuing decline in number of subpopulations	Qualifier	Justification
No	-	-

All individuals in one subpopulation: No

Number of Subpopulations	Justification	Subpopulation Details	Subpopulation description	Number of mature	Subpopulation trend	Qualifier	Location type	Number of Subpopulations	Location bounding box	Location coordinates	Notes
		-	-	-	-	-	-	-	-	-	-

- Population Reduction - Past

Percent Change in past	Reduction or Increase	Qualifier	Justification

Basis?

Reversible?

Understood?

Ceased?

- **Population Reduction - Future**

Percent Change in future	Reduction or Increase	Qualifier	Justification
23.4-26.8%	Reduction	Projected	Using the Red List criterion A3, the projected population reduction (PPR) to be met in the future (100 years because the generation length of the species is 211 years) of the *M. laurentii* population was assessed across its distribution range. Because *M. laurentii* is a widespread species in Central Africa, the PPR was estimated for the region. Three different PPR were thus estimated: PPRpa in protected areas, PPRpf in production forests and PPRnp in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas. First, protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). The population of the species in protected areas covering its range was kept stable in the future over 100 years, suggesting that the PPR in protected areas was 0%. Second, the evolution of the *M. laurentii* population was simulated using an Usher matrix model to estimate the PPR of production forests (logging concessions, PPRpf). The simulations were initialised using the density (number of trees.ha-1) per diameter class (from 20 cm diameter, mature individuals) from forest management inventories of logging companies. The evolution of this initial population depended on several demographics (recruitment, mortality, and growth rate) and logging parameters (minimum cutting diameter, cutting and damage rate) that were adjusted using data of permanent tree plot monitoring. Thus, the density of *M. laurentii* in 100 years was predicted with a logging event every 25 years, which corresponds to the average cutting cycle in Central Africa. PPRpf was then calculated as the difference

	between initial and final number of trees. Third, the major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Illegal logging and the habitat lost from deforestation rate have been both activities that allowed estimating the PPRnp in non-permanent domains. The global PPR was then computed after weighting the three values (protected area, production forest and non-permanent domain) by their relative forest areas. The global PPR result was found to be from 23.4 to 26.8%, lower than 30%. For further information about this methodology, see the Supplementary Material.

Basis?
b) an index of abundance appropriate for the taxon, d) actual or potential levels of exploitation

- **Population Reduction - Ongoing**

Both: Percent Change over any 10 year or 3 generation period, whichever is longer, and must include both past and future, future can't go beyond 100 years	Reduction or Increase	Number of years for this period	Qualifier	Justification

Basis?

Reversible?
Yes

Understood?
Yes

Ceased?

No

Habitats and Ecology

Millettia laurentii is a large tree reaching 30 m in height and 1 m in diameter, long-lived, cryptopioneer usually gregarious species, common in forests resulting from the colonisation of savannahs, in open Marantaceae forests and in forest galleries on hydromorphic soils (Meunier et al., 2015).

Its regeneration develops in an open environment, not far from the producing trees. The oldest stems can then be overgrown by neighboring trees. Shade tolerant in the young stages but its growth nevertheless requires light in the more advanced stages (Menga et al., 2012). In Democratic Republic of Congo, the species is planted for reforestation on previously cultivated land (Tchinda, 2008).

M. laurentii bears hermaphrodite flowers. The leaf phenology is strongly linked to the seasonal alternation, it loses its leaves in dry seasons and the last one's regenerate with the arrival of the rainy season. The beginning of the rainy season initiates its flowering as well as the appearance of new leaves in Democratic Republic of Congo (Menga et al., 2012). First flowers are observed at a minimum from 26 cm diameter in northern Republic of Congo and become regular and abundant at 32 cm (Ouédraogo et al., 2018). Seeds are dispersed by opening the pod (unassisted) (Meunier et al., 2015). The first fruits are observed from 26 cm, and become regular 45 cm dbh in Republic of Congo and Democratic Republic of Congo respectively (Daïnou et al., 2021; Menga et al., 2012; Ouédraogo et al., 2018).

M. laurentii can propagates by cuttings, a success rate of nearly 48% has been observed in the Democratic Republic of Congo (Tchinda, 2008).

IUCN Habitats Classification Scheme

Habitat	Season	Suitability	Major Importance?
1.6. Forest -> Forest - Subtropical/Tropical Moist Lowland	Resident	Suitable	Yes

Continuing Decline in Habitat

Continuing decline in area, extent and/or quality of habitat?	Qualifier	Justification
Yes	Observed	The annual deforestation rate of 0.35% in Central Africa (Vancutsem et al., 2021).

Life History

Generation Length	Justification	Data Quality
211	Minimum estimate of generation length for the species from the average growth rate, and the mean diameter of mature individuals (see Supplementary Material)	good

Age at maturity: female or unspecified
135 Years

Age at Maturity: Male
135 Years

Size at Maturity (in cms): Female
35

Size at Maturity (in cms): Male
35

Reproductive Periodicity
Annual

Annual Rate of Population Increase

Natural Mortality
1% (Ligot et al. 2022)

- **Systems**

System: Terrestrial

- **Plant / Fungi Specific**

Wild relative of a crop? No

Plant and Fungal Growth Forms
Tree - large

• Use and Trade

• General Use and Trade Information

Millettia laurentii is in the top 15th of the most exploited forest species in tropical Africa (Eba'a Atyi et al., 2022). *M. laurentii* is sought after for the quality of its woodheavy and very hard, and resistant to termites, dry wood insects and fungi, not very impregnable, considered a multipurpose tropical species. The wood is used for the confection of parquet, in woodworking, especially for the confection of luxury furniture, in interior and exterior carpentry. In 2006 and 2008 Central Africa produced 35131 m^3 and 77488 m^3. In 2010 Democratic Republic of the Congo exported 29 787m^3 (ATIBT, 2010). In 2016, Central Africa, produce 32 625m^3 (FRMi, 2018) and 66 972 m^3 of log in 2018 (Eba'a Atyi et al., 2022). However, since 2021, the DRC has banned the export of *M. laurentii* (FRMi, 2018).

At a local level, traditional medicine, the bark decoction is used to treat liver diseases, diabetes, hernias, skin diseases, constipation, fever, and rheumatism. The bark is also used as an expectorant and emetic, and to treat epilepsy, smallpox, and abscesses. It is still used as a fishing poison, insecticide, worming agent and arrow poison (Tchinda, 2008).

Subsistence:	Rationale:	Local Commercial:	Further detail including information on economic value if available:
Yes	-	Yes	-

National Commercial Value: Yes

International Commercial Value: Yes

Is there harvest from captive/cultivated sources of this species? Yes

Trend in level of total offtake from wild sources: Stable

Trend in level of total offtake from domesticated sources: Unknown

• Non- Consumptive Use

Non-consumptive use of the species? true

• Threats

The main threats in the non-permanent domain across the species' distribution range, are mainly related to habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging and the abusive harvesting of plant parts requested as non-wood forest products (Bradshaw et al., 2009). In Central Africa, illegal logging accounts for nearly 46% of total log production (FRMi, 2018). This production generally comes from unallocated forest areas (non-permanent forest domain). Illegal logging and local intense harvesting have been observed for the species. *M. laurentii*, logs may have been exported from Matadi (Democratic Republic of Congo) but it appears that these exports have now been stopped (FRMi, 2018).

Millettia laurentii is exploited in Central Africa. No study considers logging as a direct driver of deforestation because of the low logging densities (1-2 stems per hectare). However, studies on the impact of logging on the species and habitats are needed.

- **Threats Classification Scheme**

No past, ongoing, or future threats exist to this species. false

Threat	Timing	Scope	Severity	Impact Score
1.1. Residential & commercial development -> Housing & urban areas	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4
2.1.1. Agriculture & aquaculture -> Annual & perennial non-timber crops -> Shifting agriculture	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
2.2.2. Agriculture & aquaculture -> Wood & pulp plantations -> Agro-industry plantations	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
2.3.2. Agriculture & aquaculture -> Livestock farming & ranching -> Small-holder grazing, ranching or farming	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4
3.2. Energy production & mining -> Mining & quarrying	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
4.1. Transportation & service corridors -> Roads & railroads	Past, Likely to Return	Minority (<50%)	Negligible declines	Past Impact
5.3.1. Biological resource use -> Logging & wood harvesting -> Intentional use: (subsistence/small scale) [harvest]	Ongoing	Minority (<50%)	Rapid Declines	Medium Impact: 6
5.3.2. Biological resource use -> Logging & wood harvesting -> Intentional use: (large scale) [harvest]	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4

7.1.3. Natural system modifications -> Fire & fire suppression -> Trend Unknown/Unrecorded	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4

● Conservation

Millettia laurentii appear in 2 ex situ collections (BGCI, 2022), and may occur in many protected areas considering its distribution range. In certified forest concessions where the species is exploited, trails and or permanent forest plots are usually installed. These plots provide important data for (i) quantifying population dynamics processes at the stand level: mortality, growth and recruitment; (ii) phenological studies to determine the regular fruiting diameter (RFD).

These plots are managed in collaboration with forest concessions grouped within the DYNAFAC collective (see here for more information https://www.dynafac.org/fr/p/130/installation-de-dispositifs-de-suivi-de-la-dynamique-forestiere). Compilation of these data provide important additional information for targeted silvicultural measures for the sustainable management of this species. First summaries have provided information on important parameters such as: mortality, growth, etc. (DYNAFAC, 2022; Ligot et al., 2022). Based on almost 40 years of monitoring forest dynamics in Central Africa, the DYNAFAC collective recommends a MCD of 60 cm in Central Africa to maintain optimal gene flow and optimal regeneration (DYNAFAC, 2022). DYNAFAC also recommends the preservation of additional seed trees or the implementation of regeneration support techniques to ensure the long-term maintenance of populations. *M. laurentii* is also monitored in nurseries and planted in various forest concessions. The species also colonises savannahs.

Logging in Central Africa is subject to strict legislation, species can only be harvested above a certain diameter and measures must be taken to ensure the renewal of the resource (Fargeot et al., 2004). Indeed, management plans for tropical rainforests require the determination of a minimum cutting diameter (MCD) to ensure a minimum renewal rate at the end of a rotation period (duration between two cuts on the same cutting base), the minimum reconstitution rate (40-50% depending on the country) as well as the rotation duration, being imposed by forestry legislation (Durrieu de Madron and Forni, 1997).

In addition, it will also be necessary to :

- Ensure the implementation of the recommendations of the Dynafac collective, including the establishment of a system for monitoring the populations of commercial species in the different forest types defined in a consensual manner;
- Set up monitoring and support systems for the regeneration of commercial species, prioritising species with regeneration deficits;
- Set up programmes to guarantee the phenotypic quality of commercial species populations: seed banks, seed stands, plus trees, seed orchards, conservation plantations;
- Consider threatened species in the delimitation of conservation series and in the identification of High Conservation Values;
- Update conservation statuses on a five-yearly basis, in particular by setting up a system of "green statuses";
- Define red lists adapted to regional or national contexts;

- Evaluate the status of cryptic species or species close to commercial species evaluated during this workshop.

- **Conservation Actions In- Place**

Action Plan	Recovery	Note
Yes		Enrichment in logging concessions

Systematic monitoring scheme	Note
Yes	The species is monitored in permanent plots installed within forestry companies in Central Africa (see here for more information https://www.dynafac.org/fr)

Occur in at least one PA	Note
Yes	The species may appear in at least 10 protected areas considering it distribution range

Percentage of population protected by PAs (0-100)	Note
1-10	Considering protected area across species distribution range

Area based regional management plan	Note
Unknown	-

Invasive species control or prevention	Note
No	-

Harvest management plan	Note
Yes	In certified forest concessions, the species is exploited according to a management plan.

Subject to ex-situ conservation	Note
Yes	-

Included in international legislation	Note
No	-

Subject to any international management/trade controls	Note

- **Important Conservation Actions Needed**

Conservation Actions	Note
3.1.1. Species management -> Species management -> Harvest management	-
3.1.2. Species management -> Species management -> Trade management	-
3.4.2. Species management -> Ex-situ conservation -> Genome resource bank	-

- **Research Needed**

Research	Note
1.2. Research -> Population size, distribution & trends	-
3.1. Monitoring -> Population trends	-
3.2. Monitoring -> Harvest level trends	-
3.3. Monitoring -> Trade trends	-

- **Ecosystem Services**

- **Ecosystem Services Provided by the Species**

	Importance:	Geographic range of benefit:
1. Water Quality	2 - Important	Global
3. Flood Control	2 - Important	Global
4. Climate Regulation	2 - Important	Global
5. Landscape	2 - Important	Global
6. Air Quality	2 - Important	Global
7. Nutrient Cycling	2 - Important	Global

8. Habitat Maintenance	2 - Important	Global
9. Provision of Critical Habitat	2 - Important	Global

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Millettia laurentii - De Wild.

IUCN status using criterion A3

We adopted the criterion A3 to assess the projected population reduction (PPR) to be met in the future (up to a maximum of 100 years) of *Millettia laurentii* (wenge). To quantify the projected population reduction, simulations must be performed on mature individuals and three generations with a maximum of 100 years according to **criterion A3**. We estimated mature individuals and generation length, as recommended by the IUCN guidelines.

A **mature individual** is an individual that can reproduce, able to bear flowers or seeds (fertile in plant kingdom). To quantify the mature individuals for each species, we used phenological data of DYNAFAC network[24] from a combined dataset of 90 trees belonging to one site in Republic of Congo. Minimum and maximum sampled diameters ranged from 11 to 100 cm (median 48 cm). From the monitoring period, every month/year monitored had at least one recorded reproductive event. We assumed that the monitoring period was long enough to capture at least one reproductive event per tree such that trees without observed flowering/fruiting events were considered non-reproductive (about 30 percent of all monitored trees were non-reproductive). We used the methodology for the size at reproduction of canopy tree species in Central Africa (Ouédraogo et al., 2018): the **diameter of a mature individual** was obtained after fitting logistic regressions and the level of 50% of the probability to produce the flower or fruit was adopted for this species. Using this approach, the diameter of a mature individual was obtained after setting the 50% probability to produce flowers or fruits. The minimum diameter of mature individuals for this species was **35 cm**.

The **generation length** was the report between the mean diameter of mature individuals considering population structure and the mean increment. Given that the minimum diameter of mature individuals was 35 cm, we weighted the total number of trees by their diameter from 35 cm to 125 cm to compute the number of mature individuals. The mean diameter of mature individuals was **55 cm.** The **mean increment** of the species was **0.26 cm**, obtained from 94 observations of unpublished data in Republic of Congo. Thus, the **generation length** was 55 cm / 0.26 cm = **211 years**. The age at maturity (**135 years**) has been estimated as the report between the **minimum diameter of mature individuals** (**35 cm**) and the **mean annual increment** (**0.26 cm**).

Estimation of the projected population reduction (PPR)

We adopted the criterion A3 to assess the projected population reduction (PPR) to be met in the future (up to a maximum of 100 years). Because *Millettia laurentii* is a widespread species in Central Africa, the PPR was estimated in central Africa.

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[24] https://www.dynafac.org/en

PPR in Central Africa

In this region, forest management follows three different modalities: protected areas, production forests (logging concessions) and non-permanent forest domain. Based on occurrences, the natural range of this species includes all countries in Central Africa (Figure 1). The total natural area is estimated at 125 772 748.5 ha. Within this area, there are 42 033 389.5 ha (33.4%) for production forests, 10 498 789.5 ha (8.4%) for protected areas, and 73 240 569.51 ha (58.2%) for the non-permanent domain.

Three different PPR were thus estimated: PPR_{pa} in protected areas, PPR_{pf} in production forests and PPR_{np} in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas and then added to estimate the PPR_{C} in Central Africa.

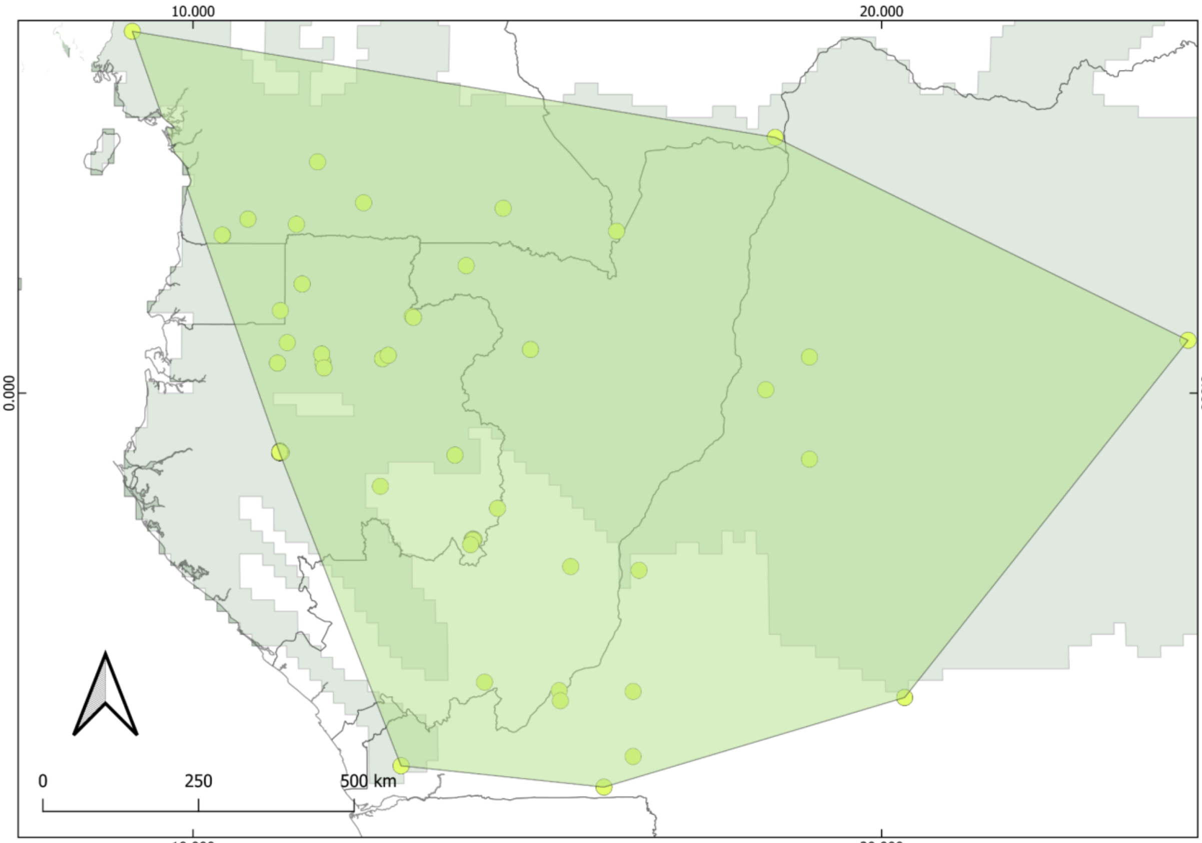

Figure 1. The range of *Millettia laurentii* in Central Africa estimated from RAINBIO and CJB data, validated in December 2022 during a workshop with a group of experts in Gabon.

PPR in protected areas

Central Africa countries have allocated a higher proportion of their land to conservation than any other tropical regions, with relatively higher conservation success (Laurance et al., 2012). Indeed, most protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). They are currently representing a large part of forest and tree species conservation in Central Africa. Thus, the population of each species in protected areas (according to FRMI, 2018) covering its range was kept stable in the future over 100 years.

In these conditions, it was hypothesized that the PPR in protected areas for each species is 0%, suggesting no population reduction in the present and future.

PPR in production forests

To quantify the evolution of the population of each timber species, matrix population models are widely used to study population dynamics (Picard & Liang, 2014). The population of this species was described at time t by a vector N_t corresponding to the density (number of trees ha^{-1}) in each diameter class (from 20 cm diameter to more than 120 cm). The density per diameter class was estimated using data from forest inventories that were carried out in 46 forest management units (FMU) of different logging companies in five countries (Cameroon, Central African Republic, Democratic Republic of Congo, Gabon, and Republic of Congo). Most logging companies followed a standardized inventory protocol (Réjou-Méchain et al., 2011). These forest inventory data covered about 11 million ha (Table 1), that are representative of 27% of Central Africa's production forests of this species. The number of trees sampled in Central Africa was 11 459 393 with a density of 1.02 tree ha^{-1}. Large-scale commercial inventories have already been found useful in the identification of large-scale patterns in Central Africa (Réjou-Méchain et al., 2011). Using large-scale data from commercial forest inventories, Réjou-Méchain et al. (2021) jointly model the distribution in the abundance of the most dominant tree species and produce continuous maps of the floristic and functional composition of central African forests.

Table 1. Forest management units (FMU) sampled in Central Africa (Cameroon, CAR: Central African Republic, DRC: Democratic Republic of the Congo, EG: Equatorial Guinea, Gabon and RCongo: Republic of the Congo).

	Sampling	
Country	FMU	Area (ha)
Cameroon	3	398 893
CAR	1	187 596
DRC	8	2 211 297
EG	-	-
Gabon	28	5 310 886
RCongo	6	3 106 003
Total	46	11 214 675

The Usher matrix model was used to simulate the evolution of the recovery rate of all population and the exploitable stock of each species after logging in Central Africa. According to the Usher assumption, between t and t+1, an individual can either stay alive in the same class, stay alive and move up to the next class, or die; it cannot move up by more than one class or move backwards, i.e., the individual is free from diameter shrinkage (Picard et al., 2012). The Usher matrix model (U) considers three parameters (mortality, recruitment and growth rate that are constant in time) to estimate the transition probabilities:

$$U = \begin{pmatrix} q_1 + g_1 & g_2 & \cdots & \cdots & g_I \\ p_1 & q_2 & 0 & \cdots & 0 \\ 0 & \ddots & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & p_{I-1} & q_I \end{pmatrix}$$

where q_i is the probability for an individual to stay alive in class i between two consecutive time steps, p_i is the upgrowth transition rate (the probability for an individual to grow up from class i to class i +1), and g_i is the recruitment rate (Picard & Liang, 2014).

Tree mortality, recruitment and growth are three central processes for predicting the dynamics of tropical rainforests and estimating these three processes requires long-term monitoring in difficult field conditions (Picard & Gourlet-Fleury, 2008). These processes determine the evolution of the species population in the forest stand. The natural mortality is defined as the number of standing dead trees, and few studies have reported estimates of mortality rates in Central Africa. Data about tree mortality are still scarce and it does not allow to precisely model the mortality rate for each species and size class. Given the current state of knowledge, it appears reasonable to use a fixed mortality rate of 1% for all species and size classes, in agreement with the results of Ligot et al. (2022) on 21,180 trees belonging to 42 timber species of Central Africa annually monitored from one to seven years.

The recruitment integrates fruiting and seed dispersal from mother trees, and the survival of plant juveniles until they reach a size threshold where they are included in the stand. The recruitment term in the model is the average annual input of new individuals into the first size class from 20 cm. The recruitment events, like mortality events, are infrequent and thus difficult to model (Karsenty & Gourlet-Fleury, 2006). The population structure showed a curve in "decreasing exponential" suggesting a good regeneration (Figure 2). To model the recruitment, we used the hypothesis defined as the recruitment rate that would maintain a constant number of trees in the first diameter class. Claeys et al. (2019) projected the future forest dynamics up to the end of the century and they showed that projected mortality and recruitment rates in 2099 could not differ from the ones observed today. Thus, the hypothesis on the recruitment and the mortality rate is used in the future (up to 100 years) as they do today.

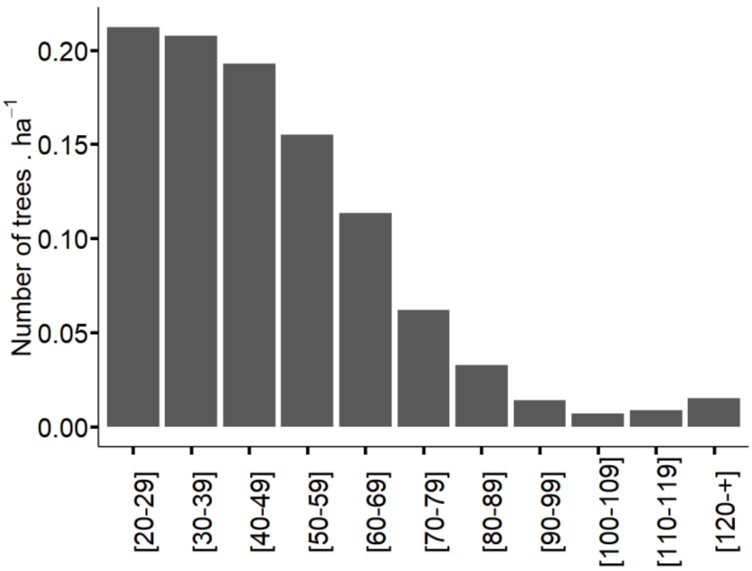

Figure 2. Population structure of *Millettia laurentii* (Wenge) defined using the number of trees per ha and per diameter class (from 20 cm of 46 logging concessions covering an area of 11 214 675 ha in Central Africa).

Since the mid-1900s, periodic tree monitoring and tree ring analyses have been carried out to study variability in tree growth across species in Central Africa (Durrieu de Madron, Nasi, et al., 2000; Ligot et al., 2019, 2022). We fitted growth models for each species using data from logged and unlogged areas of permanent tree plot monitoring from the DYNAFAC[25] network covering the five Central African countries. From the combined dataset, we identified 94 trees belonging to two site in Republic of Congo. The minimum and maximum sampled diameters ranged from 10 to 75 cm. The monitoring period ranged from 2000 to 2008. The mixed second-degree polynomial models (with a random site effect) were fitted for species monitored in several sites. Because of three estimated coefficients of the mixed model were not significant, the mean of the increment (**0.26 cm**) has been used to estimate the diameter growth (Table 2).

Table 2. Estimated coefficients (a, b, and c) of growth models between the increment (ac in cm year^{-1}) and the initial diameter (D in cm). The sample including the number of trees (n) and the number of sites (site) is also given. ^{ns} non-significant (p-value > 0.050)

species	n	site	model	a	b	c
Wengé	94	1	ac ~ D + D^2 + (1|site)	0.205^{ns}	0.005^{ns}	-0.00004^{ns}

The transition probabilities of three parameters (mortality, growth, and recruitment rate) allowed making the harvested matrix. The logging operations have been modeled using the logging parameters (minimum cutting diameter, cutting, and damage rate). The minimum cutting diameters were obtained from decrees of application of

[25] https://www.dynafac.org/en

the forestry administrations (MCD_A) at the country level and the one used in the management plan (MCD_M, with $MCD_M \geq MCD_A$) at the logging company level. At the Central Africa level, we weighted the MCD_A and MCD_M values to the occupied area (**MCD_A = 60 and MCD_M = 65 cm**. The cutting rate (CA), which defines the proportion of harvested trees (trees with a diameter greater than MCD_A or MCD_M), was given by logging companies, and it was also weighted at the Central Africa level with a value of **62%**. Given the current state of knowledge, it appears reasonable to use a fixed damage rate caused by logging of 7% of the initial population that disappears (Durrieu de Madron, Fontez, et al., 2000). The average cutting cycle (i.e. the period between two successive logging operations) is 28 years (FRMI, 2018), but we used 25 years to simplify the computation of four simulations reaching 100 years (25, 50, 75, and 100 years), as requested by IUCN criterion A.
The Figure 3 shows the PPR in production forests for the *Millettia laurentii*. The reduction in the population of each species was then calculated as the difference between the initial numbers of mature individuals and the predicted numbers of mature individuals predicted after 100 years. **The PPR in production forests** was from **−60.42% (MCD_A) to -52.85% (MCD_M)** for constant recruitment over 100 years.

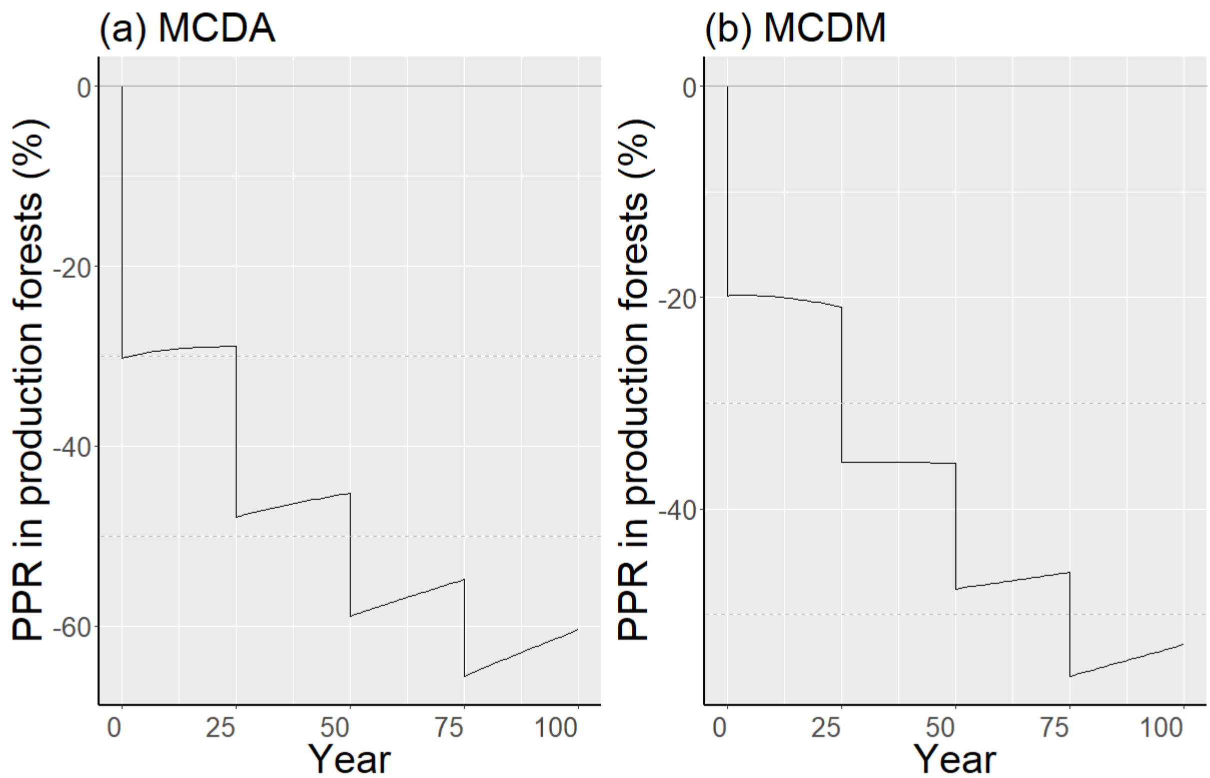

Figure 3. Simulations showing the projected population reduction (PPR) from diameter of mature individuals (35 cm) in production forests for the *Millettia laurentii* for constant recruitment over 100 years.

PPR in the non-permanent forest domain

The major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanization, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Based on the large range of this species in Central Africa, the harvested volume from illegal logging and legal logging are 36% and 64%, respectively (FRMI 2018). In this condition, it was hypothesized that there is 64% of PPR from production forests and 36% of PPR from illegal logging in 100% PPR due to forest logging. Given that the PPR of production forests associated with its forest area was known, we deduced the PPR and forest area of illegal logging from those of the production forests. As a result, 23 643 781.6 ha were affected for the illegal logging for this species. The non-permanent domain area (73 240 569.51 ha) was considered as the area which was related to today's deforestation rate of 0.35% $year^{-1}$ in Central Africa (Vancutsem et al., 2021). This is a conservative value since it will probably decrease in the future (Swamy et al., 2018).

PPR global = PPR in Central Africa

We thus had three different PPR: PPR_{pa} in protected area, PPR_{pf} in production forests, and PPR_{np} in non-permanent domain. The global PPR was then computed after weighting the three values by their relative forest areas:

$$PPR = \frac{(S_{pa} \times PPR_{pa}) + (S_{pf} \times PPR_{pf}) + (S_{np} \times PPR_{np})}{S_{pa} + S_{pf} + S_{np}}$$

where S_{pa}, S_{pf}, and S_{np} are forest areas in protected area, production forests and non-permanent domain, respectively.

The criterion A3 based on (c) a decline in area of occupancy (AOO), the extent of occurrence (EOO), and/or habitat quality; and (d) potential levels of exploitation, has been computed as follows: (i) 30%≤PPR<50%, the species is considered as Vulnerable (VU); (ii) 50%≤PPR <80%, the species is considered as Endangered (EN), and PPR ≥ 80%, the species is considered as Critically Endangered (CR).

The PPR global in the distribution range of the *Millettia laurentii* was from **−26.8% (MCD_A) to -23.4% (MCD_M)** for constant recruitment over 100 years. This PPR is < 30%, suggesting that this species is not threatened in its geographic area.

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10.16 Annexe 16. *Prioria balsamifera* - (Vermoesen) Breteler

Draft

Prioria balsamifera - (Vermoesen) Breteler

PLANTAE - TRACHEOPHYTA - MAGNOLIOPSIDA - FABALES - FABACEAE - Prioria – balsamifera

Common Names: Achi, Agba, Egba, Emongi, N'tola, Tola, Tola Branca, Tola blanc (French)

Synonyms: Pterygopodium balsamiferum Vermoesen;
Gossweilerodendron balsamiferum (Vermoesen) Harms

Red List Status
NT - Near Threatened, A3cd (IUCN version 3.1)

- **Red List Assessment**
- **Assessment Information**

Date of Assessment: 2022-09-01

Assessor(s): Monthe, F., Loubota, G., Ligot, G., Texier, N., Stévart, T. & Doucet, JL.

Reviewer(s):

Institution(s):

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Regions: Global

- **Identification Description**

Prioria balsamifera is a large tree with a spherical top and open foliage. Its trunk is very cylindrical and straight, grey-green. The bark is detached in vertical scales more or less rectangular. Its edge is pink-red with whitish interior, it lets escape a greenish resin. Its leaves are composed of 6 to 10 alternate leaflets of variable shape, marked by translucent points, with rounded top, the petiolules are twisted. Its flowers are white in clusters. Its brownish fruits are winged with a slightly curved side and the other rounded, they reach 17 cm in length and 5 cm broad. These large samara-shaped pods contain a large ellipsoid seed of ± 2.5 cm long.

- **Assessment Rationale**

Prioria balsamifera is a widespread tall lower-guinea tree of dense humid evergreen and semi-deciduous forest, long-lived, non-pioneer light demanding, and usually non-gregarious species.

It is distributed from southeast Nigeria to Cabinda (Angola). Based on a 2 x 2 km cell size, the AOO of this species is estimated as 272 km^2 with a minimum of 54 locations (number of forest management units of different logging companies in Central Africa). This species is not "Vulnerable" status under criterion B2. The EOO is calculated as 2 453 205 km^2, above the upper threshold for "Vulnerable" status under criterion B1.

Commonly known as Agba or Tola, it is a timber species in tropical Africa, sought after for its quality (soft and light wood), with high economic potential, especially in Gabon and the DRC. The minimum cutting diameter (MCD) in Central Africa varies between 80 and 100 cm. At the Central Africa level, we weighted the MCD and MCDM values to the occupied area with MCD = 80 cm (see Supplementary Material). The population structure showed a decreasing with a good representation of the small stems suggesting a good regeneration, and a population densities of 0.28 $stems.ha^{-1}$ (dbh ≥ 20 cm) in Central Africa (see Supplementary Material). Given its stem density and the mean annual increment of 0. 66 ± 0. 36 cm/year in Central Africa (see Supplementary Material), we estimate the number of mature individuals over 10 000 across the distribution range, well above the threatened category under criteria C and D.

The most serious long-term threat is the conversion of the forest to agriculture, and illegal logging. However, the species is not considered severely fragmented as 217 known occurrences represent more than 50 localities (sensu Comité des normes et des pétitions de l'UICN, 2019). Considering the species' generation length (123 years), an inference of population reduction for three generations in the past is impossible following A1 and A2 criteria.

To model the recruitment, we used the hypothesis defined as the recruitment rate that would maintain a constant number of trees in the first diameter class. Based on simulations of the expected population reduction in its distribution with constant recruitment, we estimated population reduction of 20.1% in the next 100 years below the threshold to be considered threatened under criterion A3 (for further information about this methodology, see Supplementary Material). An assessment of the population reduction according to criterion A4 considering one to two generations back and one to two generations forward would likely introduce high levels of uncertainty due to the lack of data to efficiently model the reduction of population size in the past. No quantitative analysis of the probability of extinction in the wild was conducted, and therefore criterion E does not apply.

Considering (i) the population density, (ii) the reduction of population in the future across the distribution range, the species is assessed as near threatened NT, A3cd, and it can be threatened (VU) in future on the criterion A3 with a high level of exploitation.

Reasons for change

Reason(s) for Change in Red List Category from the Previous Assessment:

Prioria balsamifera was previously assessed as "Endangered" by the IUCN (https://www.iucnredlist.org/species/33052/9753751) at the African Regional Workshop (Conservation & Sustainable Management of Trees, Zimbabwe, July 1996), 1998, following the A1cd criterion. During the last few years, important data have been produced on the self-ecology, population dynamics (growth, recruitment, mortality) of the species (DYNAFAC, 2022; Ligot et al., 2022). Moreover, a new version of the IUCN guidelines is available (from version 2.3 to 3.1). Given all these information, it was necessary to produce a new assessment of the species.

- **Distribution**
- **Geographic Range**

Prioria balsamifera is native to Central Africa and occurs in lowland semi-deciduous and evergreen forests from southeast Nigeria to Cabinda (Angola) and the Democratic Republic of the Congo (DRC). The extent of occurrence (EOO) is estimated to be 2 453 205 km^2 across its distribution range.

- **Area of Occupancy (AOO)**

Estimated area of occupancy (AOO) - in km2	Justification
276	AOO has been estimated using ConR based on the 2 × 2 km cell size of 136 occurrences from CJB (Conservatoire et Jardin botaniques de Genève) and RAINBIO

Continuing decline in area of occupancy (AOO)	Qualifier	Justification
Yes	Inferred	The species has suffered from reduction in area of occupancy, due to habitat degradation and deforestation in Central Africa forest (Vancutsem et al., 2021)

- **Extent of Occurrence (EOO)**

Estimated extent of occurrence (EOO)- in km2	EOO estimate calculated from Minimum Convex Polygon	Justification

2 453 205	true	Calculated using ConR based on 136 known occurrences from CJB (Conservatoire et Jardin botaniques de Genève) and RAINBIO

Continuing decline in extent of occurrence (EOO)	Qualifier	Justification
Yes	Observed	The species has certainly undergone extent of occurrence reduction in Central Africa, linked to the reduction in forest area (Vancutsem et al., 2021)

- **Locations Information**

Number of Locations	Justification
50-200	More than 54 localities. Based on the most serious plausible threat (conversion of its habitat) and illegal logging across the distribution range.

Continuing decline in number of locations	Qualifier	Justification
Yes	Inferred	The main threat remains the reduction of the forest area in Central Africa.

Extreme fluctuations in the number of locations	Justification
No	Habitat degradation is the main threat.

- **Very restricted AOO or number of locations (triggers VU D2)**

Very restricted in area of occupancy (AOO) and/or # of locations	Justification
No	-

- **Elevation / Depth / Depth Zones**

Elevation Lower Limit (in metres above sea level):

Elevation Upper Limit (in metres above sea level): 600

- **Map Status**

Map Status	Use map from previous assessment	How the map was created, including data sources/methods used:	Please state reason for map not available:	Data Sensitive?	Justification	Geographic range this applies to:	Date restriction imposed:
Done	-	Qgis. The dataset was created from a compilation of Rainbio and CJB	-	-	-	-	-

- **Biogeographic Realms**

Biogeographic Realm: Afrotropical

- **Occurrence**
- **Countries of Occurrence**

Country	Presence	Origin	Formerly Bred	Seasonality
Angola	Extant	Native	-	Resident
Cameroon	Extant	Native	-	Resident
Central Africa Republic	Extant	Native	-	Resident
Democratic Republic of the Congo	Extant	Native	-	Resident
Equatorial Guinea	Extant	Native	-	Resident
Gabon	Extant	Native	-	Resident
Nigeria	Extant	Native	-	Resident
Republic of Congo	Extant	Native	-	Resident

- **Population**

Prioria balsamifera is a lower-guinea species, widely distributed from Democratic Republic of Congo to Nigeria. Its average density is 0.28 stems.ha^{-1} (dbh ≥ 20 cm) in Central Africa (see Supplementary Material). This density can reach 4-6 stems.ha^{-1} (dbh ≥ 60 cm) locally in some populations in Gabon and Republic of Congo (Cobbinah and Obeng, 2011). Natural regeneration can be abundant, it regenerates in recently opened areas such as forest gaps, not far from the mother tree. In the semi-deciduous forest of southwestern Democratic Republic of Congo, up to 7800 seedlings.ha^{-1} have been observed. The average growth is 0.66 ± 0.36 cm/year (all diameters combined) in Central Africa (see Supplementary Material).

In the nursery, the germination rate of *P. balsamifera* reaches 45% (20-80%), according to the water content of the seeds (Daïnou et al., 2021). Natural mortality of this species has almost never been studied, nevertheless, an average of 1% was observed for 42 timber species in central Africa (Ligot et al., 2022).

The legal minimum cutting diameter “MCD " varies across its distribution range, (80 cm in Democratic Republic of Congo, Gabon and Republic of Congo, 90 cm in Central Africa Republic, and 100cm in Cameroon). At the Central

Africa level, we weighted the MCD and MCDM values to the occupied area with MCD = 80 cm (see Supplementary Material). This MCD is higher than the minimum fertility diameter estimated at 55 cm in Central Africa (see Supplementary Material). However, based on almost 40 years of monitoring forest dynamics in Central Africa, the DYNAFAC collective recommends a MCD of 80 cm in Central Africa to maintain optimal gene flow and optimal regeneration (DYNAFAC, 2022). Genetic data from the populations in Gabon and DRC show that the genetic diversity of *P. balsamifera* populations is relatively low, and that efforts should be made to prevent further depletion of the gene pool (Vanden Abeele, 2019).

Using the Red List criterion A3, the projected population reduction (PPR) to be met in the future (100 years because the generation length of the species is 123 years) of the *P. balsamifera* population was assessed across its distribution range. Because *P. balsamifera* is a widespread species in West and Central Africa, the PPR was estimated for each region. In Central Africa, three different PPR were thus estimated: PPRpa in protected areas, PPRpf in production forests and PPRnp in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas. First, protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). The population of the species in protected areas covering its range was kept stable in the future over 100 years, suggesting that the PPR in protected areas was 0%. Second, the evolution of the *P. balsamifera* population was simulated using an Usher matrix model to estimate the PPR of production forests (logging concessions, PPRpf). The simulations were initialised using the density (number of trees.ha-1) per diameter class (from 20 cm diameter, mature individuals) from forest management inventories of logging companies. The evolution of this initial population depended on several demographics (recruitment, mortality, and growth rate) and logging parameters (minimum cutting diameter, cutting and damage rate) that were adjusted using data of permanent tree plot monitoring. Thus, the density of *P. balsamifera* in 100 years was predicted with a logging event every 25 years, which corresponds to the average cutting cycle in Central Africa. PPRpf was then calculated as the difference between initial and final number of trees. Third, the major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Illegal logging and the habitat lost from deforestation rate have been both activities that allowed estimating the PPRnp in non-permanent domains. In West Africa, the forest areas were subject to a constant annual deforestation rate of 1.20% year-1 (Vancutsem et al., 2021). Taking this rate of deforestation as constant over the next 100 years, when it is expected to decline, is a reasonable precautionary measure. We thus had two different PPR: PPRC in Central Africa and PPRW in West Africa. The global PPR was then computed after weighting the two values by their relative forest areas. The global PPR result (20.1%) was found to be lower than 30% (for further information about this methodology, see Supplementary Material).

- **Population Information**

Current Population Trend: Decreasing

Extreme fluctuations? (in # of mature individuals)	Justification
No	-

Severely fragmented?	Justification
No	-

Continuing decline in mature individuals?	Qualifier	Justification

Continuing decline % in mature individuals within 3 generations or 10 years, whichever is longer (up to max. of 100 years in the future)	Qualifier	Justification

Extreme fluctuations in the number of subpopulations	Justification
No	-

Continuing decline in number of subpopulations	Qualifier	Justification
No	-	-

All individuals in one subpopulation: No

Number of Subpopulations	Justification	Subpopulation Details	Subpopulation description	Number of mature individuals	Subpopulation trend	Qualifier	Location type	Number of Subpopulations	Location bounding box	Location coordinates	Notes
4	Genetic analyses using 16 nuclear microsatellites for 154 individuals sampled across the distribution range of the species (Vanden Abeele, 2019)	-	-	-	-	-	-	-	-	-	-

- Population Reduction - Past

Percent Change in past	Reduction or Increase	Qualifier	Justification

Basis?

Reversible?

Understood?

Ceased?

- **Population Reduction - Future**

Percent Change in future	Reduction or Increase	Qualifier	Justification
20.1%	Reduction	Projected	Using the Red List criterion A3, the projected population reduction (PPR) to be met in the future (100 years because the generation length of the species is 123 years) of the *P. balsamifera* population was assessed across its distribution range. Because *P. balsamifera* is a widespread species in West and Central Africa, the PPR was estimated for each region. In Central Africa, three different PPR were thus estimated: PPRpa in protected areas, PPRpf in production forests and PPRnp in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas. First, protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). The population of the species in protected areas covering its range was kept stable in the future over 100 years, suggesting that the PPR in protected areas was 0%. Second, the evolution of the *P. balsamifera* population was simulated using an Usher matrix model to estimate the PPR of production forests (logging concessions, PPRpf). The simulations were initialised using the density (number of trees.ha-1) per diameter class (from 20 cm diameter, mature individuals) from forest management inventories of logging companies. The evolution of this initial population depended on several demographics (recruitment, mortality, and growth rate) and logging parameters (minimum cutting diameter, cutting and damage rate) that were adjusted using data of permanent tree plot monitoring. Thus, the density of *P. balsamifera*

	in 100 years was predicted with a logging event every 25 years, which corresponds to the average cutting cycle in Central Africa. PPRpf was then calculated as the difference between initial and final number of trees. Third, the major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Illegal logging and the habitat lost from deforestation rate have been both activities that allowed estimating the PPRnp in non-permanent domains. In West Africa, the forest areas were subject to a constant annual deforestation rate of 1.20% year-1 (Vancutsem et al., 2021). Taking this rate of deforestation as constant over the next 100 years, when it is expected to decline, is a reasonable precautionary measure. We thus had two different PPR: PPRC in Central Africa and PPRW in West Africa. The global PPR was then computed after weighting the two values by their relative forest areas. The global PPR result was found to be 20.1%, lower than 30%. For further information about this methodology, see Supplementary Material.

Basis?
b) an index of abundance appropriate for the taxon, d) actual or potential levels of exploitation

- **Population Reduction - Ongoing**

Both: Percent Change over any 10 year or 3 generation period, whichever is longer, and must include both past and future, future can't go beyond 100 years	Reduction or Increase	Number of years for this period	Qualifier	Justification

Basis?

Reversible?

Understood?

Ceased?

● Habitats and Ecology

Prioria balsamifera is a large tree reaching 50 m in height and 1.5 m in diameter, long-lived, nonpioneer light demanding and usually non-gregarious species. Mostly found in deep, sandy, ferruginous soils (Cobbinah and Obeng, 2011). Its regeneration is abundant in recently opened areas of forest gap type, not far from the mother trees (Vanden Abeele, 2019).

Prioria balsamifera bears hermaphrodite flowers. The flowering individuals first lose their leaves (Doucet, 2003). In DRC, *P. balsamifera* defoliates annually with a peak observed at the end of the dry season and the beginning of the rainy season. The new leaves unfolded shortly after shedding of the old leaves (Angoboy Ilondea et al., 2021). In Gabon, two flowering periods can be observed, the first during the short rainy season, the second during the short dry season in Gabon (Doucet, 2003). It is a pterochorous species and seeds are wind dispersed (Doucet, 2003). Fructification is generally observed at the end of the long dry season in Gabon (Doucet, 2003). In Gabon, fruits are observed from January to March, but it is also possible to find fruits later in the year from July to September (Daïnou et al., 2021). In Gabon, the first fruits are observed from 75 cm (for 70% of fruiting trees) (Doucet, 2003) and 35 cm in Luki, Democratic Republic of Congo (for 50% of fruiting trees) (Meunier et al., 2015). The minimum fertility diameter was estimate at 55 cm (see Supplementary Material).

● IUCN Habitats Classification Scheme

Habitat	Season	Suitability	Major Importance?
1.6. Forest -> Forest - Subtropical/Tropical Moist Lowland	Resident	Suitable	Yes

● Continuing Decline in Habitat

Continuing decline in area, extent and/or quality of habitat?	Qualifier	Justification
Yes	Observed	The annual deforestation rate of 0.35% in Central Africa and 1.20% in West Africa (Vancutsem et al., 2021).

● Life History

Generation Length	Justification	Data Quality
123	Minimum estimate of generation length for the species from the average growth rate, and the mean diameter of mature individuals (see Supplementary Material)	good

Age at maturity: female or unspecified
84 Years

Age at Maturity: Male
84 Years

Size at Maturity (in cms): Female
55

Size at Maturity (in cms): Male
55

Reproductive Periodicity
Annual

Annual Rate of Population Increase

Natural Mortality
1% (Ligot et al. 2022)

- **Systems**

System: Terrestrial

- **Plant / Fungi Specific**

Wild relative of a crop? No

Plant and Fungal Growth Forms

Tree - large

Use and Trade

General Use and Trade Information

Prioria balsamifera is in the top 50th of the most exploited forest species in tropical Africa (Eba'a Atyi et al., 2022). *P. balsamifera* is mainly used in the veneer industry. Its wood light yellowish brown to light reddish brown is used for (i) structures and panelling, (ii) exterior joinery (building facades), (iii) joinery and interior fittings, (iv) shipbuilding, etc. On the international market, Nigeria exported an average of 22,000 m³/year of logs and 11,000 m³/year of sawnwood between 1961 and 1970. In Gabon, log exports increased from 20,500 m³/year to 56,000 m³/year between 1991 and 2001. The Republic of Congo exported 13,000 m³ of logs in 2004 and Cameroon exported respectively 5,600 m³ of logs in 1999, 12,300 m³ in 2000 and 3,000 m³ in 2001. In 2010, Democratic Republic of the Congo exported 6 236 m³ (ATIBT, 2010). In 2016, Central Africa, produce 13 575 m³ (FRMi, 2018) and 15 267 m³ of log in 2018 (Eba'a Atyi et al., 2022), reflecting a slowly growing interest in the species.
At a local level, *P. balsamifera* is used to build dugout canoes. The resin secreted by the sapwood has been used for lighting, although it would burn and give off smoke, and for caulking dugouts.

Subsistence:	Rationale:	Local Commercial:	Further detail including information on economic value if available:
Yes	-	Yes	-

National Commercial Value: Yes

International Commercial Value: Yes

Is there harvest from captive/cultivated sources of this species? Yes

Trend in level of total offtake from wild sources: Stable

Trend in level of total offtake from domesticated sources: Unknown

Non- Consumptive Use

Non-consumptive use of the species? true

Threats

The main threats in the non-permanent domain across the species' distribution range, are mainly related to habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging and the abusive harvesting of plant parts requested as non-wood forest products (Bradshaw et al., 2009). In Central Africa, illegal logging accounts for nearly 46% of total log production (FRMi, 2018). This production generally comes from unallocated forest areas (non-permanent forest domain).

Prioria balsamifera is exploited in Central Africa. No study considers logging as a direct driver of deforestation because of the low logging densities (1-2 stems per hectare). However, studies on the impact of logging on the species and habitats are needed.

- **Threats Classification Scheme**

No past, ongoing, or future threats exist to this species. false

Threat	Timing	Scope	Severity	Impact Score
1.1. Residential & commercial development -> Housing & urban areas	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4
2.1.1. Agriculture & aquaculture -> Annual & perennial non-timber crops -> Shifting agriculture	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
2.2.2. Agriculture & aquaculture -> Wood & pulp plantations -> Agro-industry plantations	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
2.3.2. Agriculture & aquaculture -> Livestock farming & ranching -> Small-holder grazing, ranching or farming	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4
3.2. Energy production & mining -> Mining & quarrying	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
4.1. Transportation & service corridors -> Roads & railroads	Past, Likely to Return	Minority (<50%)	Negligible declines	Past Impact
5.3.1. Biological resource use -> Logging & wood harvesting -> Intentional use: (subsistence/small scale) [harvest]	Ongoing	Minority (<50%)	Rapid Declines	Medium Impact: 6
5.3.2. Biological resource use -> Logging & wood harvesting -> Intentional use: (large scale) [harvest]	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4
7.1.3. Natural system modifications -> Fire & fire suppression -> Trend Unknown/Unrecorded	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4

- **Conservation**

Prioria balsamifera does not occur ex situ collections (BGCI, 2022), but may in many protected areas considering its distribution range. In certified forest concessions where the species is exploited, permanent forest plots are usually installed. These plots provide important data for (i) quantifying population dynamics processes at the stand level: mortality, growth and recruitment; (ii) phenological studies to determine the regular fruiting diameter (RFD). These plots are managed in collaboration with forest concessions grouped within the DYNAFAC collective (see here for more information https://www.dynafac.org/fr/p/130/installation-de-dispositifs-de-suivi-de-la-dynamique-forestiere). Compilation of these data provide important additional information for targeted silvicultural measures for the sustainable management of this species. First summaries have provided information on important parameters such as: mortality, growth, etc. (DYNAFAC, 2022; Ligot et al., 2022). Based on almost 40 years of monitoring forest dynamics in Central Africa, the DYNAFAC collective recommends a MCD of 80 cm in Central Africa to maintain optimal gene flow and optimal regeneration (DYNAFAC, 2022). DYNAFAC also recommends the preservation of additional seed trees or the implementation of regeneration support techniques to ensure the long-term maintenance of populations. *P. balsamifera* is also monitored in nurseries and planted in various forest concessions.

Logging in Central Africa is subject to strict legislation, species can only be harvested above a certain diameter and measures must be taken to ensure the renewal of the resource (Fargeot et al., 2004). Indeed, management plans for tropical rainforests require the determination of a minimum cutting diameter (MCD) to ensure a minimum renewal rate at the end of a rotation period (duration between two cuts on the same cutting base), the minimum reconstitution rate (40-50% depending on the country) as well as the rotation duration, being imposed by forestry legislation (Durrieu de Madron and Forni, 1997).

In addition, it will also be necessary to :

- Ensure the implementation of the recommendations of the Dynafac collective, including the establishment of a system for monitoring the populations of commercial species in the different forest types defined in a consensual manner;
- Set up monitoring and support systems for the regeneration of commercial species, prioritising species with regeneration deficits;
- Set up programmes to guarantee the phenotypic quality of commercial species populations: seed banks, seed stands, plus trees, seed orchards, conservation plantations;
- Consider threatened species in the delimitation of conservation series and in the identification of High Conservation Values;
- Update conservation statuses on a five-yearly basis, in particular by setting up a system of "green statuses";
- Define red lists adapted to regional or national contexts;
- Evaluate the status of cryptic species or species close to commercial species evaluated during this workshop.

- **Conservation Actions In- Place**

Action Recovery Plan	Note
Yes	Reforestation within forest concessions and others in forest gaps, old parks, quarries, and large logging roads.

Systematic monitoring scheme	Note
Yes	The species is monitored in permanent plots installed within forestry companies in Central Africa (see here for more information https://www.dynafac.org/fr)

Occur in at least one PA	Note
Yes	The species may appear in at least 10 protected areas considering it distribution range

Percentage of population protected by PAs (0-100)	Note
1-10	Considering protected area across species distribution range

Area based regional management plan	Note
Unknown	-

Invasive species control or prevention	Note
No	-

Harvest management plan	Note
Yes	In certified forest concessions, the species is exploited according to a management plan.

Subject to ex-situ conservation	Note
Yes	-

Included in international legislation	Note
No	-

Subject to any international management/trade controls	Note

- Important Conservation Actions Needed

Conservation Actions	Note

3.1.1. Species management -> Species management -> Harvest management	-
3.1.2. Species management -> Species management -> Trade management	-
3.4.2. Species management -> Ex-situ conservation -> Genome resource bank	-

- **Research Needed**

Research	Note
1.1. Research -> Taxonomy	-
1.2. Research -> Population size, distribution & trends	-
3.1. Monitoring -> Population trends	-
3.2. Monitoring -> Harvest level trends	-
3.3. Monitoring -> Trade trends	-

- **Ecosystem Services**
- **Ecosystem Services Provided by the Species**

	Importance:	Geographic range of benefit:
1. Water Quality	2 - Important	Global
3. Flood Control	2 - Important	Global
4. Climate Regulation	2 - Important	Global
5. Landscape	2 - Important	Global
6. Air Quality	2 - Important	Global
7. Nutrient Cycling	2 - Important	Global
8. Habitat Maintenance	2 - Important	Global
9. Provision of Critical Habitat	2 - Important	Global

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Prioria balsamifera - (Vermoesen) Breteler

IUCN status using criterion A3

We adopted the criterion A3 to assess the projected population reduction (PPR) to be met in the future (up to a maximum of 100 years) of *Prioria balsamifera* (Agba). To quantify the projected population reduction, simulations must be performed on mature individuals and three generations with maximum 100 years according to **criterion A3**. We estimated mature individuals and generation length, as recommended by the IUCN guidelines.

A **mature individual** is an individual that can reproduce, able to bear flowers or seeds (fertile in the plant kingdom). To quantify the mature individuals for each species, we used phenological data from a combined dataset of 92 trees in Gabon (Doucet, 2003). Using the relation between the percentage of fertile trees and tree diameter, the **diameter of a mature individual** was obtained by fitting 50% of fertile trees to produce the flower or fruit. The minimum diameter of mature individuals for this species was **55 cm** (Doucet, 2003).

The **generation length** was the report between the mean diameter of mature individuals considering population structure and the mean increment. Given that the minimum diameter of mature individuals was 55 cm, we weighted the total number of trees by their diameter from 55 cm to 125 cm (Figure 1) to compute the number of mature individuals. The mean of mature individuals was **81 cm**. The **mean increment** of the species was **0.656 cm**, obtained from 91 observations of unpublished data in Gabon. Thus, the **generation length** was 81 cm / 0.656 cm = **123 years**. The age at maturity (**84 years**) has been estimated as the report between the **minimum diameter of mature individuals** (**55 cm**) and the **mean annual increment (0.656 cm)**.

Estimation of the projected population reduction (PPR)

We adopted the criterion A3 to assess the projected population reduction (PPR) to be met in the future (up to a maximum of 100 years). *Prioria balsamifera*, is found in Guineo–Congolian rainforest species, widely distributed mainly from Guinea-Bissau to Democratic Republic of Congo. The geographic range of species was in two regions (Central Africa and West Africa) characteristic of two biogeographical regions across the tropical African forests (Fayolle et al., 2014). According to each region, different data (deforestation annual rate, growth, mortality, recruitment, forest inventory, etc.) have been used with logging data in Central Africa. Thus, the PPR was estimated for each region and the global PPR was then computed after weighting the two values by their relative forest areas.

PPR in Central Africa

In this region, forest management follows three different modalities: protected areas, production forests (logging concessions) and non-permanent forest domain. Based on occurrences, the natural range of this species includes countries in Central Africa (Figure 1). The total natural area is estimated at 177 220 442.1 ha. Within this area, there are 56 156 124 ha (31.7%) for production forests, 16 120 379.1 ha (9.1%) for protected areas, and 104 943 939.1 ha (59.2%) for the non-permanent domain.

Three different PPR were thus estimated: PPR_{pa} in protected areas, PPR_{pf} in production forests and PPR_{np} in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas and then added to estimate the PPR_C in Central Africa.

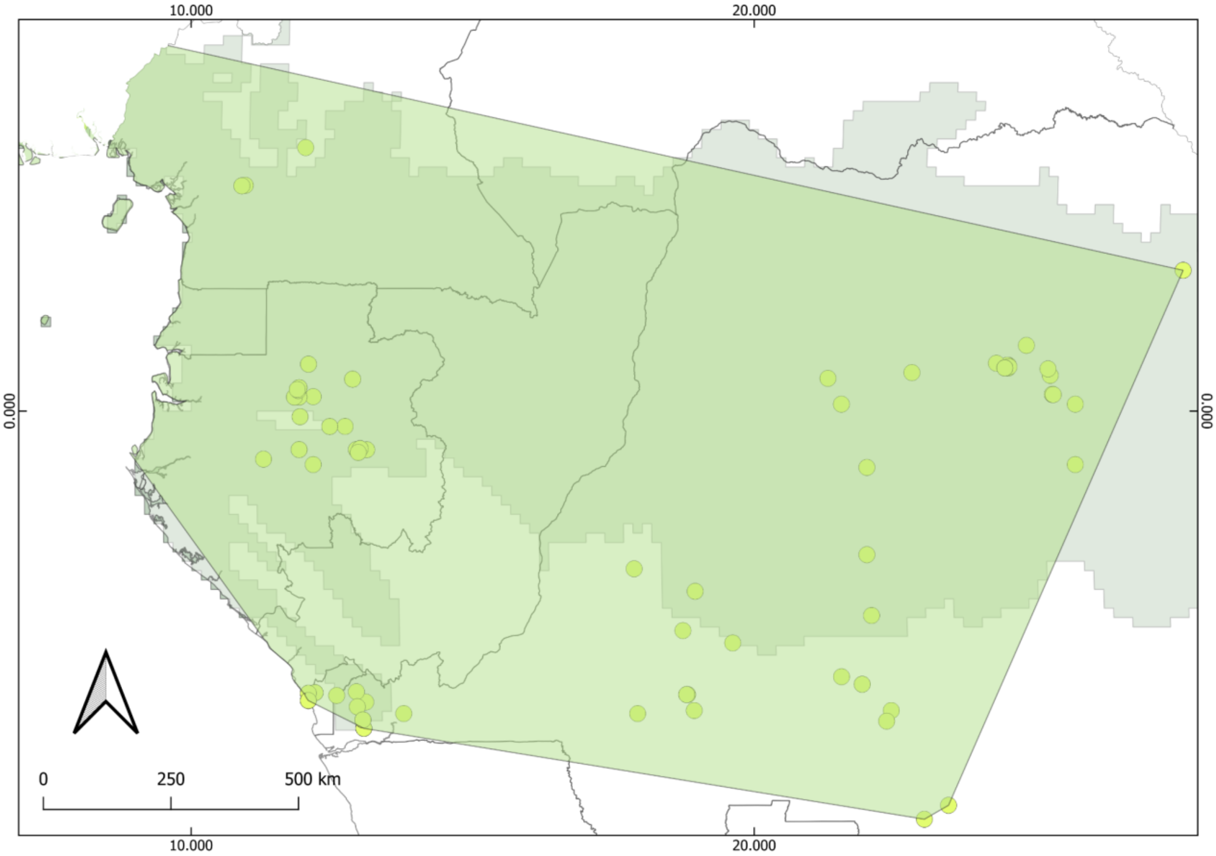

Figure 1. The range of *Prioria balsamifera* in Central Africa estimated from RAINBIO and CJB data, validated in December 2022 during a workshop with a group of experts in Gabon.

PPR in protected areas

Central Africa countries have allocated a higher proportion of their land to conservation than any other tropical regions, with relatively higher conservation success (Laurance et al., 2012). Indeed, most protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). They are currently representing a large part of forest and tree species conservation in Central Africa. Thus, the population of each species in protected areas (according to FRMI, 2018) covering its range was kept stable in the future over 100 years. **In these conditions, it was hypothesized that the PPR in protected areas for each species is 0%, suggesting no population reduction in the present and future.**

PPR in production forests

To quantify the evolution of the population of each timber species, matrix population models are widely used to study population dynamics (Picard & Liang, 2014). The population of this species was described at time t by a vector N_t corresponding to the density (number of trees ha^{-1}) in each diameter class (from 20 cm diameter to more than 120 cm). The density per diameter class was estimated using data from forest inventories that were carried out in 54 forest management units (FMU) of different logging companies in five countries (Cameroon, Central African Republic, Democratic Republic of the Congo, Gabon, and Republic of the Congo). Most logging companies followed a standardized inventory protocol (Réjou-Méchain et al., 2011). These forest inventory data covered about 12 million ha (Table 1), that are representative of 22% of Central Africa's production forests of this species. The number of trees sampled in Central Africa was 3 410 977 with a density of 0.28 tree ha^{-1}. Large-scale commercial inventories have already been found useful in the identification of large-scale patterns in Central Africa (Réjou-Méchain et al., 2011). Using large-scale data from commercial forest inventories, Réjou-Méchain et al. (2021) jointly model the distribution in abundance of the most dominant tree species and produce continuous maps of the floristic and functional composition of central African forests.

Table 1. Forest management units (FMU) sampled in Central Africa (Cameroon, CAR: Central African Republic, DRC: Democratic Republic of the Congo, EG: Equatorial Guinea, Gabon and RCongo: Republic of the Congo).

	Sampling	
Country	FMU	Area (ha)
Cameroon	4	547 560
CAR	4	1 560 625
DRC	14	3 951 528
EG	-	-
Gabon	31	5 899 710
RCongo	1	352 572
Total	54	12 311 995

The Usher matrix model was used to simulate the evolution of the recovery rate of all populations and the exploitable stock of each species after logging in Central Africa. According to the Usher assumption, between t and t+1, an individual can either stay alive in the same class, stay alive and move up to the next class, or die; it cannot move up by more than one class or move backwards, i.e., the individual is free from diameter shrinkage (Picard et al., 2012). The Usher matrix model (U) considers three parameters (mortality, recruitment and growth rate that are constant in time) to estimate the transition probabilities:

$$U = \begin{pmatrix} q_1 + g_1 & g_2 & \cdots & \cdots & g_I \\ p_1 & q_2 & 0 & \cdots & 0 \\ 0 & \ddots & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & p_{I-1} & q_I \end{pmatrix}$$

where q_i is the probability for an individual to stay alive in class i between two consecutive time steps, p_i is the upgrowth transition rate (the probability for an individual to grow up from class i to class i +1), and g_i is the recruitment rate (Picard & Liang, 2014).

Tree mortality, recruitment and growth are three central processes for predicting the dynamics of tropical rainforests and estimating these three processes requires long-term monitoring in difficult field conditions (Picard & Gourlet-Fleury, 2008). These processes determine the evolution of the species population in the forest stand. The natural mortality is defined as the number of standing dead trees, and few studies have reported estimates of mortality rates in Central Africa. Data about tree mortality are still scarce and it does not allow for precisely modeling the mortality rate for each species and size class. Given the current state of knowledge, it appears reasonable to use a fixed mortality rate of 1% for all species and size classes, in agreement with the results of Ligot et al. (2022) on 21,180 trees belonging to 42 timber species of Central Africa annually monitored from one to seven years.

The recruitment integrates fruiting and seed dispersal from mother trees, and the survival of plant juveniles until they reach a size threshold where they are included in the stand. The recruitment term in the model is the average annual input of new individuals into the first size class from 20 cm. The recruitment events, like mortality events, are infrequent and thus difficult to model (Karsenty & Gourlet-Fleury, 2006). The population structure showed a single-mode curve with a good representation of the small stems suggesting a good regeneration (Figure 2). To model the recruitment, we used the hypothesis defined as the recruitment rate that would maintain a constant number of trees in the first diameter class. Claeys et al. (2019) projected the future forest dynamics up to the end of the century and they showed that projected mortality and recruitment rates in 2099 could not differ from the ones observed today. Thus, the hypothesis on the recruitment and the mortality rate is used in the future (up to 100 years) as they do today.

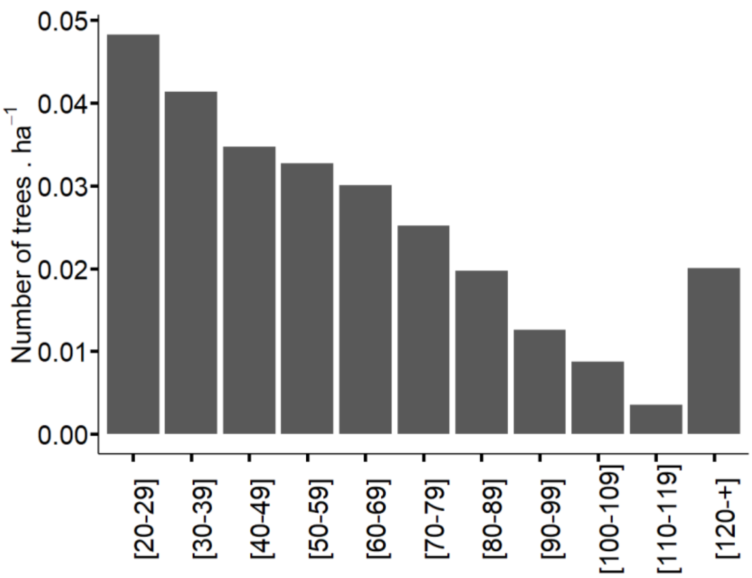

Figure 2. Population structure of *Prioria balsamifera* (Agba) defined using the number of trees per ha and per diameter class (from 20 cm of 54 logging concessions covering an area of 12 311 995 ha in Central Africa).

Since the mid-1900s, periodic tree monitoring and tree ring analyses have been carried out to study variability in tree growth across species in Central Africa (Durrieu de Madron, Nasi, et al., 2000; Ligot et al., 2019, 2022). We fitted growth models for each species using data from logged and unlogged areas of permanent tree plot monitoring from the DYNAFAC[26] network covering the five Central African countries. From the combined dataset, we identified 91 trees in Gabon. Minimum and maximum sampled diameters ranged from 11 to 121 cm. The monitoring period ranged from 2000 to 2008. The second-degree polynomial model was fitted for this species. The estimated coefficient from the second-degree polynomial model has been used in the simulation to estimate the diameter growth (Table 2).

Table 2. Estimated coefficients (a, b and c) of growth models between the increment (ac in cm year^{-1}) and the initial diameter (D in cm). The sample including the number of trees (n) and the number of sites (site) are also given. * significant (p-value < 0.05) and ^{ns} non-significant (p-value > 0.050)

species	n	site	model	a	b	c
Agba	91	1	$ac \sim D + D^2$	0.094^{ns}	0.025*	-0.0002*

The transition probabilities of three parameters (mortality, growth, and recruitment rate) allowed making the harvested matrix. The logging operations have been modeled using the logging parameters (minimum cutting diameter, cutting and damage rate). The minimum cutting diameters were obtained from decrees of application of the forestry administrations (MCD_A) at the country level and the one used in the management plan (MCD_M, with $MCD_M \geq MCD_A$) at the logging company level. At the Central Africa level, we weighted the MCD_A and MCD_M values to the occupied area (**MCD_A = MCD_M = 80 cm**). The cutting rate (CA), which defines the proportion of harvested trees (trees with a diameter greater than MCD_A or MCD_M), was given by logging companies, and it was also weighted at the Central Africa level with a value of 71%. Given the current state of knowledge, it appears reasonable to use a fixed damage rate caused by logging of 7% of the initial population that disappears (Durrieu de Madron, Fontez, et al., 2000). The average cutting cycle (i.e. the period between two successive logging operations) is 28 years (FRMI, 2018), but we used 25 years to simplify computation of four simulations reaching 100 years (25, 50, 75 and 100 years), as requested by IUCN criterion A.

The Figure 3 shows the PPR in production forests for the *Prioria balsamifera*. The reduction in the population of each species was then calculated as the difference between the initial numbers of mature individuals and the predicted numbers of mature individuals (55 cm) predicted after 100 years. The PPR in production forest was from **– 39.37 % over 100 years.**

[26] https://www.dynafac.org/en

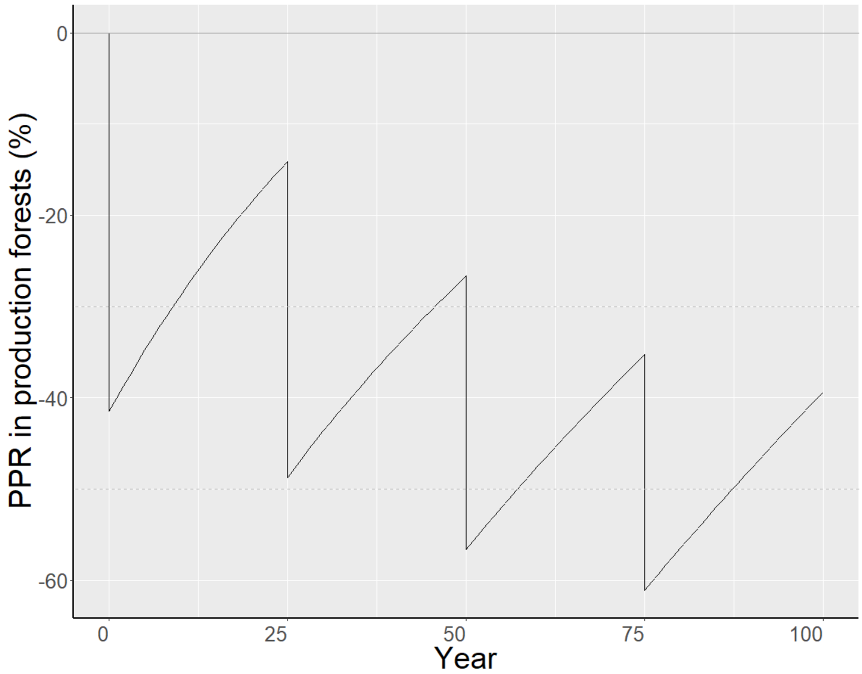

Figure 2. Simulations showing the projected population reduction (PPR) from diameter of mature individuals (55 cm) in production forests for the *Prioria balsamifera* for constant recruitment over 100 years.

PPR in the non-permanent forest domain

The major threats in the non-permanent domain are habitat loss due to the destruction of natural environments because of population growth and urbanization, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Based on the large range of this species in Central Africa, the harvested volume from illegal logging and legal logging are 46% and 54%, respectively (FRMI 2018). In this condition, it was hypothesized that there is 54% of PPR from production forests and 46% of PPR from illegal logging in 100% PPR due to forest logging. Given that the PPR of production forests associated with its forest area was known, we deduced the PPR and forest area of illegal logging from those of the production forests. As a result, 47 836 698.2 ha were affected for the illegal logging for this species. The non-permanent domain area (104 943 939.1 ha) was considered as the area which was related to today's deforestation rate of 0.35% year^{-1} in Central Africa (Vancutsem et al., 2021). This is a conservative value since it will probably decrease in the future (Swamy et al., 2018).

The PPR in Central Africa by considering the PPR in production forest, protected area and non-permanent domain was **– 21.7% over 100 years.**

PPR in West Africa

In this region, forests are generally not managed in concessions, and the large part of the rainforest has been transformed in cultivated areas (Nix, 2019). Given the high degree of anthropization in this area, the main threats are the habitat loss due to the destruction of natural environments and illegal logging, and the trees are frequently felled in fields. Applying the deforestation rate related to agricultural production can be considered as a proxy for tree removal. Thus, the forest areas in West Africa (15 600 000 ha) were subject to a constant annual deforestation rate of 1.20% $year^{-1}$ (Vancutsem et al., 2021). Taking this rate of deforestation as constant over the next 100 years, when it is expected to decline, is a reasonable precautionary measure incorporating illegal logging.

PPR global

We thus had two different PPR: PPR_C in Central Africa and PPR_W in West Africa. The global PPR was then computed after weighting the two values by their relative forest areas:

$$PPR = \frac{(S_C \times PPR_C) + (S_W \times PPR_W)}{S_C + S_W}$$

where S_C and S_W are forest areas in Central and West Africa, respectively.

The criterion A3 based on (c) a decline in area of occupancy (AOO), the extent of occurrence (EOO), and/or habitat quality; and (d) potential levels of exploitation, has been computed as follows: (i) 30%≤PPR<50%, the species is considered as Vulnerable (VU); (ii) 50%≤PPR <80%, the species is considered as Endangered (EN), and PPR ≥ 80%, the species is considered as Critically Endangered (CR).

The PPR global in the distribution range of the *Prioria balsamifera* was **– 20.1 % over 100 years.** This PPR is < 30%, suggesting that this species is not threatened in its geographic area.

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10.17 Annexe 17. *Pterocarpus soyauxii* - Taub.

Draft

Pterocarpus soyauxii - Taub.

PLANTAE - TRACHEOPHYTA - MAGNOLIOPSIDA - FABALES - FABACEAE - Pterocarpus - soyauxii

Common Names: Padouk d' Afrique (French), African Paduk (English)

Synonyms: *Pterocarpus casteelsii* De Wild.
Pterocarpus casteelsii var. *ealaensis* Hauman.

Red List Status
LC – Least Concern, A3cd (IUCN version 3.1)

- **Red List Assessment**

- **Assessment Information**

Date of Assessment: 2022-09-01
Assessor(s): Monthe, F., Loubota, G., Ligot, G., Texier, N., Stévart, T. & Doucet, JL.
Reviewer(s):
Institution(s):
Acknowledgements: This evaluation was performed by the project «Actualisation du statut de vulnérabilité des espèces ligneuses exploitées en Afrique centrale » grant number C224, funded by PPECF (Programme de Promotion de l'Exploitation Certifiée des Forêts) and the Gembloux Agro-Bio Tech faculty of the University of Liège through the AFRITIMB project subsidised by the FRFS-WISD (grant number PDR-WISD-07). We thank the forestry companies active in Central Africa and the consultancy firms (FRMi, Sylvafrica, and TEREA) for providing the management inventory data, the non-profit organisation Nature+ asbl, and the DYNAFAC collective for providing demographic data (mortality and growth). We express our gratitude to ATIBT (Association Technique Internationale des Bois Tropicaux) and ANPN (Agence Nationale des Parcs Nationaux du Gabon) for supporting this project «Actualisation du statut de vulnérabilité des espèces ligneuses exploitées en Afrique centrale ». We are also grateful to DYNAFAC collective through the P3FAC project funded by FFEM (Fonds Français pour l'Environnement Mondial) (grant number CZZ 2101.01R) and to the Fondation Franklinia for supporting this evaluation.
Regions: Global

- **Identification Description**

Pterocarpus soyauxii is a large tree reaching 50 m in height and 1.5 m in diameter, with light foliage, marked at the base by thin, straight buttresses that sometimes rise more than 5 m from the ground. Its bark is greyish-brown to reddish-brown, with long rectangular scales. Its cream to pinkish-brown slice secretes an abundant red resin that darkens as it dries and gives off a distinctive odour. The leaves are imparipinnate and have 11-15 alternate leaflets, acuminate and mucronate at the top: the main vein, which is prominent on the underside, extends beyond the tip of the leaf blade. The other veins are hardly visible. Its large inflorescences (10-35 cm long) are composed of yellow flowers. Its fruits are winged, flattened pods of ± rounded shape (6-8 cm diameter), marked with fine veins, first hairy and green when young, turning yellow and then grey at maturity. Surrounded by a broad papery wing, they contain a seed in their centre. The seed is kidney-shaped, ± 1.5 cm long, red becoming brown.

Three related species of the genus *Pterocarpus* are: the white padouk *P. mildbraedii* Harms with larger fruits reaching 12 cm and larger leaflets reaching 14 x 7 cm (compared to 7 x 3 cm for padouk), *P. tessmannii Harms* with elongated fruits, and *P. osun* Craib, which is a stocky tree with a shorter bole. *P. soyauxii* can also be misidentified especially when young, with the red eyoum (*Dialium bipindense* Harms) which has more irregular scales and a thinner edge.

- **Assessment Rationale**

Pterocarpus soyauxii is a widespread tall tree in African dense humid evergreen and semi-deciduous lower-guinean forest, long-lived, nonpioneer light demanding and usually non-gregarious species, which forms efficient root associations with arbuscular mycorrhizal fungi at all stages. It is distributed from south-eastern Nigeria to eastern Democratic Republic Congo, and south to northern Angola. Based on a 2 x 2 km cell size, the AOO of this species is estimated as 1 768 km^2 with a minimum of 98 locations (number of forest management units of different logging companies in Central Africa). This species is not “Vulnerable” status under criterion B2. The EOO is calculated as 1 922 341 km^2, above the upper threshold for “Vulnerable” status under criterion B1.

Commonly known as Padouk, it is among the most exploited forest species in tropical Africa, highly sought after for the quality of its wood. The minimum cutting diameter (MCD) in Central Africa varies between 60 and 80 cm is higher than the regular fruiting diameter (RFD) of 35 cm diameter at breast height (DBH), ensuring natural regeneration of the species. This MCD is consistent with the value of 60 cm recommended by DYNFAC to ensure optimal gene flow in populations (DYNAFAC, 2022). The population structure of this species showed decreasing suggesting a good regeneration, with a density of 0.88 $stems.ha^{-1}$ (dbh ≥ 20 cm) in Central Africa (see Supplementary Material). Given its stem density and the mean annual increment of 0.49 ± 0.41 cm/year in Central Africa (see Supplementary Material), we estimate the number of mature individuals over 10 000 across the distribution range, well above the threatened category under criteria C and D.

The most serious long-term threat is the conversion of the forest to agriculture and grazing, and illegal logging. However, the species is not considered severely fragmented as the 712 known occurrences represent more than 50 localities (sensu Comité des normes et des pétitions de l’UICN, 2019). Considering the species' generation length (123 years), an inference of population reduction for three generations in the past is impossible following A1 and A2 criteria. Based on simulations of the expected population reduction on its distribution range including protected areas, non - permanent forest areas and production forest (logging concessions), we estimated population reduction from 11.6% to 15.3% in the next 100 years below the threshold to be considered threatened under criterion A3. An assessment of the population reduction according to criterion A4 considering one to two generations back and one to two generations forward would likely introduce high levels of uncertainty due to the lack of data to efficiently model the reduction of population size in the past. No quantitative analysis of the probability of extinction in the wild was conducted, and therefore criterion E does not apply.

Considering (i) the population density, (ii) the good regeneration, (iii) the good matching between MCD and RFD, and (iv) the reduction of population in the future across the distribution range below the upper threshold for Vulnerable, the species is assessed as Least Concern (LC), A3cd.

• Distribution

• Geographic Range

Pterocarpus soyauxii is a lower-guinea species, widely distributed in moist evergreen and semi-deciduous forests form Nigeria to Democratic Republic of the Congo. The extent of occurrence (EOO) in native area is estimated 1 922 341 km^2 across its distribution range.

• Area of Occupancy (AOO)

Estimated area of occupancy (AOO) - in km2	Justification
1 768	The AOO has been estimated using ConR based on the 2 × 2 km cell size of 712 occurrences from CJB (Conservatoire et Jardin botaniques de Genève) and RAINBIO

Continuing decline in area of occupancy (AOO)	Qualifier	Justification
Yes	Inferred	The species has suffered from reduction in area of occupancy, due to habitat degradation and deforestation (Vancutsem et al., 2021).

• Extent of Occurrence (EOO)

Estimated extent of occurrence (EOO)- in km2	EOO estimate calculated from Minimum Convex Polygon	Justification
1 922 341	true	Calculated using ConR based on 712 known occurrences from CJB (Conservatoire et Jardin botaniques de Genève) and RAINBIO

Continuing decline in extent of occurrence (EOO)	Qualifier	Justification
Yes	Inferred	Global Habitat reduction of extent of occurrence (Vancutsem et al., 2021).

- **Locations Information**

Number of Locations	Justification
90-200	More than 98 localities. Based on the most serious plausible threat (conversion of its habitat) and illegal logging across the distribution range.

Continuing decline in number of locations	Qualifier	Justification
Yes	Inferred	The main threat remains the reduction of the forest area in West Africa.

Extreme fluctuations in the number of locations	Justification
No	Habitat degradation and deforestation are the main threats.

- **Very restricted AOO or number of locations (triggers VU D2)**

Very restricted in area of occupancy (AOO) and/or # of locations	Justification
No	-

- **Elevation / Depth / Depth Zones**

Elevation Lower Limit (in metres above sea level): 0

Elevation Upper Limit (in metres above sea level): 500

- **Map Status**

Map Status	Use map from previous assessment	How the map was created, including data sources/methods used:	Please state reason for map not available:	Data Sensitive?	Justification	Geographic range this applies to:	Date restriction imposed:
Done	-	Qgis. The dataset was created from a compilation of Rainbio and CJB	-	-	-	-	-

- **Biogeographic Realms**

Biogeographic Realm: Afrotropical

- **Occurrence**

- **Countries of Occurrence**

Country	Presence	Origin	Formerly Bred	Seasonality
Angola	Extant	Native	-	Resident
Cameroon	Extant	Native	-	Resident
Central African Republic	Extant	Native	-	Resident
Democratic Republic of Congo	Extant	Native	-	Resident
Equatorial Guinea	Extant	Native	-	Resident
Gabon	Extant	Native	-	Resident
Nigeria	Extant	Native	-	Resident

- **Population**

Pterocarpus soyauxii is a lower-guinean species, widely distributed from south-eastern Nigeria to Democratic Republic of the Congo, as well as Angola. Its average density is 0.88 stems.ha-1 (dbh ≥ 20 cm) in Central Africa (see Supplementary Material) and is among the most abundant species in Central Africa (FRMi, 2018). This density can be higher in secondary forests where its regeneration is important. Indeed, as for the vast majority of light-demanding species, population densities of *P. soyauxii* vary according to forest type.

In experimental plantations of 1.5 ha in Ivory Coast established in 1964 and 1968, the annual increase in height varied between 1.6 m and 2.7 m over a period of 15 years. The average diameter growth is estimated at 0.49 ± 0.41 cm/year in Central Africa (see Supplementary Material), some variation can be observed according to the forest type (Ligot et al., 2022; Meunier et al., 2015). Little information are available on natural mortality of this species, nevertheless, an average of 1% was observed for 42 timber species in central Africa (Ligot et al., 2022).

The legal minimum cutting diameter “MCD" varies across its distribution range (60 cm in Cameroon, Central Africa Republic and Democratic Republic of the Congo, 80 cm Republic of the Congo and Gabon). The MCD is higher than the regular fruiting diameter (RFD) of 35 cm observed in Cameroon and Gabon, gathering optimal regeneration of the species. Therefore, the DYNAFAC collective recommends the adoption of an MCD of 60 cm in Central Africa (DYNAFAC, 2022). In some concessions *P. soyauxii* is planted (Doucet et al., 2016).

Using the Red List criterion A3, the projected population reduction (PPR) to be met in the future (100 years because the generation length of the species is 123 years) of the *P. soyauxii* population was assessed across its distribution range. Because *P. soyauxii* is a widespread species in West and Central Africa, the PPR was estimated for each region.

In Central Africa, three different PPR were thus estimated: PPRpa in protected areas, PPRpf in production forests and PPRnp in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas. First, protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). The population of the species in protected areas covering its range was kept stable in the future over 100 years, suggesting that the PPR in protected areas was 0%. Second, the evolution of the *P. soyauxii* population was simulated using an Usher matrix model to estimate the PPR of production forests (logging concessions, PPRpf). The simulations were initialised using the density (number of trees.ha^{-1}) per diameter class (from 35 cm diameter, mature individuals) from forest management inventories of logging companies. The evolution of this initial population depended on several demographics (recruitment, mortality, and growth rate) and logging parameters (minimum cutting diameter, cutting and damage rate) that were adjusted using data of permanent tree plot monitoring. Thus, the density of *P. soyauxii* in 100 years was predicted with a logging event every 25 years, which corresponds to the average cutting cycle in Central Africa. PPRpf was then calculated as the difference between initial and final number of trees. Third, the major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Illegal logging and the habitat lost from deforestation rate have been both activities that allowed estimating the PPRnp in non-permanent domains.

In West Africa, the forest areas were subject to a constant annual deforestation rate of 1.20% year-1 (Vancutsem et al., 2021). Taking this rate of deforestation as constant over the next 100 years, when it is expected to decline, is a reasonable precautionary measure.

We thus had two different PPR: PPRC in Central Africa and PPRW in West Africa. The global PPR was then computed after weighting the two values by their relative forest areas. The global PPR result was found to be from 11.6% to 15.3%, lower than 30%.

- **Population Information**

Current Population Trend: Decreasing

Extreme fluctuations? (in # of mature individuals)	Justification
No	-

Severely fragmented?	Justification
No	-

Continuing decline in mature individuals?	Qualifier	Justification

Continuing decline % in mature individuals within 3 generations or 10 years, whichever is longer (up to max. of 100 years in the future)	Qualifier	Justification

Extreme fluctuations in the number of subpopulations	Justification
No	-

Continuing decline in number of subpopulations	Qualifier	Justification
No	-	-

All individuals in one subpopulation: No

Number of Subpopulations	Justification	Subpopulation Details	Subpopulation description	Number of mature individuals	Subpopulation trend	Qualifier	Location type	Number of Subpopulations	Location bounding box	Location coordinates	Notes
0		-	-	-	-	-	-	-	-	-	-

- Population Reduction - Past

Percent Change in past	Reduction or Increase	Qualifier	Justification

Basis?

Reversible?
Yes

Understood?
Yes

Ceased?
No

- Population Reduction - Future

Percent Change in future	Reduction or Increase	Qualifier	Justification
11.6%-15.3%	Reduction	Projected	Using the Red List criterion A3, the projected population reduction (PPR) to be met in the future (100 years because the generation length of the species is 123 years) of the *P. soyauxii* population was assessed across its distribution range. Because *P. soyauxii* is a widespread species in West and Central Africa, the PPR was estimated for each region. In Central Africa, three different PPR were thus estimated: PPRpa in protected areas, PPRpf in production forests and PPRnp in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas. First, protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). The population of the species in protected areas covering its range was kept stable in the future over 100 years, suggesting that the PPR in protected areas was 0%. Second, the evolution of the *P. soyauxii* population was simulated using an Usher matrix model to estimate the PPR of production forests (logging concessions, PPRpf). The simulations were initialised using the density (number of trees.ha^{-1}) per diameter class (from 35 cm diameter, mature individuals) from forest management inventories of logging companies. The evolution of this initial population depended on several demographics (recruitment, mortality, and growth rate) and logging parameters (minimum cutting diameter, cutting and damage rate) that were adjusted using data of permanent tree plot monitoring. Thus, the density of *P. soyauxii* in 100 years was predicted with a logging event every 25 years, which corresponds to the average cutting cycle in Central Africa. PPRpf was then calculated as the difference between initial and final number of trees. Third, the major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Illegal logging and the habitat lost from deforestation rate have been both activities that allowed estimating the PPRnp in non-permanent domains.

	In West Africa, the forest areas were subject to a constant annual deforestation rate of 1.20% year-1 (Vancutsem et al., 2021). Taking this rate of deforestation as constant over the next 100 years, when it is expected to decline, is a reasonable precautionary measure. We thus had two different PPR: PPRC in Central Africa and PPRW in West Africa. The global PPR was then computed after weighting the two values by their relative forest areas. The global PPR result was found to be from 11.6% to 15.3%, lower than 30%.

Basis?
b) an index of abundance appropriate for the taxon, d) actual or potential levels of exploitation

- **Population Reduction - Ongoing**

Both: Percent Change over any 10 year or 3 generation period, whichever is longer, and must include both past and future, future can't go beyond 100 years	Reduction or Increase	Number of years for this period	Qualifier	Justification

Basis?

Reversible?
Yes

Understood?
Yes

Ceased?
No

- **Habitats and Ecology**

Pterocarpus soyauxii is a large evergreen and semi-deciduous tree species reaching 55 m in height and 1.80 m in diameter. It is a long-lived, non-gregarious, nonpioneer light demanding species, which forms efficient root associations with arbuscular mycorrhizal fungi at all stages. Found in deep and well-drained soil (with average annual rainfall of 1500-1700 mm) and grows at an elevation of up to 500 m (Moumbolou, 2018). Young stems are often well represented in secondary forests at some distance from the mother tree.

Pterocarpus soyauxii bears hermaphrodite flowers. In Gabon flowers are observed between December and February, generally during the main rainy season in Gabon (Doucet, 2003; Ouédraogo et al., 2018). It is a pterochorous species bearing and flattened pods of more or less rounded mainly wind dispersed by (Doucet, 2003; Medjibe et al., 2011) and animals (Jansen, 2005). In Cameroon, Central African Republic and North Republic of Congo, fruits appear from July to October, while in Gabon they are observed between January and April (Daïnou et al., 2021; Doucet, 2003). Fruits are observed at a minimum of 35 cm diameter in Cameroon (Daïnou et al., 2021; Ouédraogo et al., 2018).

- **IUCN Habitats Classification Scheme**

Habitat	Season	Suitability	Major Importance?
1.6. Forest -> Forest - Subtropical/Tropical Moist Lowland	Resident	Suitable	Yes

- **Continuing Decline in Habitat**

Continuing decline in area, extent and/or quality of habitat?	Qualifier	Justification
Yes	Observed	Despite the annual deforestation rate of 0.35% and 1.2% in Central and West Africa respectively (Vancutsem et al., 2021).

- **Life History**

Generation Length	Justification	Data Quality
123	Minimum estimate of generation length for the species from the average growth rate, and the mean diameter of mature individuals (see Supplementary Material)	good

Age at maturity: female or unspecified
72 Years

Age at Maturity: Male
72 Years

Size at Maturity (in cms): Female
35

Size at Maturity (in cms): Male
35

Reproductive Periodicity
Annual

Annual Rate of Population Increase

Natural Mortality
1% (Ligot et al. 2022)

- **Systems**

System: Terrestrial

- **Plant / Fungi Specific**

Wild relative of a crop? No

Plant and Fungal Growth Forms
Tree - large

• Use and Trade

- **General Use and Trade Information**

Pterocarpus soyauxii is in the top ten of most exploited forest species in tropical Central (Eba'a Atyi et al., 2022).

At industrial level, it is used without treatment in marine or brackish water, but only in temperate and cold environments. Due to its characteristics, the wood is suitable for (i) hydraulic works, including in the maritime environment, and (ii) exterior carpentry, shipbuilding and for interior joinery, cabinet making and various other purposes. On national and domestic markets the species timber is more common and used for similar purposes and also to produce musical instruments such as xylophones and war and slit drums (Jansen, 2005).

Since 1997, the volume of exported timber has increased. In 2010, Cameroon, the Republic of Congo and the Democratic Republic of Congo exported 11 661, 26 441, and 2 356m³ respectively (ATIBT, 2010). In 2016, Central

Africa produced 168 767 m³ (FRMi, 2018) and 121 628 m³ of log in 2018 (Eba'a Atyi et al., 2022). On the international market, *P. soyauxii* is traded under the same name as *P tinctorius* and *P osun* (FRMi, 2018; Jansen, 2005). Following the inscription of the species *Pterocarpus tinctorius* in appendix II of CITES (14 February 2021), the ATIBT Commission of Materials and Standardisation has validated the following designations: *Pterocarpus soyauxii* Taub. and *Pterocarpus osun* Craib: **African Padouk** *Pterocarpus tinctorius* Welw. **Tinctorius** to distinguish the species (ATIBT, 2022).

At a local level, *Pterocarpus soyauxii* bears many medicinal properties and applications depending on what it is combined with and the part of the tree used. The species has further cultural uses as it is often used in weeding, circumcision, initiation, birth and widowing ceremonies (Jansen, 2005). The dye is most often extracted from dead trees and to produce this on a commercial scale trees are felled and left in the forest for 2-3 years before the heartwood is harvested.

Subsistence:	Rationale:	Local Commercial:	Further detail including information on economic value if available:
Yes	-	Yes	-

National Commercial Value: Yes
International Commercial Value: Yes
Is there harvest from captive/cultivated sources of this species? Yes
Trend in level of total offtake from wild sources: Stable
Trend in level of total offtake from domesticated sources: Unknown

- **Non- Consumptive Use**

Non-consumptive use of the species? true

- **Threats**

The main threats in the non-permanent domain across distribution range, are mainly related to habitat loss due to the destruction of natural environments as a result of population explosion and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging and the abusive harvesting of plant parts requested as non-wood forest products (Bradshaw et al., 2009). In Central Africa, illegal logging accounts for nearly 46% of total log production (FRMi, 2018). This production generally comes from unallocated forest areas (non-permanent forest domain).

However, illegal logging and local intense harvesting can locally occur. From February and May 2014 10 individuals smuggling over 1,700 tons (valued at CNY 2.2 billion [USD 341 million]) were arrest in Qingdao of *P. santalinus* mislabeled as *Dalbergia latifolia* and *Pterocarpus soyauxii*" (CITES CoP19 Prop., 2022).

Pterocarpus soyauxii is among the most exploited species in Central Africa. No study considers logging as a direct driver of deforestation because of the low logging densities (1-2 stems per hectare). However, studies on the impact of logging on the species and habitats are needed.

- **Threats Classification Scheme**

No past, ongoing, or future threats exist to this species. false

Threat	Timing	Scope	Severity	Impact Score
1.1. Residential & commercial development -> Housing & urban areas	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4
2.1.1. Agriculture & aquaculture -> Annual & perennial non-timber crops -> Shifting agriculture	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
2.2.2. Agriculture & aquaculture -> Wood & pulp plantations -> Agro-industry plantations	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
2.3.2. Agriculture & aquaculture -> Livestock farming & ranching -> Small-holder grazing, ranching or farming	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4
3.2. Energy production & mining -> Mining & quarrying	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
4.1. Transportation & service corridors -> Roads & railroads	Past, Likely to Return	Minority (<50%)	Slow, Significant Declines	Low Impact: 4
5.3.1. Biological resource use -> Logging & wood harvesting -> Intentional use: (subsistence/small scale) [harvest]	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 4
5.3.2. Biological resource use -> Logging & wood harvesting -> Intentional use: (large scale) [harvest]	Ongoing	Minority (<50%)	Slow, Significant Declines	Medium Impact: 6
7.1.3. Natural system modifications -> Fire & fire suppression -> Trend Unknown/Unrecorded	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4

- **Conservation**

Pterocarpus soyauxii is known to occur in at least 5 *ex situ* collections (BGCI, 2022), and may occur in many protected areas considering its distribution range. In certified forest concessions where the species is exploited, trails and or permanent forest plots are usually installed. These plots provide important data for (i) quantifying population dynamics processes at the stand level: mortality, growth and recruitment; (ii) phenological studies to determine the regular fruiting diameter (RFD). These plots are managed in collaboration with forest concessions grouped within the DYNAFAC collective (see here for more information https://www.dynafac.org/fr/p/130/installation-de-dispositifs-de-suivi-de-la-dynamique-forestiere). Compilation of these data of these data will provide important additional information for targeted silvicultural measures for the sustainable management of this species. First summaries have provided informations on important parameters such as: mortality, growth etc (DYNAFAC, 2022; Ligot et al., 2022). *P. soyauxii* is also monitored in nurseries and planted in various forest concessions.

Logging in Central Africa is subject to strict legislation, species can only be harvested above a certain diameter and measures must be taken to ensure the renewal of the resource (Fargeot et al., 2004). Indeed, management plans for tropical rainforests require the determination of a minimum cutting diameter (MCD) to ensure a minimum renewal rate at the end of a rotation period (duration between two cuts on the same cutting base), the minimum reconstitution rate (40-50% depending on the country) as well as the rotation duration, being imposed by forestry legislation (Durrieu de Madron and Forni, 1997).

In addition, it will also be necessary to :

- Ensure the implementation of the recommendations of the Dynafac collective, including the establishment of a system for monitoring the populations of commercial species in the different forest types defined in a consensual manner;
- Set up monitoring and support systems for the regeneration of commercial species, prioritising species with regeneration deficits;
- Set up programmes to guarantee the phenotypic quality of commercial species populations: seed banks, seed stands, plus trees, seed orchards, conservation plantations;
- Consider threatened species in the delimitation of conservation series and in the identification of High Conservation Values;
- Update conservation statuses on a five-yearly basis, in particular by setting up a system of "green statuses";
- Define red lists adapted to regional or national contexts;
- Evaluate the status of cryptic species or species close to commercial species evaluated during this workshop.

- **Conservation Actions In- Place**

Action Recovery Plan	Note
Yes	Reforestation within forest concessions and others in forest gaps, old parks, quarries, and large logging roads.

Systematic monitoring scheme	Note
Yes	The species is monitored in permanent plots installed within forestry companies in Central Africa (see here information https://www.dynafac.org/fr)

Occur in at least one PA	Note
Yes	The species may appear in at least 50 protected areas considering it distribution range

Percentage of population protected by PAs (0-100)	Note
1-10	Considering protected area across species distribution range

Area based regional management plan	Note
Unknown	-

Invasive species control or prevention	Note
No	-

Harvest management plan	Note
Yes	In legal forest concessions, the species is exploited according to a management plan.

Subject to ex-situ conservation	Note
Yes	-

Included in international legislation	Note
No	-

Subject to any international management/trade controls	Note
No	The species is the subject of the proposal CoP19 Prop. 50 “Inclusion of all African populations of *Pterocarpus* species in Appendix II of CITES with annotation #17, including already listed species *P. erinaceus* (CoP17, no annotation) and *P. tinctorius* (CoP18, annotation #6) in accordance with Article II, paragraph 2 (a) of the Convention”. https://cites.org/sites/default/files/documents/E-CoP19-Prop-50.pdf

- **Important Conservation Actions Needed**

Conservation Actions	Note
3.1.1. Species management -> Species management -> Harvest management	-
3.1.2. Species management -> Species management -> Trade management	-
3.4.2. Species management -> Ex-situ conservation -> Genome resource bank	-

- **Research Needed**

Research	Note
1.1. Research -> Taxonomy	-
1.2. Research -> Population size, distribution & trends	-
3.1. Monitoring -> Population trends	-
3.2. Monitoring -> Harvest level trends	-
3.3. Monitoring -> Trade trends	-

- **Ecosystem Services**

- **Ecosystem Services Provided by the Species**

	Importance:	Geographic range of benefit:
1. Water Quality	2 - Important	Global
3. Flood Control	2 - Important	Global
4. Climate Regulation	2 - Important	Global
5. Landscape	2 - Important	Global
6. Air Quality	2 - Important	Global
7. Nutrient Cycling	2 - Important	Global
8. Habitat Maintenance	2 - Important	Global
9. Provision of Critical Habitat	2 - Important	Global

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• SUPPLEMENTARY MATERIAL

Pterocarpus soyauxii - Taub.

• IUCN status using criterion A3

We adopted the criterion A3 to assess the projected population reduction (PPR) to be met in the future (up to a maximum of 100 years) of *Pterocarpus soyauxii*. To quantify the projected population reduction, simulations must be performed on mature individuals and three generations with maximum 100 years according to **criterion A3**. We estimated mature individuals and generation length, as recommended by the IUCN guidelines.

A **mature individual** is an individual that can reproduce, able to bear flowers or seeds (fertile in plant kingdom). To quantify the mature individuals for each species, we used phenological data of DYNAFAC network[27] from a combined dataset of 180 trees belonging to seven sites in four countries (Cameroun, Central African Republic, Gabon, and Republic of Congo). Minimum and maximum sampled diameters ranged from 10 to 103 cm (median 41 cm). The monitoring period ranged from 2004 to 2021 (Ouédraogo et al., 2018). We assumed that the monitoring period was long enough to capture at least one reproductive event per tree such that trees without observed flowering/fruiting events were considered non-reproductive (43 percent of all monitored trees were non-reproductive). We used the methodology for the size at reproduction of canopy tree species in Central Africa (Ouédraogo et al., 2018): the **diameter of a mature individual** was obtained after fitting logistic regressions and the level of 50% of the probability to produce the flower or fruit was adopted for this species. Using this approach, the diameter of a mature individual was obtained after setting the 50% probability to produce flowers or fruits. The minimum diameter of mature individuals for this species was **35 cm**.

The **generation length** was the report between the mean diameter of mature individuals considering population structure and the mean increment. Given that the minimum diameter of mature individuals was 35 cm, we weighted the total number of trees by their diameter from 35 cm to 125 cm (Figure 1) to compute the number of mature individuals. The mean of mature individuals was **60 cm**. The **mean increment** of the species was **0.487 cm**, obtained from 2001 observations from logged and unlogged forests of published data (Ligot et al., 2022) and unpublished data in Cameroon, Gabon, and Republic of Congo. Thus, the **generation length** was 60 cm / 0.487 cm = **123 years**. The age at maturity (**72 years**) has been estimated as the report between the **minimum diameter of mature individuals** (**35 cm**) and the **mean increment** (**0.487 cm**).

• Estimation of the projected population reduction (PPR)

We adopted the criterion A3 to assess the projected population reduction (PPR) to be met in the future (up to a maximum of 100 years). *Pterocarpus soyauxii* (Padouk), is found in Guineo–Congolian rainforest species, widely distributed mainly from Nigeria to Democratic Republic of the Congo. The geographic range of species was in two regions (Central Africa and West Africa) characteristic of two biogeographical regions across the tropical African

[27] https://www.dynafac.org/en

forests (Fayolle et al., 2014). According to each region, different data (deforestation annual rate, growth, mortality, recruitment, forest inventory, etc.) have been used with logging data in Central Africa. Thus, the PPR was estimated for each region and the global PPR was then computed after weighting the two values by their relative forest areas.

- **PPR in Central Africa**

In this region, forest management follows three different modalities: protected areas, production forests (logging concessions) and non-permanent forest domain. Based on occurrences, the natural range of this species includes all countries in Central Africa (Figure 1). The total natural area is estimated at 177 220 442.1 ha. Within this area, there are 56 180 311.8 ha (31.7%) for production forests, 13 639 609.2 ha (7.7%) for protected areas, and 107 400 521.1 ha (60.6%) for the non-permanent domain.
Three different PPR were thus estimated: PPR_{pa} in protected areas, PPR_{pf} in production forests and PPR_{np} in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas and then added to estimate the PPR_C in Central Africa.

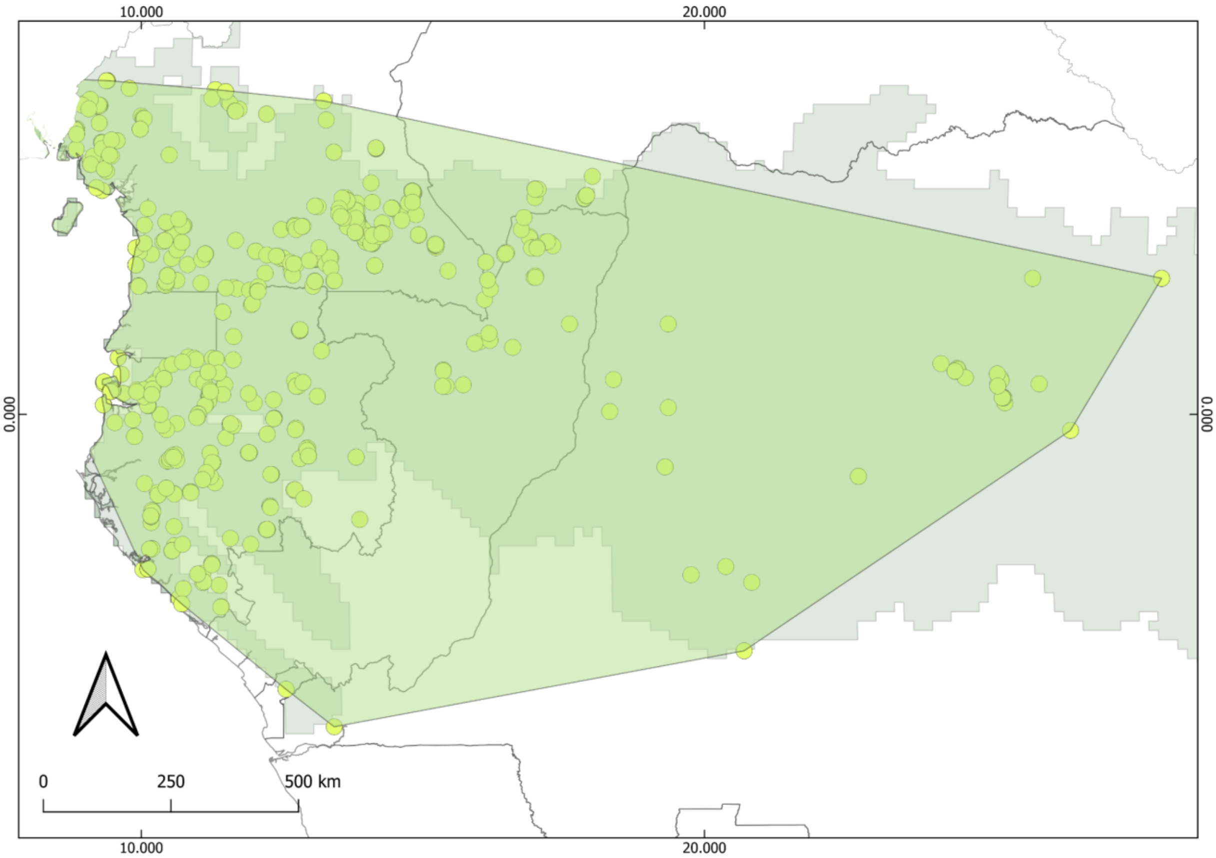

Figure 1. The range of *Pterocarpus soyauxii* in Central Africa estimated from RAINBIO and CJB data, validated in December 2022 during a workshop with a group of experts in Gabon.

- **PPR in protected areas**

Central Africa countries have allocated a higher proportion of their land to conservation than any other tropical regions, with relatively higher conservation success (Laurance et al., 2012). Indeed, most protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that

have been the main agents of forest degradation across the region (Abernethy et al., 2016). They are currently representing a large part of forest and tree species conservation in Central Africa. Thus, the population of each species in protected areas (according to FRMI, 2018) covering its range was kept stable in the future over 100 years. **In these conditions, it was hypothesized that the PPR in protected areas for each species is 0%, suggesting no population reduction in the present and future.**

- **PPR in production forests**

To quantify the evolution of the population of each timber species, matrix population models are widely used to study population dynamics (Picard & Liang, 2014). The population of this species was described at time *t* by a vector N_t corresponding to the density (number of trees ha^{-1}) in each diameter class (from 20 cm diameter to more than 120 cm). The density per diameter class was estimated using data from forest inventories that were carried out in 98 forest management units (FMU) of different logging companies in three countries (Cameroon, Gabon, and Republic of the Congo). Most logging companies followed a standardized inventory protocol (Réjou-Méchain et al., 2011). These forest inventory data covered about 22 million ha (Table 1), that are representative of 38% of Central Africa's production forests of this species. The number of trees sampled in Central Africa was 18 883 614 with a density of 0.881 tree ha^{-1}. Large-scale commercial inventories have already been found useful in the identification of large-scale patterns in Central Africa (Réjou-Méchain et al., 2011). Using large-scale data from commercial forest inventories, Réjou-Méchain et al. (2021) jointly model the distribution in the abundance of the most dominant tree species and produce continuous maps of the floristic and functional composition of central African forests.

Table 1. Forest management units (FMU) sampled in Central Africa (Cameroon, CAR: Central African Republic, DRC: Democratic Republic of the Congo, EG: Equatorial Guinea, Gabon and RCongo: Republic of the Congo).

	Sampling	
Country	FMU	Area (ha)
Cameroon	22	2 148 951.78
CAR	7	2 165 837
DRC	15	4 348 051
EG	-	-
Gabon	46	8 772 965
RCongo	8	4 005 312
Total	98	21 441 116.78

The Usher matrix model was used to simulate the evolution of the recovery rate of all population and the exploitable stock of each species after logging in Central Africa. According to the Usher assumption, between *t* and *t*+1, an individual can either stay alive in the same class, stay alive and move up to the next class, or die; it cannot move up by more than one class or move backwards, i.e., the individual is free from diameter shrinkage (Picard et al., 2012). The Usher matrix model (U) considers three parameters (mortality, recruitment and growth rate that are constant in time) to estimate the transition probabilities:

$$U = \begin{pmatrix} q_1 + g_1 & g_2 & \cdots & \cdots & g_I \\ p_1 & q_2 & 0 & \cdots & 0 \\ 0 & \ddots & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & p_{I-1} & q_I \end{pmatrix}$$

where q_i is the probability for an individual to stay alive in class i between two consecutive time steps, p_i is the upgrowth transition rate (the probability for an individual to grow up from class i to class i +1), and g_i is the recruitment rate (Picard & Liang, 2014).

Tree mortality, recruitment and growth are three central processes for predicting the dynamics of tropical rainforests and estimating these three processes requires long-term monitoring in difficult field conditions (Picard & Gourlet-Fleury, 2008). These processes determine the evolution of the species population in the forest stand. The natural mortality is defined as the number of standing dead trees, and few studies have reported estimates of mortality rates in Central Africa. Data about tree mortality are still scarce and it does not allow to precisely model the mortality rate for each species and size class. Given the current state of knowledge, it appears reasonable to use a fixed mortality rate of 1% for all species and size classes, in agreement with the results of Ligot et al. (2022) on 21,180 trees belonging to 42 timber species of Central Africa annually monitored from one to seven years.

The recruitment integrates fruiting and seed dispersal from mother trees, and the survival of plant juveniles until they reach a size threshold where they are included in the stand. The recruitment term in the model is the average annual input of new individuals into the first size class from 20 cm. The recruitment events, like mortality events, are infrequent and thus difficult to model (Karsenty & Gourlet-Fleury, 2006). The population structure showed a curve in "decreasing exponential" suggesting a good regeneration (Figure 2). To model the recruitment, we used the hypothesis defined as the recruitment rate that would maintain a constant number of trees in the first diameter class. Claeys et al. (2019) projected the future forest dynamics up to the end of the century and they showed that projected mortality and recruitment rates in 2099 could not differ from the ones observed today. Thus, the hypothesis on the recruitment and the mortality rate is used in the future (up to 100 years) as they do today.

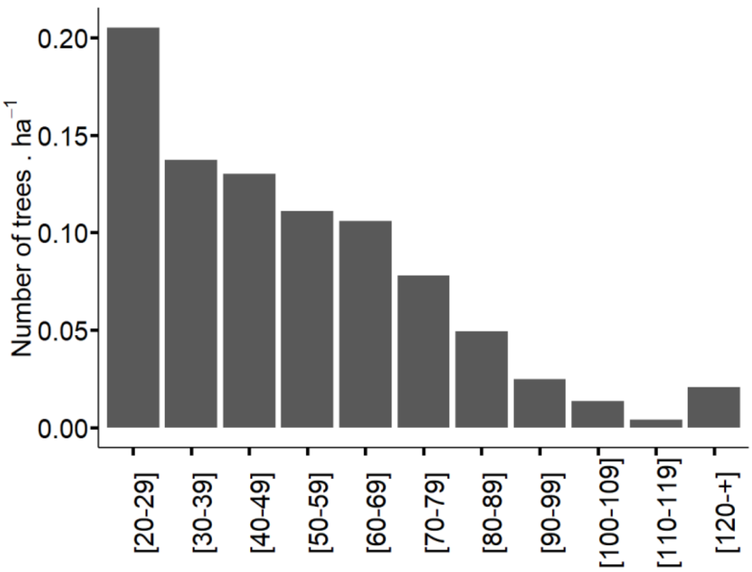

Figure 2. Population structure of *Pterocarpus soyauxii* (Padouk) defined using the number of trees per ha and per diameter class (from 20 cm of 98 logging concessions covering an area of 21 441 116.78 ha in Central Africa).

Since the mid-1900s, periodic tree monitoring and tree ring analyses have been carried out to study variability in tree growth across species in Central Africa (Durrieu de Madron, Nasi, et al., 2000; Ligot et al., 2019, 2022). We fitted growth models for each species using data from logged and unlogged areas of permanent tree plot monitoring from the DYNAFAC[28] network covering the five Central African countries. From the combined dataset, we identified 2001 trees belonging to 12 sites in three countries (Cameroun, Gabon, and Republic of Congo). Minimum and maximum sampled diameter ranged from 10 to 132 cm. The monitoring period ranged from 2000 to 2018. The mixed second-degree polynomial models (with a random site effect) were fitted for species monitored in several sites. The estimated coefficient from mixed second-degree polynomial model has been used in the simulation to estimate the diameter growth (Table 2).

Table 2. Estimated coefficients (a, b and c) of growth models between the increment (ac in cm year^{-1}) and the initial diameter (D in cm). The sample including the number of trees (n) and the number of sites (site) is also given. * significant (p-value < 0.05)

species	n	site	model	a	b	c
Padouk	2001	12	$ac \sim D + D^2 + (1\|site)$	0.292*	0.008*	-0.00007*

The transition probabilities of three parameters (mortality, growth, and recruitment rate) allowed making the harvested matrix. The logging operations have been modeled using the logging parameters (minimum cutting diameter, cutting and damage rate). The minimum cutting diameters were obtained from decrees of application of the forestry administrations (MCD_A) at the country level and the one used in the management plan (MCD_M, with $MCD_M \geq MCD_A$) at the logging company level. At the Central Africa level, we weighted the MCD_A and MCD_M values to the occupied area (**MCD_A = 70 cm** and **MCD_M = 75 cm**). The cutting rate (CA), which defines the proportion of harvested trees (trees with a diameter greater than MCD_A or MCD_M), was given by logging companies, and it was also weighted at the Central Africa level with a value of 69%. Given the current state of knowledge, it appears reasonable to use a fixed damage rate caused by logging of 7% of the initial population that disappears (Durrieu de Madron, Fontez, et al., 2000). The average cutting cycle (i.e. the period between two successive logging operations) is 28 years (FRMI, 2018), but we used 25 years to simplify computation of four simulations reaching 100 years (25, 50, 75 and 100 years), as requested by IUCN criterion A.

The Figure 3 shows the PPR in production forests for the *Pterocarpus soyauxii*. The reduction in the population of each species was then calculated as the difference between the initial numbers of mature individuals and the predicted numbers of mature individuals predicted after 100 years. The PPR in production forest was from **– 29.93 % (MCD_A) to -22.51% (MCD_M)** for the constant recruitment over 100 years.

[28] https://www.dynafac.org/en

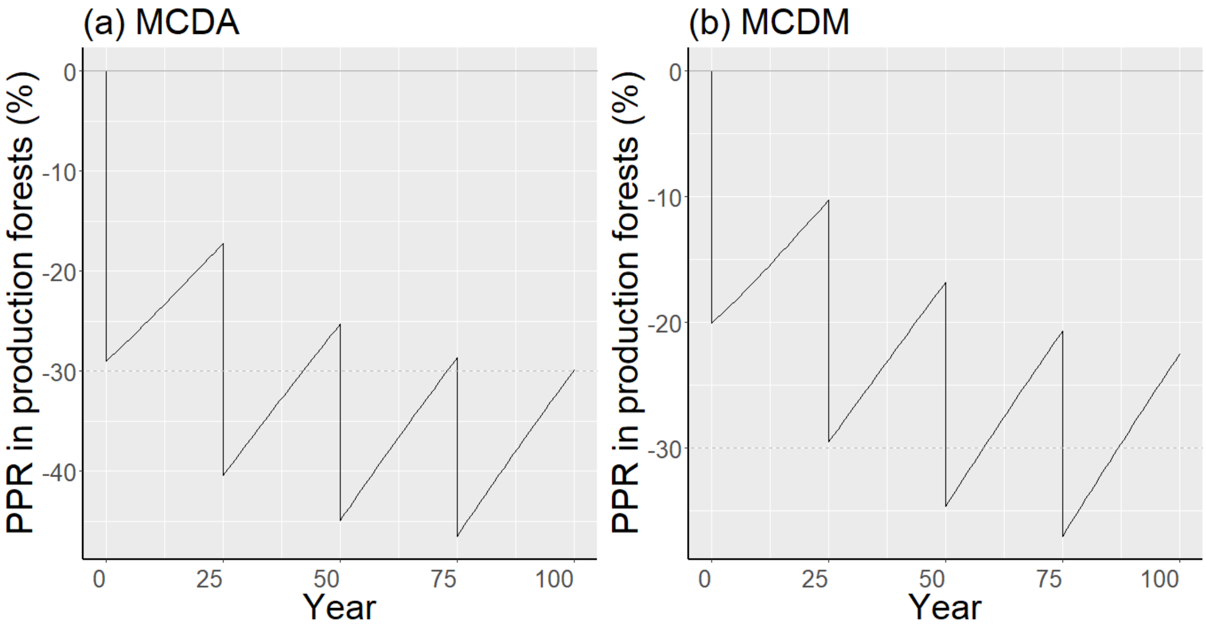

Figure 3. Simulations showing the projected population reduction (PPR) from diameter of mature individuals (35 cm) in production forests for *Pterocarpus soyauxii* over 100 years for constant recruitment.

- **PPR in the non-permanent forest domain**

The major threats in the non-permanent domain are habitat loss due to the destruction of natural environments because of population growth and urbanization, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Based on the large range of this species in Central Africa, the harvested volume from illegal logging and legal logging are 46% and 54%, respectively (FRMI 2018). In this condition, it was hypothesized that there is 54% of PPR from production forests and 46% of PPR from illegal logging in 100% PPR due to forest logging. Given that the PPR of production forests associated with its forest area was known, we deduced the PPR and forest area of illegal logging from those of the production forests. As a result, 47 857 302.7 ha were affected for the illegal logging for this species. The non-permanent domain area (107 400 521.1 ha) was considered as the area which was related to today's deforestation rate of 0.35% year^{-1} in Central Africa (Vancutsem et al., 2021). This is a conservative value since it will probably decrease in the future (Swamy et al., 2018).

The PPR in Central Africa by considering the PPR in production forest, protected area and non-permanent domain was from **− 16.59% (MCD_A) to -12.53% (MCD_M)** for the constant recruitment over 100 years.

- **PPR in West Africa**

In this region, forests are generally not managed in concessions, and the large part of the rainforest has been transformed in cultivated areas (Nix, 2019). Given the high degree of anthropization in this area, the main threats are habitat loss due to the destruction of natural environments and illegal logging, and the trees are frequently felled in fields. Applying the deforestation rate related to agricultural production can be considered as a proxy for tree removal. Thus, the forest areas in West Africa (15 600 000 ha) were subject to a constant annual deforestation rate of 1.20% $year^{-1}$ (Vancutsem et al., 2021). Taking this rate of deforestation as constant over the next 100 years, when it is expected to decline, is a reasonable precautionary measure incorporating illegal logging.

- **PPR global**

We thus had two different PPR: PPR_C in Central Africa and PPR_W in West Africa. The global PPR was then computed after weighting the two values by their relative forest areas:

$$PPR = \frac{(S_C \times PPR_C) + (S_W \times PPR_W)}{S_C + S_W}$$

where S_C and S_W are forest areas in Central and West Africa, respectively.

The criterion A3 based on (c) a decline in area of occupancy (AOO), the extent of occurrence (EOO), and/or habitat quality; and (d) potential levels of exploitation, has been computed as follows: (i) 30%≤PPR<50%, the species is considered as Vulnerable (VU); (ii) 50%≤PPR <80%, the species is considered as Endangered (EN), and PPR ≥ 80%, the species is considered as Critically Endangered (CR).

The PPR global in distribution range of *Pterocarpus soyauxii* was from **– 15.34 % (MCD_A) to -11.61% (MCD_M)** for the constant recruitment over 100 years. This PPR is < 30%, suggesting that this species is not threatened in its geographic area.

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10.18 Annexe 18. *Terminalia superba* - Engl. & Diels

Draft

Terminalia superba - Engl. & Diels

PLANTAE - TRACHEOPHYTA - MAGNOLIOPSIDA - MYRTALES - COMBRETACEAE - Terminalia - superba

Common Names: limba, fraké

Synonym: *Terminalia altissima* A. Chev. (1909)

Red List Status
NT - Near Threatened, A3bcd (IUCN version 3.1)

- **Red List Assessment**

- **Assessment Information**

Date of Assessment: 2022-09-01

Assessor(s): Monthe, F., Loubota, G., Ligot, G., Texier, N., Stévart, T. & Doucet, J.L.

Reviewer(s):

Institution(s):

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Regions: Global

- **Identification Description**

Terminalia superba is a large tree reaching up to 50 m high and 1.5 m in diameter. The bole is straight and cylindrical, with thin, upright buttresses at the base, which can be highly developed and wavy on older trees. The top is composed of horizontal, tiered branches with foliage grouped in clumps at the end of the branches. The bark is gray and smooth in young trees, then becomes yellowish brown with vertical cracks and elongated scales. The edge is yellowish, creamy or pinkish brown, often with light stripes. The leaves are simple, alternate, leathery, glabrous and long-stalked (up to 7 cm) with two alternate glands (swellings) more or less visible (and detected by touch). The inflorescences are axillary spikes bearing small discrete greenish white flowers. Fruits are sessile, hairless, with two rigid lateral wings (samaras). They are wider than long (2 x 5 cm with wings) and contain a small seed of 1 cm length.

- **Assessment Rationale**

Terminalia superba is a long-lived, and pioneer species, characteristic of (semi-)evergreen forests.
It is distributed from Guinea-Bissau to Democratic Republic of Congo and Cabinda (Angola). Based on a 2 x 2 km cell size, the AOO of this species is estimated as 692 km^2 with a minimum of 59 locations (number of forest management units of different logging companies in Central Africa). This species is not "Vulnerable" status under criterion B2. The EOO is calculated as 3 707 000 km^2, above the upper threshold for "Vulnerable" status under criterion B1.
Commonly known as Limba or Fraké, it is a timber species in tropical Africa, sought after for the quality of its wood. The minimum cutting diameter (MCD) in Central Africa varies from 60 to 70 cm and is globally higher than the regular fruiting diameter (RFD) estimated of 34 cm dbh (DYNAFAC, 2022), ensuring optimal regeneration of the species. The population structure showed a single-mode curve suggesting a regeneration deficit (see Supplementary Material). It has a relatively high population density about 1.01 $stems.ha^{-1}$ (diameter at breast height, dbh ≥ 20 cm), and fairly fast growth rates 0.47 ± 0.48 cm/year in Central Africa (see Supplementary Material). Given its stem density and the mean annual increment, we estimate the number of mature individuals (dbh ≥ 20 cm, see Supplementary Material) over 10 000 across the distribution range, well above the threatened category under criteria C and D.
Considering the species' generation length (140 years), an inference of three generations in the past goes back to around 1700 towards the end of the period characterised by high regeneration of light-demanding trees species, resulting from gardening activities of local populations in the forest, creating scattered large openings (Morin-Rivat et al., 2017). So, the species would certainly not be threatened according to the A1 and A2 criteria.
To model the recruitment, we used the hypothesis defined as the recruitment rate that would maintain a constant number of trees in the first diameter class. Based on simulations of the expected population reduction in its distribution with constant recruitment, we estimated population reduction from 26 % in the next 100 years below the threshold to be considered threatened under criterion A3 (for further information about this methodology, see Supplementary Material). An assessment of the population reduction according to criterion A4 does not apply, considering that one to two generations back and one to two generations forward would likely introduce high levels of uncertainty due to the lack of data to efficiently model the reduction of population size in the past. No quantitative analysis of the probability of extinction in the wild was conducted, and therefore criterion E does not apply.
Considering (i) the population density, (ii) the reduction of population in the future across the distribution range, the species is assessed as Near Threatened (NT), A3cd.

- **Distribution**

- **Geographic Range**

Terminalia superba is largely distributed from Guinea-Bissau to Democratic Republic of Congo. The extent of occurrence (EOO) in native area is estimated at 3 707 396 km^2 across its distribution range.

- **Area of Occupancy (AOO)**

Estimated area of occupancy (AOO) - in km2	Justification
692	AOO has been estimated using ConR based on the 2 × 2 km cell size of 274 occurrences from CJBD and RAINBIO

Continuing decline in area of occupancy (AOO)	Qualifier	Justification
Yes	Inferred	The species has suffered from reduction in area of occupancy, due to habitat degradation and deforestation in West Africa forest (Vancutsem et al., 2021).

- **Extent of Occurrence (EOO)**

Estimated extent of occurrence (EOO)- in km2	EOO estimate calculated from Minimum Convex Polygon	Justification
3 707 3964	true	Calculated using ConR based on 274 known occurrences from CJBD and RAINBIO

Continuing decline in extent of occurrence (EOO)	Qualifier	Justification
Yes	Observed	The species has certainly undergone an extent of occurrence reduction in West Africa, linked to the reduction in forest area (Vancutsem et al., 2021).

- **Locations Information**

Number of Locations	Justification
50-200	More than 59 locations. Largely distributed species

Continuing decline in number of locations	Qualifier	Justification
No	Inferred	The main threat remains the reduction of the forest area in West Africa.

Extreme fluctuations in the number of locations	Justification
No	Habitat degradation is the main threat.

- **Very restricted AOO or number of locations (triggers VU D2)**

Very restricted in area of occupancy (AOO) and/or # of locations	Justification
No	-

- **Elevation / Depth / Depth Zones**

Elevation Lower Limit (in metres above sea level): 0

Elevation Upper Limit (in metres above sea level): 1600

- **Map Status**

Map Status	Use map from previous assessment	How the map was created, including data sources/methods used:	Please state reason for map not available:	Data Sensitive?	Justification	Geographic range this applies to:	Date restriction imposed:
Done	-	Qgis	-	-	-	-	-

- **Biogeographic Realms**

Biogeographic Realm: Afrotropical

- **Occurrence**

- **Countries of Occurrence**

Country	Presence	Origin	Formerly Bred	Seasonality
Bissau Guinea	Extant	Native	-	Resident
Benin	Extant	Native	-	Resident
Cameroon	Extant	Native	-	Resident
Central African Republic	Extant	Native	-	Resident
Democratic Republic of Congo	Extant	Native	-	Resident

Ivory Coast	Extant	Native	-	Resident
Equatorial Guinea	Extant	Native	-	Resident
Equatorial Guinea -> Equatorial Guinea (mainland)	Extant	Native	-	Resident
Gabon	Extant	Native	-	Resident
Ghana	Extant	Native	-	Resident
Guinea	Extant	Native	-	Resident
Liberia	Extant	Native	-	Resident
Nigeria	Extant	Native	-	Resident
Republic of Congo	Extant	Native	-	Resident
Sierra Leone	Extant	Native	-	Resident

• Population

T. superba is a guineo-congolian species, widely distributed in West Africa to Central Africa from Guinea-Bissau to Democratic Republic of Congo and Cabinda (Angola). Its average density is 1.01 stems.ha-1 (dbh ≥ 20 cm) in Central Africa (see Supplementary Material). This density can locally reach 3.5 stems.ha^{-1} in some populations in Cameroon (Kimpouni, 2009).

The mean diameter growth of this species is 0.47 ± 0.48 cm/year in unlogged and logged forests in Central Africa (see Supplementary Material). *T. superba* has been planted in many tropical countries outside its natural range as a promising plantation species, such as Uganda, Tanzania, Zimbabwe, Madagascar, Indonesia, Malaysia, Philippines, Solomon Islands and Fiji, Australia, Brazil and Argentina. *T. superba* is planted in savannahs or degraded forests in Central Africa and forest concessions (De Wasseige et al., 2013; Doucet et al., 2016). Plantations of 30 to 60 years old have been established in the Mayombe region of DRC. A selection of superior clones has been successfully carried out in these plantations and observations show in particular a good quality of wood, already exploited in a part of the massif (De Wasseige et al., 2013). However, illegal logging and local intense harvesting can occur. It is the case in southern Cameroon where the species is an exploited species for the local market. In such areas, efforts should be made to limit this illegal exploitation.

The legal minimum cutting diameter "MCD" varies across its distribution range, (60 cm in Cameroon, Central Africa Republic, Democratic Republic of Congo, Ivory Coast, Republic of Congo, and 70 in Gabon). (MCD_M). At the Central Africa level, we weighted the MCD and MCD_M values to the occupied area with MCD = 60 cm and MCD_M = 75 cm (see Supplementary Material).

Using the Red List criterion A3, the projected population reduction (PPR) to be met in the future (100 years because the generation length of the species is 140 years) of the *T. superba* population was assessed across its distribution range. Because *T. superba* is a widespread species in West and Central Africa, the PPR was estimated for each region. In Central Africa, three different PPR were thus estimated: PPRpa in protected areas, PPRpf in production forests and PPRnp in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas. First, protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). The population of the species in protected areas covering its range was kept stable in the future over 100 years, suggesting that the PPR in protected areas was 0%. Second, the evolution of the *T. superba* population was simulated using an Usher matrix model to estimate the PPR of production forests (logging concessions, PPRpf). The simulations were initialised using the density (number of trees.ha-1) per diameter class (from 20 cm diameter, mature individuals) from forest management inventories of logging companies. The evolution of this initial population depended on several demographics (recruitment, mortality, and growth rate) and logging parameters (minimum cutting diameter, cutting and damage rate) that were adjusted using data of permanent tree plot monitoring. Thus, the density of *T. superba* in 100 years was predicted with a logging event every 25 years, which corresponds to the average cutting cycle in Central Africa. PPRpf was then calculated as the difference between initial and final number of trees. Third, the major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Illegal logging and the habitat lost from deforestation rate have been both activities that allowed estimating the PPRnp in non-permanent domains. In West Africa, the forest areas were subject to a constant annual deforestation rate of 1.20% year-1 (Vancutsem et al., 2021). Taking this rate of deforestation as constant over the next 100 years, when it is expected to decline, is a reasonable precautionary measure. We thus had two different PPR: PPRC in Central Africa and PPRW in West Africa.

The global PPR was then computed after weighting the two values by their relative forest areas. The global PPR result (26%) was found to be lower than 30% (for further information about this methodology, see Supplementary Material).

- **Population Information**

Current Population Trend: Decreasing

Extreme fluctuations? (in # of mature individuals)	Justification
No	-

Severely fragmented?	Justification
No	-

Continuing decline in mature individuals?	Qualifier	Justification

Continuing decline % in mature individuals within 3 generations or 10 years, whichever is longer (up to max. of 100 years in the future)	Qualifier	Justification

Extreme fluctuations in the number of subpopulations	Justification
No	-

Continuing decline in number of subpopulations	Qualifier	Justification
No	-	-

All individuals in one subpopulation: No

Number of Subpopulations	Justification	Subpopulation Details	Subpopulation description	Number of mature individuals	Subpopulation trend	Qualifier	Location type	Number of Subpopulations	Location bounding box	Location coordinates	Notes
5	Genetic analyses using 14 nuclear microsatellites for 299 individuals sampled across the distribution range of the species (Demenou et al., 2018)	-	-	-	-	-	-	-	-	-	-

- ## Population Reduction - Past

Percent Change in past	Reduction or Increase	Qualifier	Justification

Basis?

Reversible?

Understood?

Ceased?

- **Population Reduction - Future**

Percent Change in future	Reduction or Increase	Qualifier	Justification
26%	Reduction	Projected	Using the Red List criterion A3, the projected population reduction (PPR) to be met in the future (100 years because the generation length of the species is 140 years) of the *T. superba* population was assessed across its distribution range. Because *T. superba* is a widespread species in West and Central Africa, the PPR was estimated for each region. In Central Africa, three different PPR were thus estimated: PPRpa in protected areas, PPRpf in production forests and PPRnp in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas. First, protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). The population of the species in protected areas covering its range was kept stable in the future over 100 years, suggesting that the PPR in protected areas was 0%. Second, the evolution of the *T. superba* population was simulated using an Usher matrix model to estimate the PPR of production forests (logging concessions, PPRpf). The simulations were initialised using the density (number of trees.ha-1) per diameter class (from 20 cm diameter, mature individuals) from forest management inventories of logging companies. The evolution of this initial population depended on several demographics (recruitment, mortality, and growth rate) and logging parameters (minimum cutting diameter, cutting and damage rate) that were adjusted using data of permanent tree plot monitoring. Thus, the density of *T. superba* in 100 years was predicted with a logging event every 25 years, which corresponds to the average cutting cycle in Central Africa. PPRpf was then calculated as the difference between initial and final number of trees. Third, the major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Illegal logging and the habitat lost from deforestation rate

	have been both activities that allowed estimating the PPRnp in non-permanent domains. In West Africa, the forest areas were subject to a constant annual deforestation rate of 1.20% year-1 (Vancutsem et al., 2021). Taking this rate of deforestation as constant over the next 100 years, when it is expected to decline, is a reasonable precautionary measure. We thus had two different PPR: PPRC in Central Africa and PPRW in West Africa. The global PPR was then computed after weighting the two values by their relative forest areas. The global PPR result (26%) was found to be lower than 30%. For further information about this methodology, see Supplementary Material.

Basis?
b) an index of abundance appropriate for the taxon, d) actual or potential levels of exploitation

- **Population Reduction - Ongoing**

Both: Percent Change over any 10 year or 3 generation period, whichever is longer, and must include both past and future, future can't go beyond 100 years	Reduction or Increase	Number of years for this period	Qualifier	Justification
		-		

Basis?

Reversible?
Yes

Understood?
Yes

Ceased?
No

- **Habitats and Ecology**

Terminalia superba is a large tree reaching up to 50 m high and 1.5 m in diameter, long-lived African pioneer species, wind-dispersed, and gregarious tree species that is usually found in the upper storey in deciduous, semi-deciduous and moist tropical forests, where it occurs naturally. The species has succeeded in penetrating evergreen forests in its natural habitats in the tropical West and Central African countries and it is sometimes found in the savanna. Its stands are particularly developed on well-drained fertile soils, rich in exchangeable bases, but is also found on other types such as lateritic sands, gravel and clays, lava, black basaltic clays and crystalline soils in old secondary forests, from 150-1 000 m altitude. The specific name of the species 'superba' refers to this imposing habit of the tree (Onyekwelu and Stimm, 2004).

T. superba bears andromonoic flowers. Flowering occurs from 23-33 cm in diameter in the Central Africa Republic (Ouédraogo et al., 2018). The flowering was during August and September, whereas fruiting and seed dispersal phenophases occurred between October and February. Its regeneration is ensured in the large openings (roadside, large gaps ...) not far from mother trees. The inclusion of *T. superba*, specific shade tree species, in cocoa agroforestry systems is important to maintain high yields in cocoa systems with low inputs (Asitoakor et al. 2022).

- **IUCN Habitats Classification Scheme**

Habitat	Season	Suitability	Major Importance?
1.6. Forest -> Forest - Subtropical/Tropical Moist Lowland	Resident	Suitable	Yes

- **Continuing Decline in Habitat**

Continuing decline in area, extent and/or quality of habitat?	Qualifier	Justification
Yes	Observed	Despite the annual deforestation rate of 0.35% and 1.2% in Central and West Africa respectively (Vancutsem et al., 2021).

- **Life History**

Generation Length	Justification	Data Quality
140	Minimum estimate of generation length for the species from the average growth rate, and the mean diameter of mature individuals (see Supplementary Material)	good

Age at maturity: female or unspecified
43 Years

Age at Maturity: Male
43 Years

Size at Maturity (in cms): Female
20

Size at Maturity (in cms): Male
20

Reproductive Periodicity
Annual

Annual Rate of Population Increase

Natural Mortality
1% (Ligot et al. 2022)

- **Systems**

System: Terrestrial

- **Plant / Fungi Specific**

Wild relative of a crop? No

Plant and Fungal Growth Forms
Tree - large

- **Use and Trade**

- **General Use and Trade Information**

Terminalia superba is among important timber species in tropical Africa, it produces the popular timber and its importance as a timber species has been known for many decades (Onyekwelu and Stimm, 2004) At industrial level, *T. superba* is mainly used for indoor applications because of its low resistance to fungi and insects. Timber applications are skirting boards, interior joinery and doors (Groulez and Wood 1985). It provides a fairly soft, rather brittle wood that is easy to work with. It is used in construction as well as in furniture making. *T. superba* was one of the major veneer timber species exported by African timber producers. The peeled veneer is mainly used for plywood and furniture. *T. superba* is also chosen for the fabrication of moldings during the construction of buildings, especially locally. The most important exporting countries currently are Cameroon, Ghana, and Ivory Coast. The wood of *T. superba* is mostly imported by Sahelian countries such as Senegal and by South European countries such as Greece, Italy, and Spain (ITTO 1993-2011). The wood of *T. superba* was heavily exploited and exported in the 1970s in West and Central Africa, but this importance has subsequently declined, with commercial volumes which recently decreased to less than of 25 000 m^3 since 2011 in Africa (De Wasseige et al., 2013; FRMi, 2018).

At a local level, the bark is traditionally used to dye fibers used for matting and basketry. It is also used to dye textiles black. Decoctions and macerations of bark are used in traditional medicine to treat wounds, lesions, hemorrhoids, diarrhea, dysentery, malaria, vomiting, gingivitis, bronchitis, canker sores, edema and ovarian disorders, as an expectorant and analgesic. The leaves are used as diuretic, the roots as laxative. In Ivory Coast, *Terminalia superba* is planted as a shade tree in cocoa and coffee plantations, and in democratic Republic of Congo in coffee, cocoa and banana plantations.

Subsistence:	Rationale:	Local Commercial:	Further detail including information on economic value if available:
Yes	-	Yes	-

National Commercial Value: Yes

International Commercial Value: Yes

Is there harvest from captive/cultivated sources of this species? Yes

Trend in level of total offtake from wild sources: Stable

Trend in level of total offtake from domesticated sources: Unknown

- **Non- Consumptive Use**

Non-consumptive use of the species? true

- **Threats**

The main threats in the non-permanent domain across distribution range, are mainly related to habitat loss due to the destruction of natural environments as a result of population explosion and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging and the abusive harvesting of plant parts requested as non-wood forest products (Bradshaw et al., 2009). Due to the long history of exploitation, and the uncontrolled rate at which *T. superba* was being removed from the natural forest, it was already considered over-exploited by the 1950s (Onyekwelu and Stimm 2004).

T. superba is exploited in Central Africa. No study considers logging as a direct driver of deforestation because of the low logging densities (1-2 stems per hectare). However, studies on the impact of logging on the species and habitats are needed.

- **Threats Classification Scheme**

No past, ongoing, or future threats exist to this species. false

Threat	Timing	Scope	Severity	Impact Score
1.1. Residential & commercial development -> Housing & urban areas	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4
2.1.1. Agriculture & aquaculture -> Annual & perennial non-timber crops -> Shifting agriculture	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
2.2.2. Agriculture & aquaculture -> Wood & pulp plantations -> Agro-industry plantations	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
2.3.2. Agriculture & aquaculture -> Livestock farming & ranching -> Small-holder grazing, ranching or farming	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4
3.2. Energy production & mining -> Mining & quarrying	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
4.1. Transportation & service corridors -> Roads & railroads	Past, Likely to Return	Minority (<50%)	Negligible declines	Past Impact
5.3.1. Biological resource use -> Logging & wood harvesting -> Intentional use: (subsistence/small scale) [harvest]	Ongoing	Minority (<50%)	Rapid Declines	Medium Impact: 6
5.3.2. Biological resource use -> Logging & wood harvesting -> Intentional use: (large scale) [harvest]	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4
7.1.3. Natural system modifications -> Fire & fire suppression -> Trend Unknown/Unrecorded	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4

- **Conservation**

T. superba is known to occur in protected areas and in at least 18 *ex situ* collections (BGCI, 2022). In certified forest concessions where the species is exploited, trails and or permanent forest plots are usually installed. These plots provide important data for (i) quantifying population dynamics processes at the stand level: mortality, growth and recruitment; (ii) phenological studies to determine the regular fruiting diameter (RFD). These tails and plots are managed in collaboration with forest concessions grouped within the DYNAFAC collective (see here for more information https://www.dynafac.org/fr/p/130/installation-de-dispositifs-de-suivi-de-la-dynamique-forestiere). Compilation of these data will provide important additional information for targeted silvicultural measures for the sustainable management of this species. First summaries have provided information on important parameters such as: mortality, growth etc (DYNAFAC, 2022; Ligot et al., 2022).

T. superba is also monitored in nurseries and planted in various forest concessions. It also colonises savannahs and open areas in general. Literature shows that the extent of past human disturbance in the forests of the Congo Basin has a positive impact on the abundance of pioneer species such as *T. superba* (Daïnou et al., 2016; Morin-Rivat et al., 2017; Van Gemerden et al., 2003). Keeping the environment open would ensure good regeneration of the species.

Genetic studies using Bayesian clustering analysis of 299 individuals genotyped at 14 nuclear microsatellites revealed five parapatric genetic clusters (UG, DG, and three in LG) with low to moderate genetic differentiation (Demenou et al., 2018).
In addition, it will also be necessary to :

- Ensure the implementation of the recommendations of the Dynafac collective, including the establishment of a system for monitoring the populations of commercial species in the different forest types defined in a consensual manner;
- Set up monitoring and support systems for the regeneration of commercial species, prioritising species with regeneration deficits;
- Set up programmes to guarantee the phenotypic quality of commercial species populations: seed banks, seed stands, plus trees, seed orchards, conservation plantations;
- Consider threatened species in the delimitation of conservation series and in the identification of High Conservation Values;
- Update conservation statuses on a five-yearly basis, in particular by setting up a system of "green statuses";
- Define red lists adapted to regional or national contexts;
- Evaluate the status of cryptic species or species close to commercial species evaluated during this workshop.

- **Conservation Actions In- Place**

Action Recovery Plan	Note
Yes	Reforestation within forest concessions and others.

Systematic monitoring scheme	Note
Yes	The species is monitored in permanent plots installed within forestry companies in Central Africa (see here for more information https://www.dynafac.org/fr)

Occur in at least one PA	Note

Yes	The species may appear in at least 100 protected areas considering it distribution range

Percentage of population protected by PAs (0-100)	Note
1-10	Considering protected area across species distribution range

Area based regional management plan	Note
Unknown	-

Invasive species control or prevention	Note
No	-

Harvest management plan	Note
Yes	In certified forest concessions, the species is exploited according to a management plan.

Subject to ex-situ conservation	Note
Yes	-

Included in international legislation	Note
No	-

Subject to any international management/trade controls	Note
Yes	FLEGTxxxxx x

- **Important Conservation Actions Needed**

Conservation Actions	Note
3.1.1. Species management -> Species management -> Harvest management	-
3.1.2. Species management -> Species management -> Trade management	-
3.4.2. Species management -> Ex-situ conservation -> Genome resource bank	-

- **Research Needed**

Research	Note
1.2. Research -> Population size, distribution & trends	-
3.1. Monitoring -> Population trends	-
3.2. Monitoring -> Harvest level trends	-
3.3. Monitoring -> Trade trends	-

• Ecosystem Services

• Ecosystem Services Provided by the Species

	Importance:	Geographic range of benefit:
1. Water Quality	2 - Important	Global
3. Flood Control	2 - Important	Global
4. Climate Regulation	2 - Important	Global
5. Landscape	2 - Important	Global
6. Air Quality	2 - Important	Global
7. Nutrient Cycling	2 - Important	Global
8. Habitat Maintenance	2 - Important	Global
9. Provision of Critical Habitat	2 - Important	Global

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● SUPPLEMENTARY MATERIAL

Terminalia superba - Engl. & Diels

IUCN status using criterion A3

We adopted the criterion A3 to assess the projected population reduction (PPR) to be met in the future (up to a maximum of 100 years) of *Terminalia superba*. To quantify the projected population reduction, simulations must be performed on mature individuals and three generations with a maximum of 100 years according to **criterion A3**. We estimated mature individuals and generation length, as recommended by the IUCN guidelines.

A **mature individual** is an individual that can reproduce, able to bear flowers or seeds (fertile in plant kingdom). To quantify the mature individuals for each species, we used phenological data of DYNAFAC network[29] from a combined dataset of 331 trees belonging to five sites in two countries (Cameroun and Republic of Congo). Minimum and maximum sampled diameters ranged from 10 to 116 cm (median 50 cm). The monitoring period ranged from 2015 to 2021. We assumed that the monitoring period was long enough to capture at least one reproductive event per tree such that trees without observed flowering/fruiting events were considered non-reproductive (26 percent of all monitored trees were non-reproductive). We used the methodology for the size at reproduction of canopy tree species in Central Africa (Ouédraogo et al., 2018): the **diameter of a mature individual** was obtained after fitting logistic regressions and the level of 50% of the probability to produce the flower or fruit was adopted for this species. Using this approach, the diameter of a mature individual was obtained after setting the 50% probability to produce flowers or fruits. The minimum diameter of mature individuals for this species was **20 cm**.

The **generation length** was the report between the mean diameter of mature individuals considering population structure and the mean increment. Given that the minimum diameter of mature individuals was 20 cm, we weighted the total number of trees by their diameter from 20 cm to 125 cm (Figure 1) to compute the number of mature individuals. The mean of mature individuals was **65 cm**. The **mean increment** of the species was **0.465 cm**, obtained from 853 observations of published data (Ligot et al., 2022) and unpublished data in two countries (Cameroon and Republic of Congo). Thus, the **generation length** was 65 cm / 0.465 cm = **140 years**. The age at maturity (**43 years**) has been estimated as the report between the **minimum diameter of mature individuals** (**20 cm**) and the **mean increment (0.465 cm)**.

Estimation of the projected population reduction (PPR)

We adopted the criterion A3 to assess the projected population reduction (PPR) to be met in the future (up to a maximum of 100 years). *Terminalia superba*, is found in Guineo–Congolian rainforest species, widely distributed

[29] https://www.dynafac.org/en

mainly from Guinea-Bissau to Democratic Republic of Congo. The geographic range of species was in two regions (Central Africa and West Africa) characteristic of two biogeographical regions across the tropical African forests (Fayolle et al., 2014). According to each region, different data (deforestation annual rate, growth, mortality, recruitment, forest inventory, etc.) have been used with logging data in Central Africa. Thus, the PPR was estimated for each region and the global PPR was then computed after weighting the two values by their relative forest areas.

PPR in Central Africa

In this region, forest management follows three different modalities: protected areas, production forests (logging concessions) and non-permanent forest domain. Based on occurrences, the natural range of this species includes countries in Central Africa (Figure 1). The total natural area is estimated at 153 913 210.2 ha. Within this area, there are 51 622 374.1 ha (33.5%) for production forests, 11 103 787.7 ha (7.2%) for protected areas, and 91 187 048.36 ha (59.3%) for the non-permanent domain.

Three different PPR were thus estimated: PPR_{pa} in protected areas, PPR_{pf} in production forests and PPR_{np} in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas and then added to estimate the PPR_{C} in Central Africa.

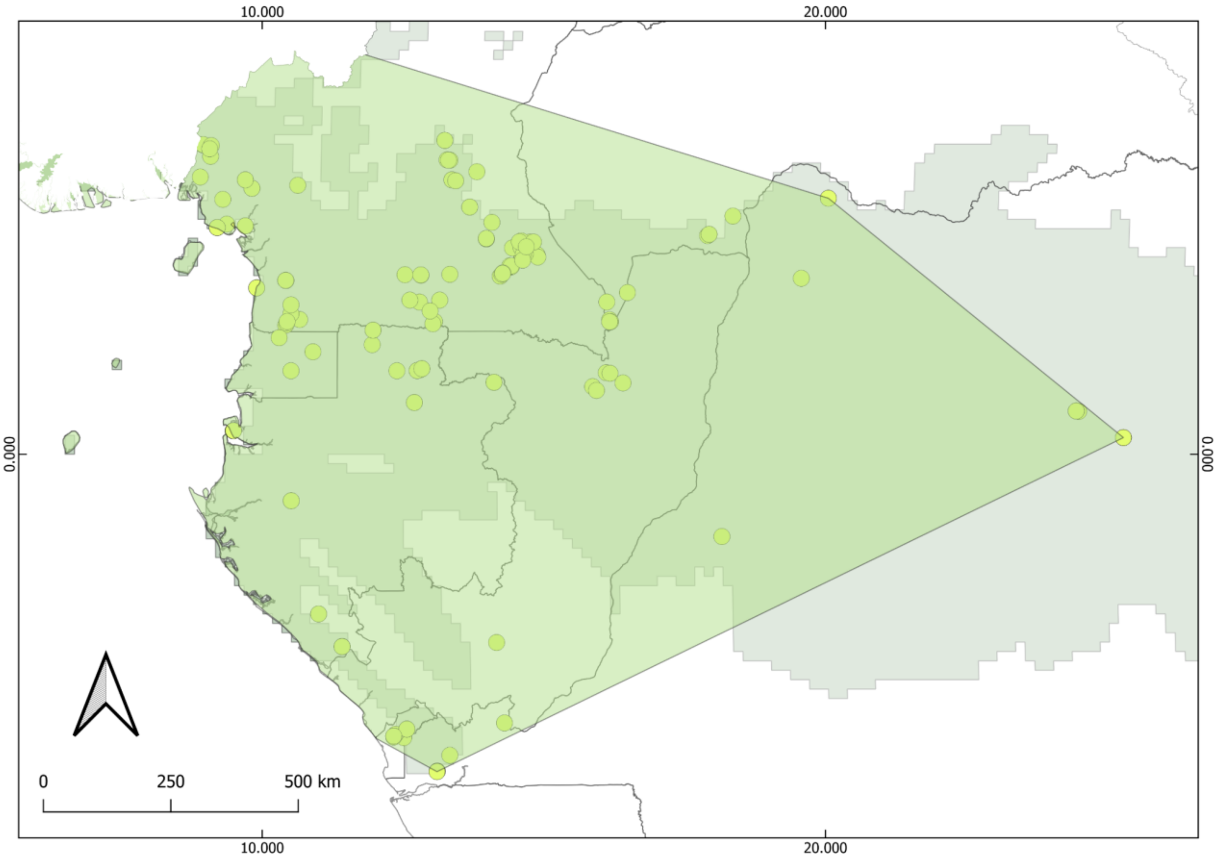

Figure 1. The range of *Terminalia superba* in Central Africa estimated from RAINBIO and CJB data, validated in December 2022 during a workshop with a group of experts in Gabon.

PPR in protected areas

Central Africa countries have allocated a higher proportion of their land to conservation than any other tropical regions, with relatively higher conservation success (Laurance et al., 2012). Indeed, most protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). They are currently representing a large part of forest and tree species conservation in Central Africa. Thus, the population of each species in protected areas (according to FRMI, 2018) covering its range was kept stable in the future over 100 years. **In these conditions, it was hypothesized that the PPR in protected areas for each species is 0%, suggesting no population reduction in the present and future.**

PPR in production forests

To quantify the evolution of the population of each timber species, matrix population models are widely used to study population dynamics (Picard & Liang, 2014). The population of this species was described at time t by a vector N_t corresponding to the density (number of trees ha^{-1}) in each diameter class (from 20 cm diameter to more than 120 cm). The density per diameter class was estimated using data from forest inventories that were carried out in 59 forest management units (FMU) of different logging companies in five countries (Cameroon, Central African Republic, Democratic Republic of the Congo, Gabon, and Republic of the Congo). Most logging companies followed a standardized inventory protocol (Réjou-Méchain et al., 2011). These forest inventory data covered about 12 million ha (Table 1), that are representative of 24% of Central Africa's production forests of this species. The number of trees sampled in Central Africa was 12 250 900 with a density of 1.004 tree ha^{-1}. Large-scale commercial inventories have already been found useful in the identification of large-scale patterns in Central Africa (Réjou-Méchain et al., 2011). Using large-scale data from commercial forest inventories, Réjou-Méchain et al. (2021) jointly model the distribution in the abundance of the most dominant tree species and produce continuous maps of the floristic and functional composition of central African forests.

Table 1. Forest management units (FMU) sampled in Central Africa (Cameroon, CAR: Central African Republic, DRC: Democratic Republic of the Congo, EG: Equatorial Guinea, Gabon and RCongo: Republic of the Congo).

	Sampling	
Country	FMU	Area (ha)
Cameroon	22	2 148 947.78
CAR	5	1 018 129
DRC	6	2 036 755
EG	-	-
Gabon	18	2 990 949
RCongo	8	4 005 312
Total	59	12 200 092.78

The Usher matrix model was used to simulate the evolution of the recovery rate of all population and the exploitable stock of each species after logging in Central Africa. According to the Usher assumption, between *t* and *t*+1, an individual can either stay alive in the same class, stay alive and move up to the next class, or die; it cannot move up by more than one class or move backwards, i.e., the individual is free from diameter shrinkage (Picard et al., 2012). The Usher matrix model (U) considers three parameters (mortality, recruitment and growth rate that are constant in time) to estimate the transition probabilities:

$$U = \begin{pmatrix} q_1 + g_1 & g_2 & \cdots & \cdots & g_I \\ p_1 & q_2 & 0 & \cdots & 0 \\ 0 & \ddots & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & p_{I-1} & q_I \end{pmatrix}$$

where q_i is the probability for an individual to stay alive in class *i* between two consecutive time steps, p_i is the upgrowth transition rate (the probability for an individual to grow up from class *i* to class *i* +1), and g_i is the recruitment rate (Picard & Liang, 2014).

Tree mortality, recruitment and growth are three central processes for predicting the dynamics of tropical rainforests and estimating these three processes requires long-term monitoring in difficult field conditions (Picard & Gourlet-Fleury, 2008). These processes determine the evolution of the species population in the forest stand. The natural mortality is defined as the number of standing dead trees, and few studies have reported estimates of mortality rates in Central Africa. Data about tree mortality are still scarce and it does not allow to precisely model the mortality rate for each species and size class. Given the current state of knowledge, it appears reasonable to use a fixed mortality rate of 1% for all species and size classes, in agreement with the results of Ligot et al. (2022) on 21,180 trees belonging to 42 timber species of Central Africa annually monitored from one to seven years.

The recruitment integrates fruiting and seed dispersal from mother trees, and the survival of plant juveniles until they reach a size threshold where they are included in the stand. The recruitment term in the model is the average annual input of new individuals into the first size class from 20 cm. The recruitment events, like mortality events, are infrequent and thus difficult to model (Karsenty & Gourlet-Fleury, 2006). The population structure showed a single-mode curve with a good representation of the small stems suggesting a good regeneration (Figure 2). To model the recruitment, we used the hypothesis defined as the recruitment rate that would maintain a constant number of trees in the first diameter class. Claeys et al. (2019) projected the future forest dynamics up to the end of the century and they showed that projected mortality and recruitment rates in 2099 could not differ from the ones observed today. Thus, the hypothesis on the recruitment and the mortality rate is used in the future (up to 100 years) as they do today.

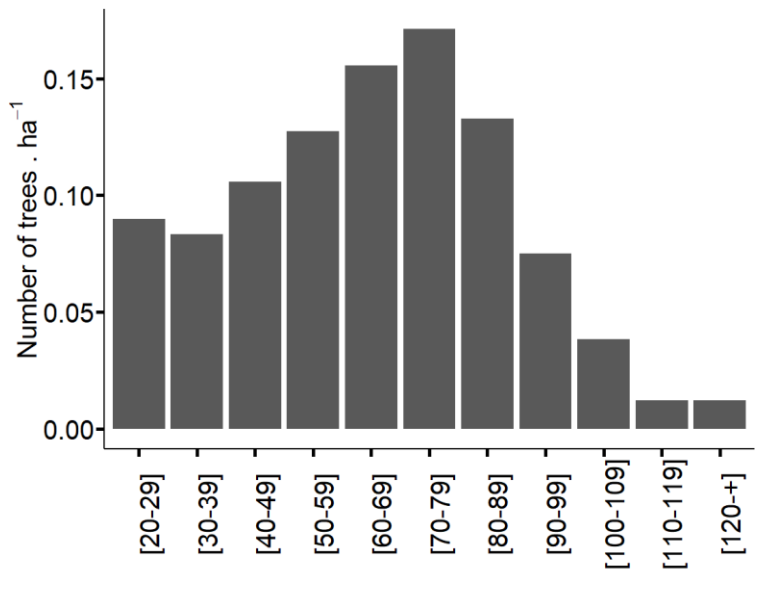

Figure 2. Population structure of *Terminalia superba* defined using the number of trees per ha and per diameter class (from 20 cm of 59 logging concessions covering an area of 12 200 092.78 ha in Central Africa).

Since the mid-1900s, periodic tree monitoring and tree ring analyses have been carried out to study variability in tree growth across species in Central Africa (Durrieu de Madron, Nasi, et al., 2000; Ligot et al., 2019, 2022). We fitted growth models for each species using data from logged and unlogged areas of permanent tree plot monitoring from the DYNAFAC[30] network covering the five Central African countries. From the combined dataset, we identified 858 trees belonging to 7 sites in three countries (Cameroun, Gabon, and Republic of Congo). Minimum and maximum sampled diameters ranged from 10 to 120 cm. The monitoring period ranged from 2005 to 2017. The mixed second-degree polynomial models (with a random site effect) were fitted for species monitored in several sites. Because of the estimated coefficient from second degree (diameter^2) of the mixed model was not significant, the growth model (increment ~ 0.911-0.01*diameter) has been used in the simulation to estimate the diameter growth (Table 2).

Table 2. Estimated coefficients (a, b and c) of growth models between the increment (ac in cm year^{-1}) and the initial diameter (D in cm). The sample including the number of trees (n) and the number of sites (site) are also given. * significant (p-value < 0.05) and ^{ns} non-significant (p-value > 0.050)

species	n	site	model	a	b	c
Limba/fraké	477	7	ac ~ D + D^2 + (1|site)	0.911*	-0.01*	0.00003^{ns}

The transition probabilities of three parameters (mortality, growth, and recruitment rate) allowed making the harvested matrix. The logging operations have been modeled using the logging parameters (minimum cutting diameter, cutting and damage rate). The minimum cutting diameters were obtained from decrees of application of

[30] https://www.dynafac.org/en

the forestry administrations (MCD_A) at the country level and the one used in the management plan (MCD_M, with $MCD_M \geq MCD_A$) at the logging company level. At the Central Africa level, we weighted the MCD_A and MCD_M values to the occupied area (**MCD_A = 60 cm** and **MCD_M = 75 cm**). The cutting rate (CA), which defines the proportion of harvested trees (trees with a diameter greater than MCD_A or MCD_M), was given by logging companies, and it was also weighted at the Central Africa level with a value of 67%. Given the current state of knowledge, it appears reasonable to use a fixed damage rate caused by logging of 7% of the initial population that disappears (Durrieu de Madron, Fontez, et al., 2000). The average cutting cycle (i.e. the period between two successive logging operations) is 28 years (FRMI, 2018), but we used 25 years to simplify computation of four simulations reaching 100 years (25, 50, 75 and 100 years), as requested by IUCN criterion A.
The Figure 3 shows the PPR in production forests for the *Terminalia superba*. The reduction in the population of each species was then calculated as the difference between the initial numbers of mature individuals and the predicted numbers of mature individuals predicted after 100 years. The PPR in production forest was from **– 59.20 % (MCD_A) to -49.57% (MCD_M) over 100 years.**

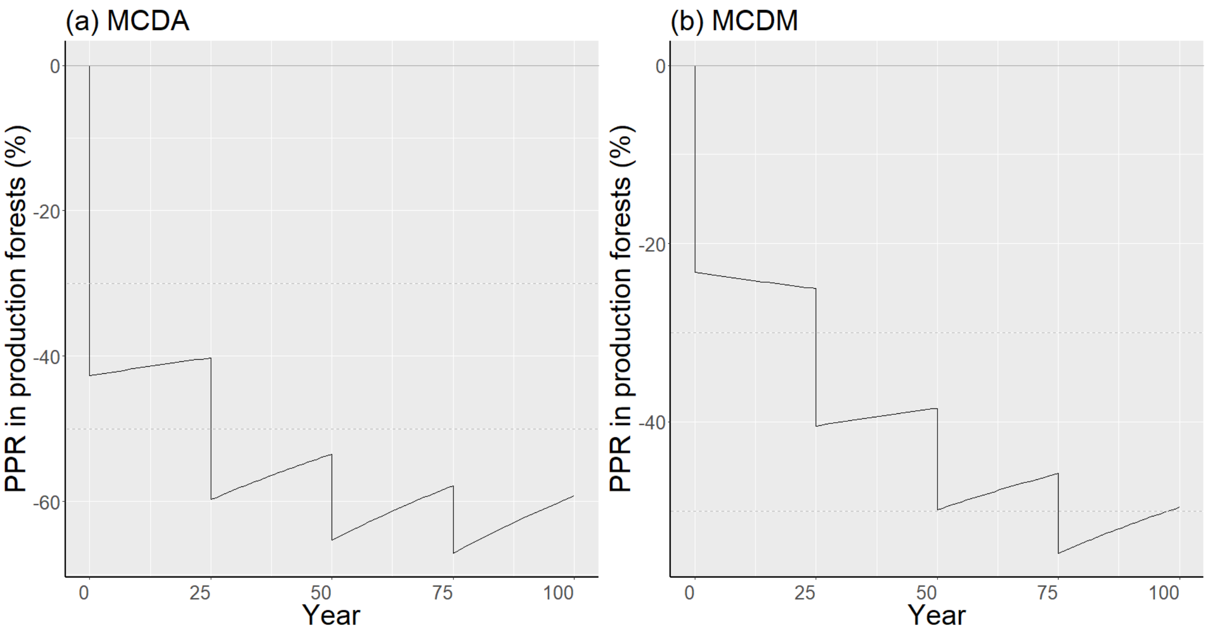

Figure 3. Simulations showing the projected population reduction (PPR) from the diameter of mature individuals (20 cm) in production forests for the *Terminalia superba* for constant recruitment over 100 years.

PPR in the non-permanent forest domain

The major threats in the non-permanent domain are habitat loss due to the destruction of natural environments because of population growth and urbanization, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). ion, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Based on the large range of this species in Central Africa, the harvested volume from illegal logging and legal logging are 46% and 54%, respectively (FRMI 2018). In this condition, it was hypothesized that there is 54% of PPR from production forests and 46% of PPR from illegal logging in 100% PPR due to forest logging. Given that the PPR of production forests associated with its forest area was known, we deduced the PPR and forest area of illegal logging from those of the production forests. As a result, 43 974 615 ha were affected for the illegal logging for this species. The non-permanent domain area (91 187 048.36 ha) was considered as the area which was related to today's deforestation rate of 0.35% year^{-1} in Central Africa (Vancutsem et al., 2021). This is a conservative value since it will probably decrease in the future (Swamy et al., 2018).

The PPR in Central Africa by considering the PPR in production forest, protected area and non-permanent domain was from **– 34.47 % (MCD_A) to -28.90% (MCD_M) over 100 years.**

PPR in West Africa

In this region, forests are generally not managed in concessions, and the large part of the rainforest has been transformed in cultivated areas (Nix, 2019). Given the high degree of anthropization in this area, the main threats are the habitat loss due to the destruction of natural environments and illegal logging, and the trees are frequently felled in fields. Applying the deforestation rate related to agricultural production can be considered as a proxy for tree removal. Thus, the forest areas in West Africa (15 600 000 ha) were subject to a constant annual deforestation rate of 1.20% year^{-1} (Vancutsem et al., 2021). Taking this rate of deforestation as constant over the next 100 years, when it is expected to decline, is a reasonable precautionary measure incorporating illegal logging.

PPR global

We thus had two different PPR: PPR_C in Central Africa and PPR_W in West Africa. The global PPR was then computed after weighting the two values by their relative forest areas:

$$PPR = \frac{(S_C \times PPR_C) + (S_W \times PPR_W)}{S_C + S_W}$$

where S_C and S_W are forest areas in Central and West Africa, respectively.

The criterion A3 based on (c) a decline in area of occupancy (AOO), the extent of occurrence (EOO), and/or habitat quality; and (d) potential levels of exploitation, has been computed as follows: (i) 30%≤PPR<50%, the species is considered as Vulnerable (VU); (ii) 50%≤PPR <80%, the species is considered as Endangered (EN), and PPR ≥ 80%, the species is considered as Critically Endangered (CR).

The PPR global in distribution range of the *Terminalia superba* was from **– 26.36 over 100 years.** This PPR is < 30%, suggesting that this species is not threatened in its geographic area.

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10.19 Annexe 19. *Testulea gabonensis* Pellegr.

Draft

Testulea gabonensis Pellegr.

PLANTAE - TRACHEOPHYTA - MAGNOLIOPSIDA - MALPIGHIALES – OCHNACEAE - Testulea - gabonensis

Common Names: Izombe, akewe

Synonyms: No Synonyms

Red List Status
LC - Least Concern, A3cd (IUCN version 3.1)

- **Red List Assessment**

- **Assessment Information**

Date of Assessment: 2022-09-01

Assessor(s): Monthe, F., Loubota, G., Ligot, G., Texier, N., Stévart, T. & Doucet, J.L.

Reviewer(s):

Institution(s):

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Regions: Global

- **Identification Description**

Testulea gabonensis is a large tree reaching 50 m in height and 1.5 m in diameter. The top is small with dark foliage grouped in clumps at the end of the branches. Its trunk has a thickened base, often with horizontal folds on the few small thick buttresses that develop with age. Its yellow-gray bark is detached in large irregular and brittle scales under which yellow-ochre depressions appear. Its edge is pinkish with orange granules, the light yellow inner part darkens with exposure. Its large, very elongated leaves (15-35 x 4-8 cm), simple alternate, are whole but with wavy edges. The main vein is prominent on both sides with numerous parallel but spaced secondary veins and tertiary veins in a fine perpendicular network. Its long inflorescences (up to 35 cm) carry large yellowish to pinkish flowers with 2 large petals and 2 smaller ones. Its fruits are heart-shaped capsules, green then brown, which open in two swollen but thin-walled valves, from 3 to 6 cm long. They contain numerous small fine and curved seeds (± 1 cm long), brown at maturity, provided with a small membranous wing with rounded top of ± 2 x 1 cm.

- **Assessment Rationale**

Testulea gabonensis is a long-lived and non-gregarious pioneer species characteristic of Atlantic evergreen rainforests. It is distributed from Cameroon to the Republic of Congo. Based on a 2 x 2 km cell size, the AOO of this species is estimated as 112 km^2 with a minimum of 44 locations (number of forest management units of different logging companies in Central Africa). This species is not "Vulnerable" status under criterion B2. The EOO is calculated as 227 202 km^2, above the upper threshold for "Vulnerable" status under criterion B1.

Commonly known as Izombe, the species is available on the international timber market in limited quantities. It has relatively high population densities 0.15 stems.ha^{-1} (dbh ≥ 20 cm) in Central Africa, fairly fast growth rates 0.4 cm/year, and good regeneration (see Supplementary Material). The minimum cutting diameter (MCD) in Central Africa varies between 60 and 80 cm and is globally higher than the minimum fertility diameter of 20 cm diameter at breast height (DBH) and the fruiting diameter observed at 50 cm, ensuring optimal regeneration of the species. The population structure showed decreasing suggesting a good regeneration (see Supplementary Material). Given its stem density and the mean annual increment, we estimate the number of mature individuals (dbh ≥ 20 cm, see Supplementary Material) over 10 000 across the distribution range, well above the threatened category under criteria C and D.

Considering the species' generation length (130 years), an inference of three generations in the past goes back to around 1700 towards the end of the period characterised by high regeneration of light-demanding trees species, resulting from gardening activities of local populations in the forest, creating scattered large openings (Morin-Rivat et al., 2017). So, the species would certainly not be threatened according to the A1 and A2 criteria.

To model the recruitment, we used the hypothesis defined as the recruitment rate that would maintain a constant number of trees in the first diameter class. Based on simulations of the expected population reduction in its distribution with constant recruitment, we estimated population reduction of 18.4% in the next 100 years below the threshold to be considered threatened under criterion A3 (for further information about this methodology, see Supplementary Material). An assessment of the population reduction according to criterion A4 does not apply, considering that one to two generations back and one to two generations forward would likely introduce high levels of uncertainty due to the lack of data to efficiently model the reduction of population size in the past. No quantitative analysis of the probability of extinction in the wild was conducted, and therefore criterion E does not apply.

Considering (i) the population density, (ii) the reduction of population in the future across the distribution range, the species is assessed as Least Concern (LC), A3cd.

Reasons for change

Reason(s) for Change in Red List Category from the Previous Assessment:

Testulea gabonensis was previously assessed as "Vulnerable" by the IUCN (https://www.iucnredlist.org/species/33215/9767056) at the African Regional Workshop (Conservation & Sustainable Management of Trees, Zimbabwe, July 1996), 1998, following the A1cd criterion. During the last few years, important data have been produced on the self-ecology, population dynamics (growth, recruitment, mortality) of the species (DYNAFAC, 2022; Ligot et al., 2022). Moreover, a new version of the IUCN guidelines is available (from version 2.3 to 3.1). Given all these information, it was necessary to produce a new assessment of the species.

• Distribution

• Geographic Range

Testulea *gabonensis* is restricted to western Central Africa, occurring in south-western Cameroon, Equatorial Guinea, Gabon and Congo. The extent of occurrence (EOO) in native area is estimated at 227 202 km^2 across its distribution range.

• Area of Occupancy (AOO)

Estimated area of occupancy (AOO) - in km2	Justification
112	AOO has been estimated using ConR based on the 2 × 2 km cell size of 52 occurrences from CJBD and RAINBIO

Continuing decline in area of occupancy (AOO)	Qualifier	Justification
Yes	Inferred	The species has suffered from reduction in area of occupancy, due to habitat degradation and deforestation in Central Africa forest (Vancutsem et al., 2021).

• Extent of Occurrence (EOO)

Estimated extent of occurrence (EOO)- in km2	EOO estimate calculated from Minimum Convex Polygon	Justification
227 202	true	Calculated using ConR based on 52 known occurrences from CJBD and RAINBIO

Continuing decline in extent of occurrence (EOO)	Qualifier	Justification
Yes	Observed	The species has certainly undergone extent of occurrence reduction in Central Africa, linked to habitat degradation (Vancutsem et al., 2021)

- **Locations Information**

Number of Locations	Justification
40-100	More than 44 locations. Largely distributed species in Central Africa

Continuing decline in number of locations	Qualifier	Justification
No		

Extreme fluctuations in the number of locations	Justification
No	

- **Very restricted AOO or number of locations (triggers VU D2)**

Very restricted in area of occupancy (AOO) and/or # of locations	Justification
No	-

- **Elevation / Depth / Depth Zones**

Elevation Lower Limit (in metres above sea level): 0

Elevation Upper Limit (in metres above sea level): 1600

- **Map Status**

Map Status	Use map from previous assessment	How the map was created, including data sources/methods used:	Please state reason for map not available:	Data Sensitive?	Justification	Geographic range this applies to:	Date restriction imposed:
Done	-	Qgis	-	-	-	-	-

- **Biogeographic Realms**

Biogeographic Realm: Afrotropical

- **Occurrence**

- **Countries of Occurrence**

Country	Presence	Origin	Formerly Bred	Seasonality
Cameroon	Extant	Native	-	Resident
Equatorial Guinea -> Equatorial Guinea (mainland)	Extant	Native	-	Resident
Gabon	Extant	Native	-	Resident
Republic of Congo	Extant	Native	-	Resident

- **Population**

Testulea gabonensis is a lower guinea species, widely distributed in western Central Africa from south-western Cameroon, Equatorial Guinea, and Gabon to Republic of Congo. Its average density is 0.15 stems.ha-1 (dbh ≥ 20 cm) with a growth rate of 0.4 cm/year in Central Africa (see Supplementary Material).

The legal minimum cutting diameter "MCD" varies across its distribution range (80 cm in Cameroon, 60 cm in Republic of Congo and 70 cm in Gabon). Furthermore, the mean weighted cutting and the average implemented MCD was 80 cm (see Supplementary Material). The MCD is higher than the fruiting diameter observed at 50 cm (Sépulchre et al., 2008), and the minimum fertility diameter estimated at 20 cm in Central Africa (see Supplementary Material).

Using the Red List criterion A3, the projected population reduction (PPR) to be met in the future (100 years because the generation length of the species is 130 years) of the *T. gabonensis* population was assessed across its distribution range. Because *T. gabonensis* is a widespread species in Central Africa, the PPR was estimated in central Africa. In Central Africa, three different PPR were thus estimated: PPRpa in protected areas, PPRpf in production forests and PPRnp in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas. First, protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). The population of the species in protected areas covering its range was kept stable in the future over 100 years, suggesting that the PPR in protected areas was 0%. Second, the evolution of the *T. gabonensis* population was simulated using an Usher matrix model to estimate the PPR of production forests (logging concessions, PPRpf). The simulations were initialised using the density (number of trees.ha-1) per diameter class (from 20 cm diameter, mature individuals) from forest management inventories of logging companies. The evolution of this initial population depended on several demographics (recruitment, mortality, and growth rate) and logging parameters (minimum cutting diameter, cutting and damage rate) that were adjusted using data of permanent tree plot monitoring. Thus, the density of *T. gabonensis* in 100 years was predicted with a logging event every 25 years, which corresponds to the average cutting cycle in Central Africa. PPRpf was then calculated as the difference between initial and final number of trees. Third, the major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Illegal logging and the habitat lost from deforestation rate have been both activities that allowed estimating the PPRnp in non-permanent domains.

The global PPR was then computed after weighting the three values (PPRpa, PPRpf, PPRnp) by their relative forest areas. The global PPR result (18.4%) was found to be lower than 30% (for further information about this methodology, see Supplementary Material).

- **Population Information**

Current Population Trend: Decreasing

Extreme fluctuations? (in # of mature individuals)	Justification
No	-

Severely fragmented?	Justification
No	-

Continuing decline in mature individuals?	Qualifier	Justification

Continuing decline % in mature individuals within 3 generations or 10 years, whichever is longer (up to max. of 100 years in the future)	Qualifier	Justification

Extreme fluctuations in the number of subpopulations	Justification
No	-

Continuing decline in number of subpopulations	Qualifier	Justification
No	-	-

All individuals in one subpopulation: No

Number of Subpopulations	Justification	Subpopulation Details	Subpopulation description	Number of mature individuals	Subpopulation trend	Qualifier	Location type	Number of Subpopulations	Location bounding box	Location coordinates	Notes
0	-	-	-	-	-	-	-	-	-	-	

- **Population Reduction - Past**

Percent Change in past	Reduction or Increase	Qualifier	Justification

Basis?

Reversible?

Understood?

Ceased?

- Population Reduction - Future

Percent Change in future	Reduction or Increase	Qualifier	Justification
18.4%	Reduction	Projected	Using the Red List criterion A3, the projected population reduction (PPR) to be met in the future (100 years because the generation length of the species is 130 years) of the *T. gabonensis* population was assessed across its distribution range. Because *T. gabonensis* is a widespread species in Central Africa, the PPR was estimated in central Africa. In Central Africa, three different PPR were thus estimated: PPRpa in protected areas, PPRpf in production forests and PPRnp in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas. First, protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). The population of the species in protected areas covering its range was kept stable in the future over 100 years, suggesting that the PPR in protected areas was 0%. Second, the evolution of the *T. gabonensis* population was simulated using an Usher matrix model to estimate the PPR of production forests (logging concessions, PPRpf). The simulations were initialised using the density (number of trees.ha-1) per diameter class (from 20 cm diameter, mature individuals) from forest management inventories

	of logging companies. The evolution of this initial population depended on several demographics (recruitment, mortality, and growth rate) and logging parameters (minimum cutting diameter, cutting and damage rate) that were adjusted using data of permanent tree plot monitoring. Thus, the density of *T. gabonensis* in 100 years was predicted with a logging event every 25 years, which corresponds to the average cutting cycle in Central Africa. PPRpf was then calculated as the difference between initial and final number of trees. Third, the major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Illegal logging and the habitat lost from deforestation rate have been both activities that allowed estimating the PPRnp in non-permanent domains. The global PPR was then computed after weighting the three values (PPRpa, PPRpf, PPRnp) by their relative forest areas. The global PPR result (18.4%) was found to be lower than 30%. For further information about this methodology, see Supplementary Material.

Basis?
b) an index of abundance appropriate for the taxon, d) actual or potential levels of exploitation

- **Population Reduction - Ongoing**

Both: Percent Change over any 10 year or 3 generation period, whichever is longer, and must include both past and future, future can't go beyond 100 years	Reduction or Increase	Number of years for this period	Qualifier	Justification
		-		

Basis?

Reversible?
Yes

Understood?
Yes

Ceased?
No

Habitats and Ecology

Testulea gabonensis is a large tree reaching 50 m in height and 1.5 m in diameter. The tree has some resemblance to *Lophira alata* Banks ex P.Gaertn. (also *Ochnaceae*), which occurs in the same region (Oduro, 2012). It is a long-lived pioneer, wind-dispersed, and gregarious tree species that usually occurs in primary humid rainforest on well-drained localities.

T. gabonensis bears hermaphrodite flowers. It is a pterochorous species and its seeds are dispersed by wind (Doucet, 2003). Unfortunately, the phenology is not sufficiently described. However, the species is well represented in permanent plots installed by the DYNAFAC Collective in Central Africa. The collection of data will help to fill the gap in the coming years.

IUCN Habitats Classification Scheme

Habitat	Season	Suitability	Major Importance?
1.6. Forest -> Forest - Subtropical/Tropical Moist Lowland	Resident	Suitable	Yes

Continuing Decline in Habitat

Continuing decline in area, extent and/or quality of habitat?	Qualifier	Justification
Yes	Observed	Despite the annual deforestation rate of 0.35% in Central (Vancutsem et al., 2021)

Life History

Generation Length	Justification	Data Quality
130	Minimum estimate of generation length for the species from the average growth rate, and the mean diameter of mature individuals (see Supplementary Material)	good

Age at maturity: female or unspecified

50 Years

Age at Maturity: Male
50 Years

Size at Maturity (in cms): Female
20

Size at Maturity (in cms): Male
20

Reproductive Periodicity
Annual

Annual Rate of Population Increase

Natural Mortality
1% (Ligot et al. 2022)

- **Systems**

System: Terrestrial

- **Plant / Fungi Specific**

Wild relative of a crop? No

Plant and Fungal Growth Forms
Tree - large

- **Use and Trade**

- **General Use and Trade Information**

Testulea gabonensis has been exploited for a long time. Nowadays it is even banned from exploitation in Gabon. At industrial level, *T. gabonensis* is used for construction, flooring, joinery, panelling, windows, doors, stairs, ship building, vehicle bodies, furniture, cabinet work, sporting goods, sculptures, carvings, turnery and sliced veneer. It is suitable for mine props, boxes, crates, toys, novelties and pattern making. In 1999 *Testulea gabonensis* ranked 14th on the list of most important export timbers of Gabon, with an export volume of 19,250 m³. In 2003, 5000 m³ of logs were exported from Gabon at an average price of US$ 135/m³, and in 2005 18,000 m³ at US$ 64/m³. In 2004 Congo exported 1000 m³ of sawn wood at an average price of US$ 155/m³ (Oduro, 2012).

At a local level, the bark is used in traditional medicine. Ground in water, it is applied to the nostrils to treat headache, and it is also used as an aphrodisiac.

Subsistence:	Rationale:	Local Commercial:	Further detail including information on economic value if available:
Yes	-	Yes	-

National Commercial Value: Yes

International Commercial Value: Yes

Is there harvest from captive/cultivated sources of this species? Yes

Trend in level of total offtake from wild sources: Stable

Trend in level of total offtake from domesticated sources: Unknown

- **Non- Consumptive Use**

Non-consumptive use of the species? true

- **Threats**

The main threats in the non-permanent domain across distribution range, are mainly related to habitat loss due to the destruction of natural environments as a result of population explosion and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging and the abusive harvesting of plant parts requested as non-wood forest products (Bradshaw et al., 2009). Due to the long history of exploitation, and the uncontrolled rate the species was banned for exploitation in Gabon.

However, it is exploited in Central Africa. No study considers logging as a direct driver of deforestation because of the low logging densities (1-2 stems per hectare). Studies on the impact of logging on the species and habitats are needed.

- **Threats Classification Scheme**

No past, ongoing, or future threats exist to this species. false

Threat	Timing	Scope	Severity	Impact Score
1.1. Residential & commercial development -> Housing & urban areas	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4

2.1.1. Agriculture & aquaculture -> Annual & perennial non-timber crops -> Shifting agriculture	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
2.2.2. Agriculture & aquaculture -> Wood & pulp plantations -> Agro-industry plantations	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
2.3.2. Agriculture & aquaculture -> Livestock farming & ranching -> Small-holder grazing, ranching or farming	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4
3.2. Energy production & mining -> Mining & quarrying	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
4.1. Transportation & service corridors -> Roads & railroads	Past, Likely to Return	Minority (<50%)	Negligible declines	Past Impact
5.3.1. Biological resource use -> Logging & wood harvesting -> Intentional use: (subsistence/small scale) [harvest]	Ongoing	Minority (<50%)	Rapid Declines	Medium Impact: 6
5.3.2. Biological resource use -> Logging & wood harvesting -> Intentional use: (large scale) [harvest]	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4
7.1.3. Natural system modifications -> Fire & fire suppression -> Trend Unknown/Unrecorded	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4

● Conservation

Testulea gabonensis is known to occur in any protected area or *ex situ* collections (BGCI, 2022). In certified forest concessions where the species is exploited, trails and or permanent forest plots are usually installed. These plots provide important data for (i) quantifying population dynamics processes at the stand level: mortality, growth and recruitment; (ii) phenological studies to determine the regular fruiting diameter (RFD). These tails and plots are managed in collaboration with forest concessions grouped within the DYNAFAC collective (see here for more information https://www.dynafac.org/fr/p/130/installation-de-dispositifs-de-suivi-de-la-dynamique-forestiere). Compilation of these data will provide important additional information for targeted silvicultural measures for the sustainable management of this species. First summaries have provided information on important parameters such as: mortality, growth etc (DYNAFAC, 2022; Ligot et al., 2022).

- *Testulea gabonensis* presents a very pronounced endemism, is recommended, depending on the population structure, to support the regeneration of the species.
- In addition, it will also be necessary to :

- Ensure the implementation of the recommendations of the Dynafac collective, including the establishment of a system for monitoring the populations of commercial species in the different forest types defined in a consensual manner;
- Set up monitoring and support systems for the regeneration of commercial species, prioritising species with regeneration deficits;
- Set up programmes to guarantee the phenotypic quality of commercial species populations: seed banks, seed stands, plus trees, seed orchards, conservation plantations;
- Consider threatened species in the delimitation of conservation series and in the identification of High Conservation Values;
- Update conservation statuses on a five-yearly basis, in particular by setting up a system of "green statuses";
- Define red lists adapted to regional or national contexts;
- Evaluate the status of cryptic species or species close to commercial species evaluated during this workshop.

- **Conservation Actions In- Place**

Action Recovery Plan	Note
Yes	Reforestation within forest concessions and others.

Systematic monitoring scheme	Note
Yes	The species is monitored in permanent plots installed within forestry companies in Central Africa (see here for more information https://www.dynafac.org/fr)

Occur in at least one PA	Note
Yes	Appear in at least 10 protected areas.

Percentage of population protected by PAs (0-100)	Note
1-10	-

Area based regional management plan	Note
Unknown	-

Invasive species control or prevention	Note
No	-

Harvest management plan	Note

Yes	In certified forest concessions, the species is exploited according to a management plan.

Subject to ex-situ conservation	Note
Yes	-

Included in international legislation	Note
No	-

Subject to any international management/trade controls	Note
Yes	FLEGTxxxxxx

- Important Conservation Actions Needed

Conservation Actions	Note
3.1.1. Species management -> Species management -> Harvest management	-
3.1.2. Species management -> Species management -> Trade management	-
3.4.2. Species management -> Ex-situ conservation -> Genome resource bank	-

- Research Needed

Research	Note
1.1. Research -> Taxonomy	-
1.2. Research -> Population size, distribution & trends	-
3.1. Monitoring -> Population trends	-
3.2. Monitoring -> Harvest level trends	-
3.3. Monitoring -> Trade trends	-

- Ecosystem Services

- Ecosystem Services Provided by the Species

	Importance:	Geographic range of benefit:
1. Water Quality	2 - Important	Global
3. Flood Control	2 - Important	Global

4. Climate Regulation	2 - Important	Global
5. Landscape	2 - Important	Global
6. Air Quality	2 - Important	Global
7. Nutrient Cycling	2 - Important	Global
8. Habitat Maintenance	2 - Important	Global
9. Provision of Critical Habitat	2 - Important	Global

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Testulea gabonensis Pellegr.

IUCN status using criterion A3

We adopted the criterion A3 to assess the projected population reduction (PPR) to be met in the future (up to a maximum of 100 years) of *Testulea gabonensis*. To quantify the projected population reduction, simulations must be performed on mature individuals and three generations with maximum 100 years according to **criterion A3**. We estimated mature individuals and generation length, as recommended by the IUCN guidelines (UICN, 2019).
A **mature individual** is an individual that can reproduce, able to bear flowers or seeds (fertile in plant kingdom). Since information and data on phenology are absent, we considered the minimum diameter in the forest inventories. The minimum diameter of mature individuals for this species was **20 cm**.
The **generation length** was the report between the mean diameter of mature individuals considering population structure and the mean increment. Given that the minimum diameter of mature individuals was 20 cm, we weighted the total number of trees by their diameter from 20 cm to 125 cm (Figure 1) to compute the number of mature individuals. The mean of mature individuals was **52 cm**. The **mean increment** of the species was **0.4 cm** from unpublished data. Thus, the **generation length** was 52 cm / 0.4 cm = **130 years**. The age at maturity (**50 years**) has been estimated as the report between the **minimum diameter of mature individuals** (**20 cm**) and the **mean increment** (**0.4 cm**).

Estimation of the projected population reduction (PPR)

We adopted the criterion A3 to assess the projected population reduction (PPR) to be met in the future (up to a maximum of 100 years). Because *Testulea gabonensis* is a widespread species in Central Africa, the PPR was estimated in central Africa.

PPR in Central Africa

In this region, forest management follows three different modalities: protected areas, production forests (logging concessions) and non-permanent forest domain. Based on occurrences, the natural range of this species includes all countries in Central Africa (Figure 1). The total natural area is estimated at 22 738 192.41 ha. Within this area, there are 14 506 608.6 ha (63.8%) for production forests, 1 731 602.72 ha (7.6%) for protected areas, and 6 499 981.071 ha (28.6%) for the non-permanent domain.
Three different PPR were thus estimated: PPR_{pa} in protected areas, PPR_{pf} in production forests and PPR_{np} in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas and then added to estimate the PPR_{C} in Central Africa.

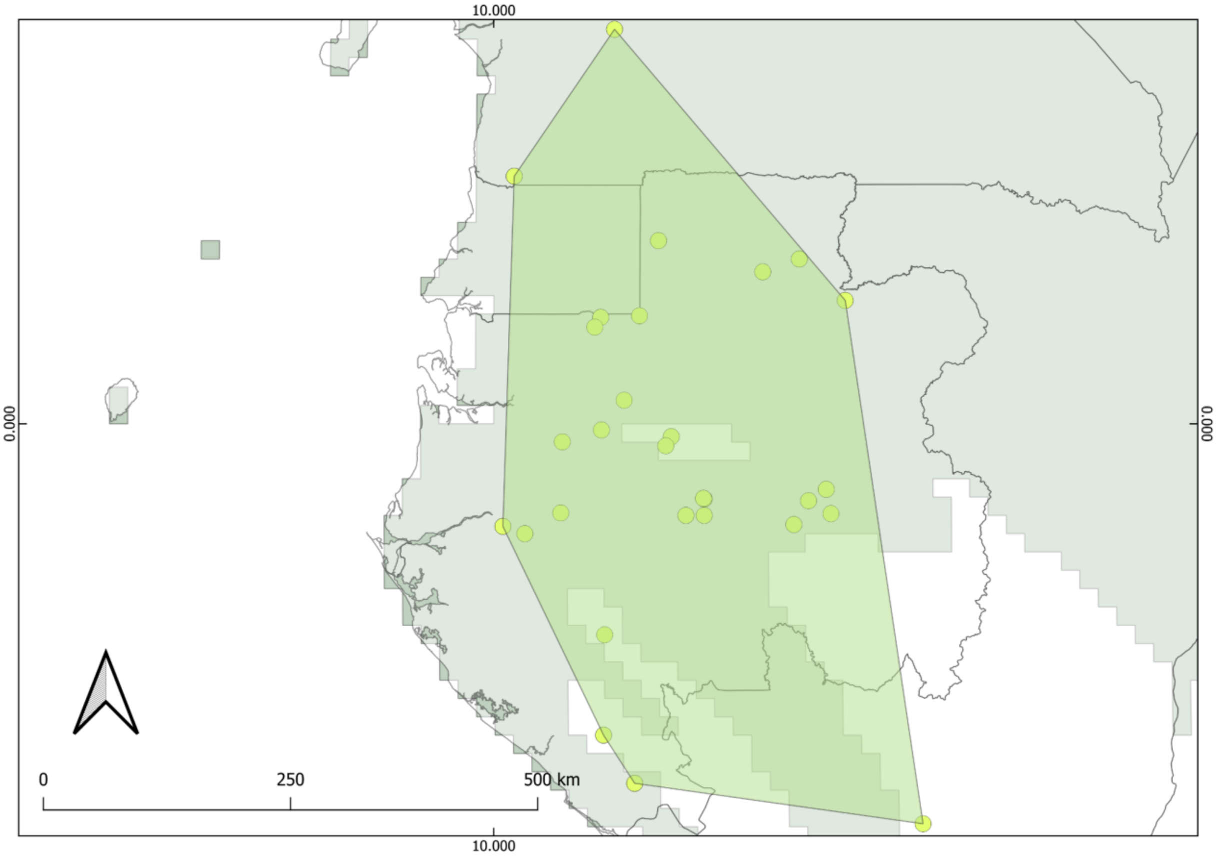

Figure 1. The range of *Testulea gabonensis* in Central Africa estimated from RAINBIO and CJB data, validated in December 2022 during a workshop with a group of experts in Gabon.

PPR in protected areas

Central Africa countries have allocated a higher proportion of their land to conservation than any other tropical regions, with relatively higher conservation success (Laurance et al., 2012). Indeed, most protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). They are currently representing a large part of forest and tree species conservation in Central Africa. Thus, the population of each species in protected areas (according to FRMI, 2018) covering its range was kept stable in the future over 100 years. **In these conditions, it was hypothesized that the PPR in protected areas for each species is 0%, suggesting no population reduction in the present and future.**

PPR in production forests

To quantify the evolution of the population of each timber species, matrix population models are widely used to study population dynamics (Picard & Liang, 2014). The population of this species was described at time t by a vector N_t corresponding to the density (number of trees ha^{-1}) in each diameter class (from 20 cm diameter to more than 120 cm). The density per diameter class were estimated using data of forest inventories that were carried out in 44 forest management units (FMU) of different logging companies in three countries (Cameroon, Central African Republic, and Gabon). Most logging companies followed a standardized inventory protocol (Réjou-Méchain et al., 2011). These forest inventory data covered about 9 million ha (Table 1), that are representative of 63% of Central Africa's production forests of this species. The number of trees sampled in Central Africa was 1 363 772 with a density of 0.15 tree ha^{-1}. Large-scale commercial inventories have already been found useful in the identification of large-scale patterns in Central Africa (Réjou-Méchain et al., 2011). Using a large-scale data of commercial forest inventories, Réjou-Méchain et al. (2021) jointly model the distribution in abundance of the most dominant tree species and produce continuous maps of the floristic and functional composition of central African forests.

Table 1. Forest management units (FMU) sampled in Central Africa (Cameroon, CAR: Central African Republic, DRC: Democratic Republic of the Congo, EG: Equatorial Guinea, Gabon and RCongo: Republic of the Congo).

	Sampling	
Country	FMU	Area (ha)
Cameroon	2	259 183.06
CAR	2	1 147 708
DRC	-	-
EG	-	-
Gabon	40	7 686 686
RCongo	-	-
Total	44	9 093 577.06

The Usher matrix model was used to simulate the evolution of the recovery rate of all population and the exploitable stock of each species after logging in Central Africa. According to the Usher assumption, between t and t+1, an individual can either stay alive in the same class, stay alive and move up to the next class, or die; it cannot move up by more than one class or move backwards, i.e., the individual is free from diameter shrinkage (Picard et al., 2012). The Usher matrix model (U) considers three parameters (mortality, recruitment and growth rate that are constant in time) to estimate the transition probabilities:

$$U = \begin{pmatrix} q_1 + g_1 & g_2 & \cdots & \cdots & g_I \\ p_1 & q_2 & 0 & \cdots & 0 \\ 0 & \ddots & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & p_{I-1} & q_I \end{pmatrix}$$

where q_i is the probability for an individual to stay alive in class i between two consecutive time steps, p_i is the upgrowth transition rate (the probability for an individual to grow up from class i to class i +1), and g_i is the recruitment rate (Picard & Liang, 2014).

Tree mortality, recruitment and growth are three central processes for predicting the dynamics of tropical rainforests and estimating these three processes requires long-term monitoring in difficult field conditions (Picard & Gourlet-Fleury, 2008). These processes determine the evolution of the species population in the forest stand. The natural mortality is defined as the number of standing dead trees, and few studies have reported estimates of mortality rates in Central Africa. Data about tree mortality are still scarce and it does not allow to precisely model the mortality rate for each species and size class. Given the current state of knowledge, it appears reasonable to use a fixed mortality rate of 1% for all species and size classes, in agreement with the results of Ligot et al. (2022) on 21,180 trees belonging to 42 timber species of Central Africa annually monitored from one to seven years.

The recruitment integrates fruiting and seed dispersal from mother trees, and the survival of plant juveniles until they reach a size threshold where they are included in the stand. The recruitment term in the model is the average annual input of new individuals into the first size class from 20 cm. The recruitment events, like mortality events, are infrequent and thus difficult to model (Karsenty & Gourlet-Fleury, 2006). The population structure showed a curve in "decreasing exponential" suggesting a good regeneration (Figure 2). To model the recruitment, we used the hypothesis defined as the recruitment rate that would maintain a constant number of trees in the first diameter class. Claeys et al. (2019) projected the future forest dynamics up to the end of the century and they showed that projected mortality and recruitment rates in 2099 could not differ from the ones observed today. Thus, the hypothesis on the recruitment and the mortality rate is used in the future (up to 100 years) as they do today. Given that the large data on the diameter growth of the species is absent, the **mean increment** of the species was **0.4 cm** from unpublished data in Gabon.

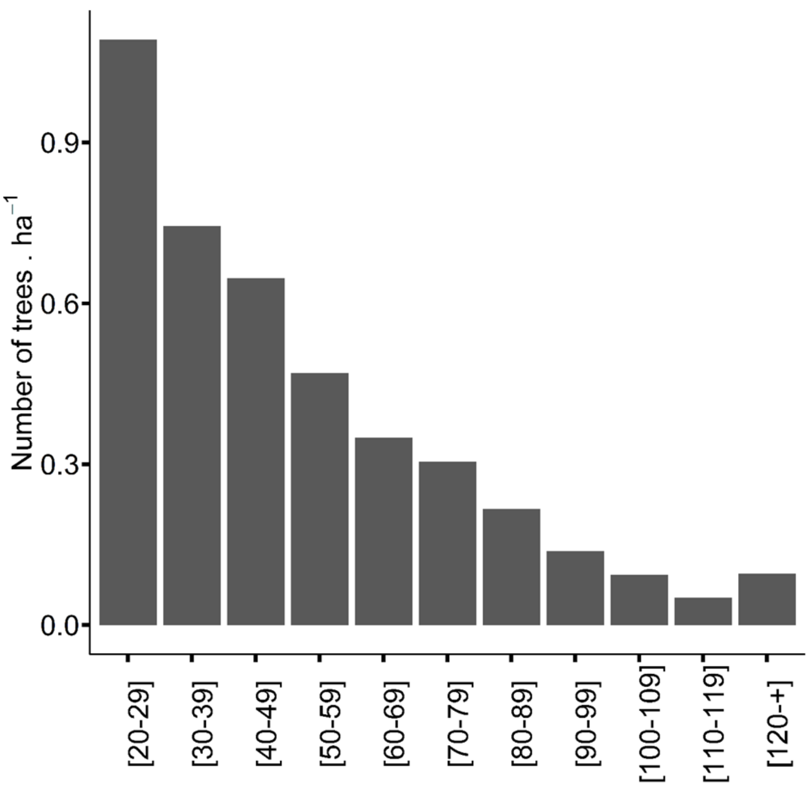

Figure 2. Population structure of *Testulea gabonensis* defined using the number of trees per ha and per diameter class (from 20 cm, from 44 logging concessions in Central Africa covering an area of 9 093 577.06 ha).

The transition probabilities of three parameters (mortality, growth, and recruitment rate) allowed making the harvested matrix. The logging operations have been modeled using the logging parameters (minimum cutting diameter, cutting and damage rate). The minimum cutting diameters were obtained from decrees of application of the forestry administrations (MCD_A) at the country level and the one used in the management plan (MCD_M, with $MCD_M \geq MCD_A$) at the logging company level. At the Central Africa level, we weighted the MCD_A and MCD_M values to the occupied area and **$MCD_A = MCD_M = 80$ cm**. The cutting rate (CA), which defines the proportion of harvested trees (trees with a diameter greater than MCD_A or MCD_M), was given by logging companies, and it was also weighted at the Central Africa level with a value of 74%. Given the current state of knowledge, it appears reasonable to use a fixed damage rate caused by logging of 7% of the initial population that disappears (Durrieu de Madron, Fontez, et al., 2000). The average cutting cycle (i.e. the period between two successive logging operations) is 28 years (FRMI, 2018), but we used 25 years to simplify computation of four simulations reaching 100 years (25, 50, 75 and 100 years), as requested by IUCN criterion A.

The Figure 3 shows the PPR in production forests for the *Testulea gabonensis*. The reduction in the population of each species was then calculated as the difference between the initial numbers of mature individuals and the predicted numbers of mature individuals predicted after 100 years. **The PPR in production forest was – 28.42 % over 100 years.**

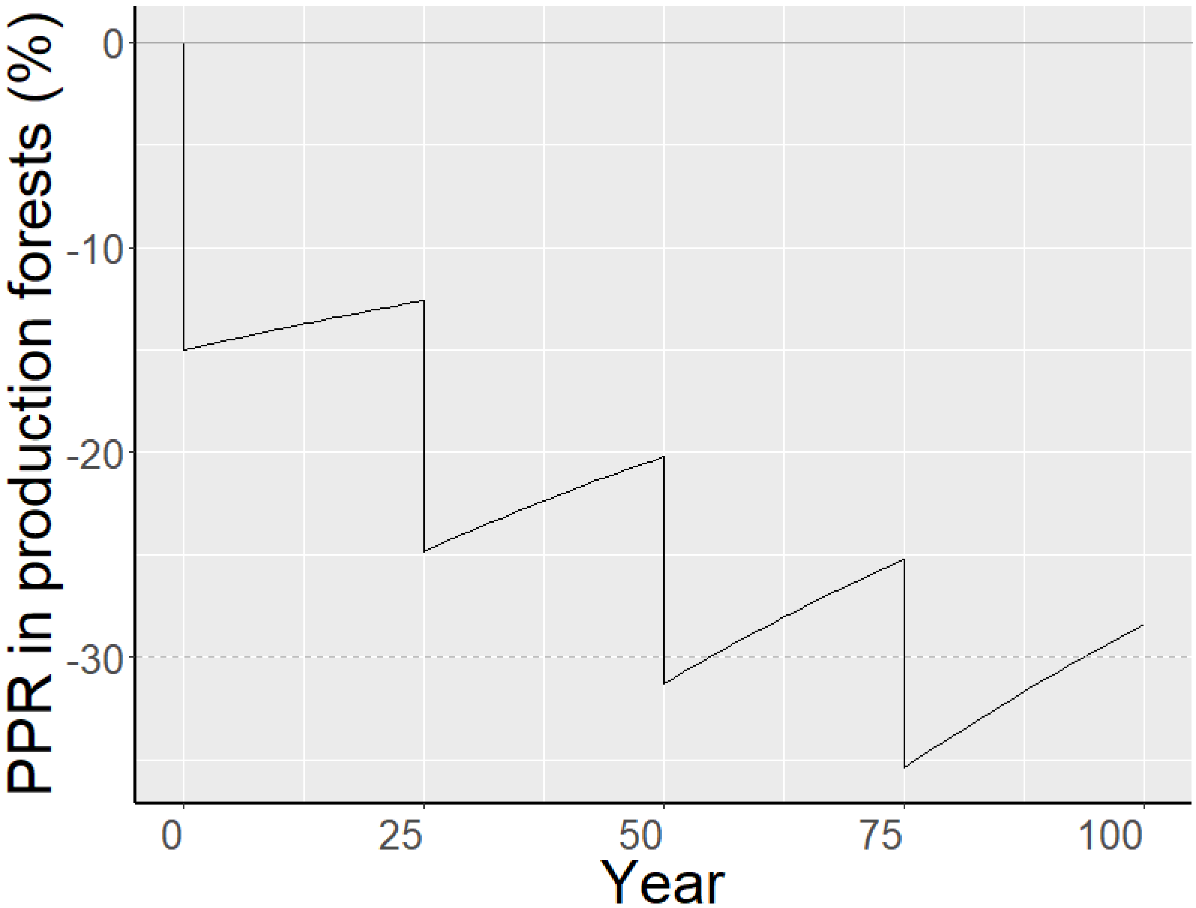

Figure 3. Simulations showing the projected population reduction (PPR) from diameter of mature individuals (20 cm) in production forests for the *Testulea gabonensis* for constant recruitment over 100 years.

PPR in the non-permanent forest domain

The major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanization, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Based on the large range of this species in Central Africa, the harvested volume from illegal logging and legal logging are 10% and 90%, respectively (FRMI 2018). In this condition, it was hypothesized that there is 90% of PPR from production forests and 10% of PPR from illegal logging in 100% PPR due to forest logging. Given that the PPR of production forests associated with its forest area was known, we deduced the PPR and forest area of illegal logging from those of the production forests. As a result, 1 611 845.4 ha were affected for the illegal logging for this species. The non-permanent domain area (6 499 981.071 ha) was considered as the area which was related to today's deforestation rate of 0.02% $year^{-1}$ in the geographic range of this species (Eba'a et al., 2022). This is a conservative value since it will probably decrease in the future (Swamy et al., 2018).

PPR global = PPR in Central Africa

We thus had three different PPR: PPR_{pa} in protected area, PPR_{pf} in production forests, and PPR_{np} in non-permanent domain. The global PPR was then computed after weighting the three values by their relative forest areas:

$$PPR = \frac{(S_{pa} \times PPR_{pa}) + (S_{pf} \times PPR_{pf}) + (S_{np} \times PPR_{np})}{S_{pa} + S_{pf} + S_{np}}$$

where S_{pa}, S_{pf}, and S_{np} are forest areas in protected area, production forests and non-permanent domain, respectively.

The criterion A3 based on (c) a decline in area of occupancy (AOO), the extent of occurrence (EOO), and/or habitat quality; and (d) potential levels of exploitation, has been computed as follows: (i) 30%≤PPR<50%, the species is considered as Vulnerable (VU); (ii) 50%≤PPR <80%, the species is considered as Endangered (EN), and PPR ≥ 80%, the species is considered as Critically Endangered (CR).

The PPR global in the distribution range of the *Testulea gabonensis* was **– 18.4%**. This PPR is < 30%, suggesting that this species is not threatened in its geographic area.

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10.20 Annexe 20. *Tieghemella africana* - Pierre

Draft

Tieghemella africana - Pierre

PLANTAE - TRACHEOPHYTA - MAGNOLIOPSIDA - ERICALES - SAPOTACEAE - Tieghemella – africana

Common Names: Douka, Makore, Ukola

Synonyms: *Dumoria africana* (Pierre) Dubard (1915),
Mimusops africana (Pierre) Lecomte (1921),
Baillonella africana (Pierre) Baehni (1965).

Red List Status
NT - Near Threatened, A3cd (IUCN version 3.1)

- **Red List Assessment**

- **Assessment Information**

Date of Assessment: 2022-09-01

Assessor(s): Monthe, F., Loubota, G., Ligot, G., Texier, N., Stévart, T. & Doucet, JL.

Reviewer(s):

Institution(s):

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Regions: Global

- **Identification Description**

Tieghemella africana is a large tree exceeding 40 m in height and 1.5 m in diameter, straight and cylindrical with a dark ball-shaped crown carried by large sinuous branches, with its base serrations becoming very prominent in large subjects, more rarely buttresses. Its brown to reddish-brown trunk is marked with vertical cracks of varying depths that break off into elongated scales. Its pink-red to orange slice lets out a white latex. It may have a slight fruity smell. Its simple alternate leaves are more or less grouped in tufts at the end of the branches. They are leathery, glabrous, lanceolate (8-15 x 4-6 cm), with pointed to rounded apex, and an attenuated base extending on the long and thin petiole of 1.5-3.5 cm. The main vein is prominent below, while the secondaries (16-18 pairs) and the tertiaries are hardly visible but parallel to each other. Its white flowers are grouped by 2 or 3 at the end of the branches. Its big fleshy fruits, yellowish green then reddish brown, are ovoid (5-10 cm diameter), with the often pointed end. Their yellow flesh contains 1 to 3 large, compressed kidney-shaped oleaginous seeds with a very hard shiny beige tegument (j5-7 x 3 cm), and crossed by a broad rough scar.
The young stems of *Tieghemella africana* are very difficult to distinguish in the field. They can be confused with other Sapotaceae such as *Autranella congolensis* (mukulungu) and *Baillonella toxisperma* (moabi). However, the characteristics of the leaves allow us to distinguish them without too much difficulty.

- **Assessment Rationale**

Tieghemella africana is a large tree of African evergreen forests in the lower guinean region. It is a long-lived and non-gregarious shade-tolerant species characteristic of Atlantic evergreen rainforests. It is distributed from Cameroon to Democtatic Republic of Congo. Based on a 2 x 2 km cell size, the AOO of this species is estimated as 118 km^2 with a minimum of 51 locations (number of forest management units of different logging companies in Central Africa). This species is not "Vulnerable" status under criterion B2. The EOO is calculated as 697 500 km^2, above the upper threshold for "Vulnerable" status under criterion B1.

Commonly known as Douka the species is available on the international timber market in limited quantities. Since the 2000s, the species has been very little exploited and only 4 700 m³ of logs exported from Congo Basin in 2018. In addition, the species has been prohibited from exploitation in Gabon since 2010. The population structure showed a decreasing suggesting a good regeneration (see Supplementary Material). Seeds are mainly dispersed by African forest elephants (*Loxodonta cyclotis*) (Scalbert et al., 2022), assessed as Critically Endangered A2abd (Gobush et al., 2021). It has relatively low population densities of 0.03 stems.ha^{-1} (diameter at breast height, dbh ≥ 20 cm) and fairly fast growth rates of 0.51 ± 0.24 cm/year in Gabon (see Supplementary Material). Given its stem density and the mean annual increment, we estimate the number of mature individuals (dbh ≥ 80 cm, see Supplementary Material) over 10 000 across the distribution range, well above the threatened category under criteria C and D.

Considering the species' generation length (209 years), an inference of population reduction for three generations in the past is impossible following A1 and A2 criteria. Based on simulations of the expected population reduction in its distribution range including protected areas, non - permanent forest areas, and production forests (logging concessions), we estimated a population reduction of 13.5% (regardless of the recruitment scenario, see Supplementary Material) in the next 100 years below the threshold to be considered threatened under criterion A3. An assessment of the population reduction according to criterion A4 does not apply, considering that one to two generations back and one to two generations forward would likely introduce high levels of uncertainty due to the lack of data to efficiently model the reduction of population size in the past. No quantitative analysis of the probability of extinction in the wild was conducted, and therefore criterion E does not apply.

Considering (i) the population density and the natural regeneration, (ii) taking into account the impact of the reduction of populations of main dispersers, the reduction of population in the future across the distribution range, the species is assessed as near threatened NT, A3cd.

Reasons for change

Reason(s) for Change in Red List Category from the Previous Assessment:

Tieghemella africana was previously assessed as "Endangered" by the IUCN (https://www.iucnredlist.org/species/33189/9759094) at the African Regional Workshop (Conservation & Sustainable Management of Trees, Zimbabwe, July 1996), 1998, following the A1cd criterion. During the last few years, important data have been produced on the self-ecology, population dynamics (growth, recruitment, mortality) of the species (DYNAFAC, 2022; Ligot et al., 2022). Moreover, a new version of the IUCN guidelines is available (from version 2.3 to 3.1). Given all this information, it was necessary to produce a new assessment of the species.

• Distribution

• Geographic Range

Tieghemella africana is found in Cameroon, Equatorial Guinea, Gabon, Congo and Democratic Republic of Congo. However, a few specimens have been reported from Ivory Coast, where the related species *Tieghemella heckelii* (A.Chev.) Roberty occurs. The extent of occurrence (EOO) in native area is estimated at 697 527 km^2 across its native distribution range.

• Area of Occupancy (AOO)

Estimated area of occupancy (AOO) - in km2	Justification
118	AOO has been estimated using ConR based on the 2 × 2 km cell size of 97 occurrences from CJBD and RAINBIO

Continuing decline in area of occupancy (AOO)	Qualifier	Justification
Yes	Inferred	The species has suffered from reduction in area of occupancy, due to habitat degradation and deforestation in Central Africa forest (Vancutsem et al., 2021).

• Extent of Occurrence (EOO)

Estimated extent of occurrence (EOO)- in km2	EOO estimate calculated from Minimum Convex Polygon	Justification
697 527	true	Calculated using ConR based on 97 known occurrences from CJBD and RAINBIO

Continuing decline in extent of occurrence (EOO)	Qualifier	Justification
Yes	Observed	The species has certainly undergone extent of occurrence reduction in Central Africa, linked to habitat degradation (Vancutsem et al., 2021)

- Locations Information

Number of Locations	Justification
50-100	More than 51 locations. Largely distributed species in Central Africa

Continuing decline in number of locations	Qualifier	Justification
No		

Extreme fluctuations in the number of locations	Justification
No	

- Very restricted AOO or number of locations (triggers VU D2)

Very restricted in area of occupancy (AOO) and/or # of locations	Justification
No	-

- Elevation / Depth / Depth Zones

Elevation Lower Limit (in metres above sea level): 0

Elevation Upper Limit (in metres above sea level): 1600

- Map Status

Map Status	Use map from previous assessment	How the map was created, including data sources/methods used:	Please state reason for map not available:	Data Sensitive?	Justification	Geographic range this applies to:	Date restriction imposed:

Done	-	Qgis	-	-	-	-	-

- **Biogeographic Realms**

Biogeographic Realm: Afrotropical

- **Occurrence**

- **Countries of Occurrence**

Country	Presence	Origin	Formerly Bred	Seasonality
Cameroon	Extant	Native	-	Resident
Democratic Republic of Congo	Extant	Native	-	Resident
Equatorial Guinea -> Equatorial Guinea (mainland)	Extant	Native	-	Resident
Gabon	Extant	Native	-	Resident
Republic of Congo	Extant	Native	-	Resident

- **Population**

Tieghemella africana is a Lower Guinea species, widely distributed in Central Africa from south-western Cameroon, Equatorial Guinea, and Gabon to the Republic of Congo. Its average density is 0.03 stems.ha^{-1} (dbh ≥ 20 cm) in Central Africa (see Supplementary Material). The species is considered as rare in Central Africa. The average growth was 0.51 ± 0.24 cm/year in Gabon (see Supplementary Material).

In plantations in Gabon, seedlings averaged 9 m in height 6 years after planting. Survival rate is about 90% and was almost equal when plants were exposed to direct sunlight compared to planting in the shade of a forest cleared of undergrowth. Young trees grew faster when planted in light shade; 11-year-old trees averaged 18.5 m tall and 13 cm in diameter in light shade, and 15.5 m tall and 9 cm in diameter in full sun. In a 66-year-old plantation, average annual growth was 0.4 cm in diameter (Lemmens, 2005).

The legal minimum cutting diameter “MCD" varies across its distribution range, (60 cm in Cameroon and Democratic Republic of Congo, 80 cm in Republic of Congo, 90 cm in Gabon where it has been banned from exploitation). Furthermore, the mean weighted cutting and the average implemented MCD was 85 cm (see Supplementary Material). In the legal logging concession of central Africa, the MCD must be adapted to ensure sufficient recovery rates after each cutting cycle. At the Central Africa level, we weighted the MCD values to the occupied area with MCD = 85 cm (see Supplementary Material). Data is currently collected through the DYNAFAC collective's network of permanent plots and trails. These data are useful to set up adequate strategies of species conservation.

Using the Red List criterion A3, the projected population reduction (PPR) to be met in the future (100 years because the generation length of the species is 209 years) of the *T. africana* population was assessed across its distribution range. Because *T. africana* is a widespread species in Central Africa, the PPR was estimated in central Africa. In Central Africa, three different PPR were thus estimated: PPRpa in protected areas, PPRpf in production forests and PPRnp in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas. First, protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). The population of the species in protected areas covering its range was kept stable in the future over 100 years, suggesting that the PPR in protected areas was 0%. Second, the evolution of the *T. africana* population was simulated using an Usher matrix model to estimate the PPR of production forests (logging concessions, PPRpf). The simulations were initialised using the density (number of trees.ha-1) per diameter class (from 80 cm diameter, mature individuals) from forest management inventories of logging companies. The evolution of this initial population depended on several demographics (recruitment, mortality, and growth rate) and logging parameters (minimum cutting diameter, cutting and damage rate) that were adjusted using data of permanent tree plot monitoring. Thus, the density of *T. africana* in 100 years was predicted with a logging event every 25 years, which corresponds to the average cutting cycle in Central Africa. PPRpf was then calculated as the difference between initial and final number of trees. Third, the major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Illegal logging and the habitat lost from deforestation rate have been both activities that allowed estimating the PPRnp in non-permanent domains. The global PPR was then computed after weighting the three values (PPRpa, PPRpf, PPRnp) by their relative forest areas. The global PPR result (13.5%) was found to be lower than 30% (for further information about this methodology, see Supplementary Material).

- **Population Information**

Current Population Trend: Decreasing

Extreme fluctuations? (in # of mature individuals)	Justification
No	-

Severely fragmented?	Justification
No	-

Continuing decline in mature individuals?	Qualifier	Justification

Continuing decline % in mature individuals within 3 generations or 10 years, whichever is longer (up to max. of 100 years in the future)	Qualifier	Justification

Extreme fluctuations in the number of subpopulations	Justification
No	-

Continuing decline in number of subpopulations	Qualifier	Justification
No	-	-

All individuals in one subpopulation: No

Number of Subpopulations	Justification	Subpopulation Details	Subpopulation description	Number of mature individuals	Subpopulation trend	Qualifier	Location type	Number of Subpopulations	Location bounding box	Location coordinates	Notes
0		-	-	-	-	-	-	-	-	-	-

- Population Reduction - Past

Percent Change in past	Reduction or Increase	Qualifier	Justification

Basis?

Reversible?

Understood?

Ceased?

- Population Reduction - Future

Percent Change in future	Reduction or Increase	Qualifier	Justification

13.5%	Reduction	Projected	Using the Red List criterion A3, the projected population reduction (PPR) to be met in the future (100 years because the generation length of the species is 209 years) of the *T. africana* population was assessed across its distribution range. Because *T. africana* is a widespread species in Central Africa, the PPR was estimated in central Africa. In Central Africa, three different PPR were thus estimated: PPRpa in protected areas, PPRpf in production forests and PPRnp in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas. First, protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). The population of the species in protected areas covering its range was kept stable in the future over 100 years, suggesting that the PPR in protected areas was 0%. Second, the evolution of the *T. africana* population was simulated using an Usher matrix model to estimate the PPR of production forests (logging concessions, PPRpf). The simulations were initialized using the density (number of trees.ha-1) per diameter class (from 80 cm diameter, mature individuals) from forest management inventories of logging companies. The evolution of this initial population depended on several demographics (recruitment, mortality, and growth rate) and logging parameters (minimum cutting diameter, cutting and damage rate) that were adjusted using data of permanent tree plot monitoring. Thus, the density of *T. africana* in 100 years was predicted with a logging event every 25 years, which corresponds to the average cutting cycle in Central Africa. PPRpf was then calculated as the difference between initial and final number of trees. Third, the major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Illegal logging and the habitat lost from deforestation rate have been both activities that allowed estimating the PPRnp in non-permanent domains. The global PPR was then computed after weighting the three values (PPRpa, PPRpf, PPRnp) by their relative forest areas. The global PPR result (13.5%) was found to be lower than 30%. For further information about this methodology, see Supplementary Material.

Basis?
b) an index of abundance appropriate for the taxon, d) actual or potential levels of exploitation

- **Population Reduction - Ongoing**

Both: Percent Change over any 10 year or 3 generation period, whichever is longer, and must include both past and future, future can't go beyond 100 years	Reduction or Increase	Number of years for this period	Qualifier	Justification

Basis?

Reversible?
Yes

Understood?
Yes

Ceased?
No

- **Habitats and Ecology**

Tieghemella africana is a large tree of Atlantic dense evergreen forests reaching 40 m in height and 1.5 m in diameter with serifs or buttresses. The young stems can be confused with other Sapotaceae such as *Autranella congolensis* (mukulungu) and *Baillonella toxisperma* (moabi). However, the characteristics of the leaves allow us to distinguish them without too much difficulty.

It is long-lived shade tolerant and non-gregarious tree species whose roots associate with arbuscular mycorrhizal fungi and it regenerates in forest gaps of the chablis type.

The species bears hermaphrodite flowers and seeds are mainly dispersed by elephants (zoochory) from November to January (Meunier et al., 2015; Scalbert et al., 2022). The species is well represented in the trail and complete plots installed by the DYNAFAC Collective in Central Africa. These data will help to fill the gap in the future.

- **IUCN Habitats Classification Scheme**

Habitat	Season	Suitability	Major Importance?
1.6. Forest -> Forest - Subtropical/Tropical Moist Lowland	Resident	Suitable	Yes

- **Continuing Decline in Habitat**

Continuing decline in area, extent and/or quality of habitat?	Qualifier	Justification
Yes	Observed	Despite the annual deforestation rate of 0.35% in Central (Vancutsem et al., 2021)

- **Life History**

Generation Length	Justification	Data Quality
209	Minimum estimate of generation length for the species from the average growth rate, and the mean diameter of mature individuals (see Supplementary Material)	good

Age at maturity: female or unspecified
159 Years

Age at Maturity: Male
159 Years

Size at Maturity (in cms): Female
80

Size at Maturity (in cms): Male
80

Reproductive Periodicity
Annual

Annual Rate of Population Increase

Natural Mortality
1% (Ligot et al. 2022)

- **Systems**

System: Terrestrial

- **Plant / Fungi Specific**

Wild relative of a crop? No

Plant and Fungal Growth Forms
Tree - large

- **Use and Trade**

- **General Use and Trade Information**

Tieghemella africana has been exploited for a long time, but log production was limited as the species appear in low density in natural stands. Logging of this species is prohibited in Gabon. On the international market, the wood is used for furniture making, interior and exterior joinery, flooring, doors, vehicle frames, sporting goods, railroad sleepers, boat building, turning and carving, and produces good quality, decorative veneer panels, often used over plywood. Between 2001 and 2003, Cameroon and Gabon produced nearly 77,000 m³ of logs (Lemmens, 2005). Nevertheless, since the 2000s, the species has been very little exploited, in 2018 the Congo Basin exported more than 4 700 m³ of logs (FRMi, 2018).

The seeds are rich in an edible fat, at local level they are appreciated as cooking oil or seasoning. In Gabon, this fat is also applied externally to treat rheumatism.

Subsistence:	Rationale:	Local Commercial:	Further detail including information on economic value if available:
Yes	-	Yes	-

National Commercial Value: Yes
International Commercial Value: Yes
Is there harvest from captive/cultivated sources of this species? Yes
Trend in level of total offtake from wild sources: Stable
Trend in level of total offtake from domesticated sources: Unknown

- **Non- Consumptive Use**

Non-consumptive use of the species? true

• Threats

The main threats in the non-permanent domain across distribution range, are mainly related to habitat loss due to the destruction of natural environments as a result of population explosion and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging and the abusive harvesting of plant parts requested as non-wood forest products (Bradshaw et al., 2009). Due to the long history of exploitation, and the uncontrolled rate the species was banned for exploitation in Gabon. In Central Africa, illegal logging accounts for nearly 46% of total log production (FRMi, 2018). This production generally comes from unallocated forest areas (non-permanent forest domain).

• Threats Classification Scheme

No past, ongoing, or future threats exist to this species. false

Threat	Timing	Scope	Severity	Impact Score
1.1. Residential & commercial development -> Housing & urban areas	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4
2.1.1. Agriculture & aquaculture -> Annual & perennial non-timber crops -> Shifting agriculture	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
2.2.2. Agriculture & aquaculture -> Wood & pulp plantations -> Agro-industry plantations	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
2.3.2. Agriculture & aquaculture -> Livestock farming & ranching -> Small-holder grazing, ranching or farming	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4
3.2. Energy production & mining -> Mining & quarrying	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
4.1. Transportation & service corridors -> Roads & railroads	Past, Likely to Return	Minority (<50%)	Negligible declines	Past Impact
5.3.1. Biological resource use -> Logging & wood harvesting -> Intentional use: (subsistence/small scale) [harvest]	Ongoing	Minority (<50%)	Rapid Declines	Medium Impact: 6
5.3.2. Biological resource use -> Logging & wood harvesting -> Intentional use: (large scale) [harvest]	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4

7.1.3. Natural system modifications -> Fire & fire suppression -> Trend Unknown/Unrecorded	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4

● Conservation

Tieghemella africana is known to occur in any protected area or *ex situ* collections (BGCI, 2022). In certified forest concessions where the species is exploited, trails and or permanent forest plots are usually installed. These plots provide important data for (i) quantifying population dynamics processes at the stand level: mortality, growth and recruitment; (ii) phenological studies to determine the regular fruiting diameter (RFD). These tails and plots are managed in collaboration with forest concessions grouped within the DYNAFAC collective (see here for more information https://www.dynafac.org/fr/p/130/installation-de-dispositifs-de-suivi-de-la-dynamique-forestiere). Compilation of these data will provide important additional information for targeted silvicultural measures for the sustainable management of this species. First summaries have provided information on important parameters such as: mortality, growth etc. (DYNAFAC, 2022; Ligot et al., 2022).

In addition, it will also be necessary to :

- Ensure the implementation of the recommendations of the Dynafac collective, including the establishment of a system for monitoring the populations of commercial species in the different forest types defined in a consensual manner;
- Set up monitoring and support systems for the regeneration of commercial species, prioritising species with regeneration deficits;
- Set up programmes to guarantee the phenotypic quality of commercial species populations: seed banks, seed stands, plus trees, seed orchards, conservation plantations;
- Consider threatened species in the delimitation of conservation series and in the identification of High Conservation Values;
- Update conservation statuses on a five-yearly basis, in particular by setting up a system of "green statuses";
- Define red lists adapted to regional or national contexts;
- Evaluate the status of cryptic species or species close to commercial species evaluated during this workshop.

● Conservation Actions In- Place

Action Recovery Plan	Note
Yes	Reforestation within forest concessions and others.

Systematic monitoring scheme	Note

Yes	The species is monitored in permanent plots installed within forestry companies in Central Africa (see here for more information https://www.dynafac.org/fr)

Occur in at least one PA	Note
Yes	The species may appear in at least 100 protected areas considering it distribution range

Percentage of population protected by PAs (0-100)	Note
1-10	Considering protected area across species distribution range

Area based regional management plan	Note
Unknown	-

Invasive species control or prevention	Note
No	-

Harvest management plan	Note
Yes	In certified forest concessions, the species is exploited according to a management plan.

Subject to ex-situ conservation	Note
Yes	-

Included in international legislation	Note
No	-

Subject to any international management/trade controls	Note
Yes	FLEGT

- **Important Conservation Actions Needed**

Conservation Actions	Note
3.1.1. Species management -> Species management -> Harvest management	-
3.1.2. Species management -> Species management -> Trade management	-

3.4.2. Species management -> Ex-situ conservation -> Genome resource bank	-

- **Research Needed**

Research	Note
1.2. Research -> Population size, distribution & trends	-
3.1. Monitoring -> Population trends	-
3.2. Monitoring -> Harvest level trends	-
3.3. Monitoring -> Trade trends	-

- **Ecosystem Services**

- **Ecosystem Services Provided by the Species**

	Importance:	Geographic range of benefit:
1. Water Quality	2 - Important	Global
3. Flood Control	2 - Important	Global
4. Climate Regulation	2 - Important	Global
5. Landscape	2 - Important	Global
6. Air Quality	2 - Important	Global
7. Nutrient Cycling	2 - Important	Global
8. Habitat Maintenance	2 - Important	Global
9. Provision of Critical Habitat	2 - Important	Global

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Tieghemella africana Pellegr.

IUCN status using criterion A3

We adopted the criterion A3 to assess the projected population reduction (PPR) to be met in the future (up to a maximum of 100 years) of *Tieghemella africana*. To quantify the projected population reduction, simulations must be performed on mature individuals and three generations with maximum 100 years according to **criterion A3**. We estimated mature individuals and generation length, as recommended by the IUCN guidelines.

A **mature individual** is an individual that can reproduce, able to bear flowers or seeds (fertile in plant kingdom). To quantify the mature individuals for this species, we used phenological data of DYNAFAC network[31] from a combined dataset of 32 trees in Gabon (one site). Minimum and maximum sampled diameter ranged from 25 to 150 cm (median 91 cm). The monitoring period ranged from 2021 to 2022. We assumed that the monitoring period was long enough to capture at least one reproductive event per tree such that trees without observed flowering/fruiting events were considered non-reproductive (60 percent of all monitored trees were non-reproductive). We used the methodology for the size at reproduction of canopy tree species in Central Africa (Ouédraogo et al., 2018): the **diameter of a mature individual** was obtained after fitting logistic regressions and the level of 50% of the probability to produce the flower or fruit was adopted for this species. Using this approach, the diameter of a mature individual was obtained after setting the 50% probability to produce flowers or fruits. The minimum diameter of mature individuals for this species was **80 cm**.

The **generation length** was the report between the mean diameter of mature individuals considering population structure and the mean increment. Given that the minimum diameter of mature individuals was 80 cm, we weighted the total number of trees by their diameter from 80 cm to 125 cm to compute the number of mature individuals. The mean of mature individuals was **105 cm**. The **mean increment** of the species was **0.51 cm**, obtained from 35 observations of unpublished data in Gabon. Thus, the **generation length** was 105 cm / 0.51 cm = **209 years**. The age at maturity (**159 years**) has been estimated as the report between the **minimum diameter of mature individuals** (**80 cm**) and the **mean increment** (**0.51 cm**).

Estimation of the projected population reduction (PPR)

We adopted the criterion A3 to assess the projected population reduction (PPR) to be met in the future (up to a maximum of 100 years). Because *Tieghemella africana* is a widespread species in Central Africa, the PPR was estimated in central Africa.

[31] https://www.dynafac.org/en

PPR in Central Africa

In this region, forest management follows three different modalities: protected areas, production forests (logging concessions) and non-permanent forest domain. Based on occurrences, the natural range of this species includes all countries in Central Africa (Figure 1). The total natural area is estimated at 69 334 353.52 ha. Within this area, there are 27 550 491.4 ha (39.7%) for production forests, 5 613 967.72 ha (8.1%) for protected areas, and 36 169 894.35 ha (52.2%) for the non-permanent domain.

Three different PPR were thus estimated: PPR_{pa} in protected areas, PPR_{pf} in production forests and PPR_{np} in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas and then added to estimate the PPR_{C} in Central Africa.

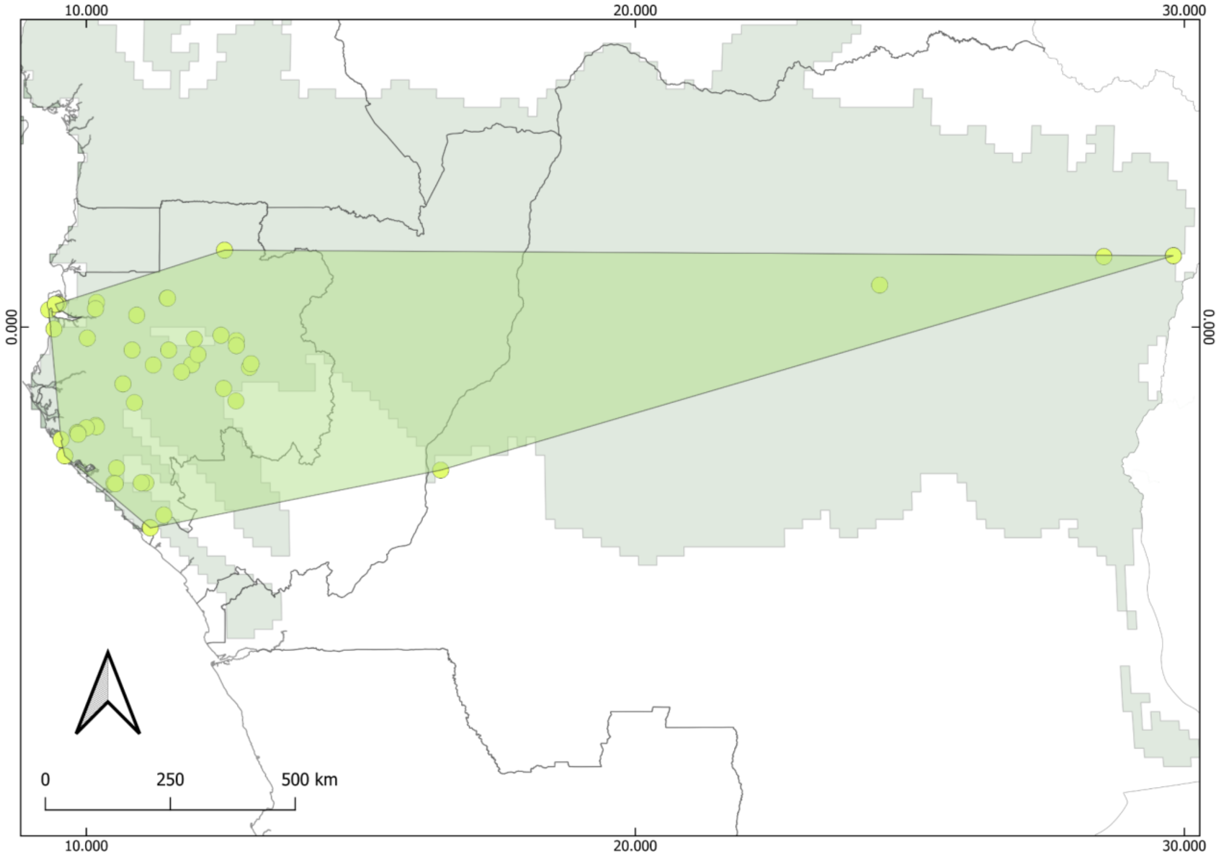

Figure 1. The range of *Tieghemella africana* in Central Africa estimated from RAINBIO and CJB data, validated in December 2022 during a workshop with a group of experts in Gabon.

PPR in protected areas

Central Africa countries have allocated a higher proportion of their land to conservation than any other tropical regions, with relatively higher conservation success (Laurance et al., 2012). Indeed, most protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). They are currently representing a large part of forest and tree species conservation in Central Africa. Thus, the population of each species in protected areas (according to FRMI, 2018) covering its range was kept stable in the future over 100 years.

In these conditions, it was hypothesized that the PPR in protected areas for each species is 0%, suggesting no population reduction in the present and future.

PPR in production forests

To quantify the evolution of the population of each timber species, matrix population models are widely used to study population dynamics (Picard & Liang, 2014). The population of this species was described at time *t* by a vector N_t corresponding to the density (number of trees ha^{-1}) in each diameter class (from 20 cm diameter to more than 120 cm). The density per diameter class was estimated using data from forest inventories that were carried out in 51 forest management units (FMU) of different logging companies in four countries (Cameroon, Democratic Republic of Congo, Gabon, and Republic of Congo). Most logging companies followed a standardized inventory protocol (Réjou-Méchain et al., 2011). These forest inventory data covered about 12 million ha (Table 1), that are representative of 49% of Central Africa's production forests of this species. The number of trees sampled in Central Africa was 442 062 with a density of 0.04 tree ha^{-1}. Large-scale commercial inventories have already been found useful in the identification of large-scale patterns in Central Africa (Réjou-Méchain et al., 2011). Using large-scale data from commercial forest inventories, Réjou-Méchain et al. (2021) jointly model the distribution in the abundance of the most dominant tree species and produce continuous maps of the floristic and functional composition of central African forests.

Table 1. Forest management units (FMU) sampled, and areas affected to different management modalities in Central Africa (Cameroon, CAR: Central African Republic, DRC: Democratic Republic of the Congo, EG: Equatorial Guinea, Gabon and RCongo: Republic of the Congo). The relative proportion (value in %) for the sampled area is also given according to the areas of production forest of each country.

	Sampling	
Country	FMU	Area (ha)
Cameroon	1	75 834.06
CAR	-	-
DRC	7	2 349 507
EG	-	-
Gabon	42	8 288 212
RCongo	1	1 159 643
Total	51	11 873 196.06

The Usher matrix model was used to simulate the evolution of the recovery rate of all population and the exploitable stock of each species after logging in Central Africa. According to the Usher assumption, between *t* and *t*+1, an individual can either stay alive in the same class, stay alive and move up to the next class, or die; it cannot move up by more than one class or move backwards, i.e., the individual is free from diameter shrinkage (Picard et al., 2012). The Usher matrix model (U) considers three parameters (mortality, recruitment and growth rate that are constant in time) to estimate the transition probabilities:

$$U = \begin{pmatrix} q_1 + g_1 & g_2 & \cdots & \cdots & g_I \\ p_1 & q_2 & 0 & \cdots & 0 \\ 0 & \ddots & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & p_{I-1} & q_I \end{pmatrix}$$

where q_i is the probability for an individual to stay alive in class i between two consecutive time steps, p_i is the upgrowth transition rate (the probability for an individual to grow up from class i to class i +1), and g_i is the recruitment rate (Picard & Liang, 2014).

Tree mortality, recruitment and growth are three central processes for predicting the dynamics of tropical rainforests and estimating these three processes requires long-term monitoring in difficult field conditions (Picard & Gourlet-Fleury, 2008). These processes determine the evolution of the species population in the forest stand. The natural mortality is defined as the number of standing dead trees, and few studies have reported estimates of mortality rates in Central Africa. Data about tree mortality are still scarce and it does not allow to precisely model the mortality rate for each species and size class. Given the current state of knowledge, it appears reasonable to use a fixed mortality rate of 1% for all species and size classes, in agreement with the results of Ligot et al. (2022) on 21,180 trees belonging to 42 timber species of Central Africa annually monitored from one to seven years.

The recruitment integrates fruiting and seed dispersal from mother trees, and the survival of plant juveniles until they reach a size threshold where they are included in the stand. The recruitment term in the model is the average annual input of new individuals into the first size class from 20 cm. The recruitment events, like mortality events, are infrequent and thus difficult to model (Karsenty & Gourlet-Fleury, 2006). The population structure showed a curve in "decreasing exponential" suggesting a good regeneration (Figure 2). Simulations in production forests were performed using the minimum diameter of mature individuals. For this species, the minimum diameter of mature individuals was 80 cm. Since trees recruited from 20 cm with a growth of 0.51 cm per year, it takes more of 100 years for these trees to reach 80 cm to be considered in the simulation. Given that the simulation has been performed over 100 years, there was not a tree recruitment effect in the PPR results in production forests. Claeys et al. (2019) projected the future forest dynamics up to the end of the century and they showed that projected mortality and recruitment rates in 2099 could not differ from the ones observed today. Thus, the hypothesis on the recruitment and the mortality rate is used in the future (up to 100 years) as they do today.

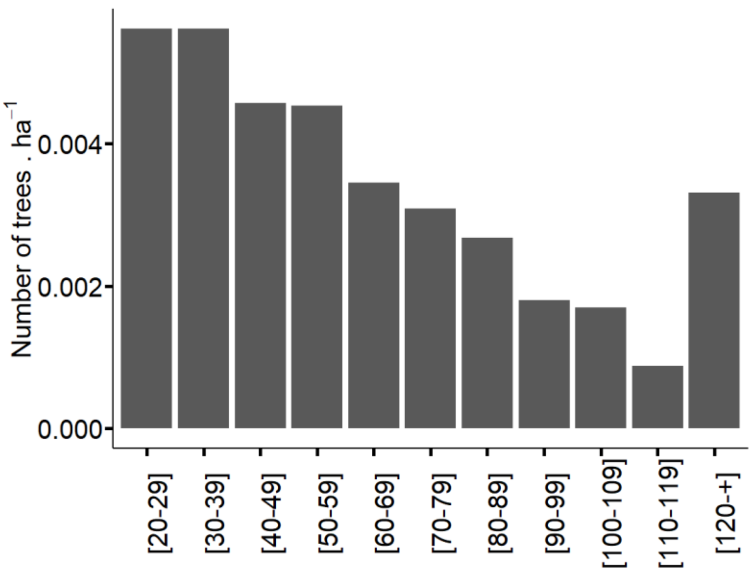

Figure 2. Population structure of *Tieghemella africana* defined using the number of trees per ha and per diameter class (from 20 cm of 51 logging concessions covering an area of 11 873 196.06 ha in Central Africa).

Since the mid-1900s, periodic tree monitoring and tree ring analyses have been carried out to study variability in tree growth across species in Central Africa (Durrieu de Madron, Nasi, et al., 2000; Ligot et al., 2019, 2022). We fitted growth models for each species using data from logged and unlogged areas of permanent tree plot monitoring from the DYNAFAC[32] network covering the five Central African countries. From the combined dataset, we identified 35 trees belonging to two sites in Gabon. Minimum and maximum sampled diameter ranged from 25 to 142 cm. The monitoring period ranged from 2000 to 2010. The mixed second-degree polynomial models (with a random site effect) were fitted for species monitored in several sites. Because of two estimated coefficients of the mixed model were not significant, the mean of the increment (**0.51 cm**) has been used to estimate the diameter growth (Table 2).

Table 2. Estimated coefficients (a, b and c) of growth models between the increment (ac in cm year^{-1}) and the initial diameter (D in cm). The sample including the number of trees (n) and the number of sites (site) are also given. ^{ns} non-significant (p-value > 0.050)

species	n	site	model	a	b	c
Douka	35	2	ac ~ D + D^2 + (1|site)	0.545^{ns}	0.0.00000^{ns}	-0.000002^{ns}

The transition probabilities of three parameters (mortality, growth, and recruitment rate) allowed making the harvested matrix. The logging operations have been modeled using the logging parameters (minimum cutting diameter, cutting and damage rate). The minimum cutting diameters were obtained from decrees of application of the forestry administrations (MCD_A) at the country level and the one used in the management plan (MCD_M, with

32 https://www.dynafac.org/en

$MCD_M \geq MCD_A$) at the logging company level. At the Central Africa level, we weighted the MCD_A and MCD_M values to the occupied area and **MCD_A = MCD_M = 85 cm**. The cutting rate (CA), which defines the proportion of harvested trees (trees with a diameter greater than MCD_A or MCD_M), was given by logging companies, and it was also weighted at the Central Africa level with a value of 74%. Given the current state of knowledge, it appears reasonable to use a fixed damage rate caused by logging of 7% of the initial population that disappears (Durrieu de Madron, Fontez, et al., 2000). The average cutting cycle (i.e. the period between two successive logging operations) is 28 years (FRMI, 2018), but we used 25 years to simplify computation of four simulations reaching 100 years (25, 50, 75 and 100 years), as requested by IUCN criterion A.

The Figure 3 shows the PPR in production forests for the *Tieghemella africana*. The reduction in the population of each species was then calculated as the difference between the initial numbers of mature individuals and the predicted numbers of mature individuals predicted after 100 years. **The PPR in production forest was – 33.55% over 100 years.**

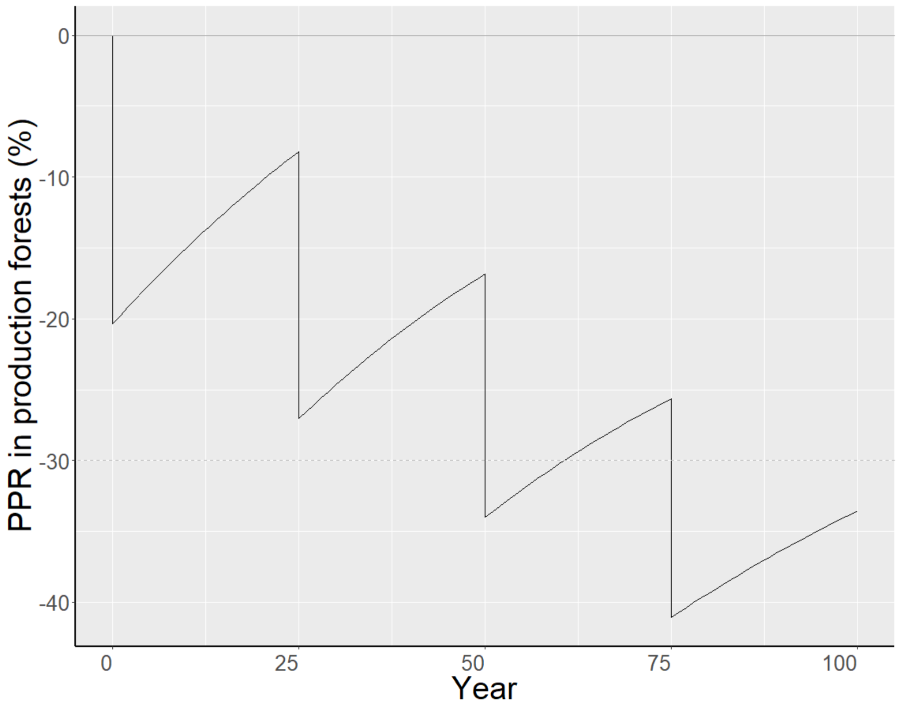

Figure 3. Simulations showing the projected population reduction (PPR) from diameter of mature individuals (80 cm) in production forests for the *Tieghemella africana* over 100 years.

PPR in the non-permanent forest domain

The major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanization, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Based on the large range of this species in Central Africa, the harvested volume from illegal logging and legal logging are 10% and 90%, respectively (FRMI

2018). In this condition, it was hypothesized that there is 90% of PPR from production forests and 10% of PPR from illegal logging in 100% PPR due to forest logging. Given that the PPR of production forests associated with its forest area was known, we deduced the PPR and forest area of illegal logging from those of the production forests. As a result, 3 061 165.72 ha were affected for the illegal logging for this species. The non-permanent domain area (36 169 894.35 ha) was considered as the area which was related to today's deforestation rate of 0.08% year^{-1} in the geographic range of this species (Eba'a et al., 2022). This is a conservative value since it will probably decrease in the future (Swamy et al., 2018).

PPR global = PPR in Central Africa

We thus had three different PPR: PPR_{pa} in protected area, PPR_{pf} in production forests, and PPR_{np} in non-permanent domain. The global PPR was then computed after weighting the three values by their relative forest areas:

$$PPR = \frac{(S_{pa} \times PPR_{pa}) + (S_{pf} \times PPR_{pf}) + (S_{np} \times PPR_{np})}{S_{pa} + S_{pf} + S_{np}}$$

where S_{pa}, S_{pf}, and S_{np} are forest areas in protected area, production forests and non-permanent domain, respectively.

The criterion A3 based on (c) a decline in area of occupancy (AOO), the extent of occurrence (EOO), and/or habitat quality; and (d) potential levels of exploitation, has been computed as follows: (i) 30%≤PPR<50%, the species is considered as Vulnerable (VU); (ii) 50%≤PPR <80%, the species is considered as Endangered (EN), and PPR ≥ 80%, the species is considered as Critically Endangered (CR).

The PPR global in the distribution range of the *Tieghemella africana* was **-13.5%.** This PPR is < 30%, suggesting that this species is not threatened in its geographic area.

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10.21 Annexe 21. *Triplochiton scleroxylon* - K.Schum.

Draft

Triplochiton scleroxylon - K.Schum.

PLANTAE - TRACHEOPHYTA - MAGNOLIOPSIDA - MALVALES - MALVACEAE - Triplochiton - scleroxylon

Common Names: Abachi, Arere, Ayous, Obeche, Samba, Wawa

Synonyms: No Synonyms

Red List Status
VU - Vulnerable, A3cd (IUCN version 3.1)

- **Red List Assessment**

- **Assessment Information**

Date of Assessment: 2022-09-01

Assessor(s): Monthe, F., Loubota, G., Ligot, G., Texier, N., Stévart, T. & Doucet, JL.

Reviewer(s):

Institution(s):

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Regions: Global

- **Identification Description**

Triplochiton scleroxylon is a large tree that can exceed 50 m in height and 2 m in diameter, with a dense, dark crown supported by large sinuous, ascending branches. Its trunk is straight, often angular, with upright buttresses at the base that can become very large with age. The bark is light, yellowish-brown to grey, smooth to finely fissured, becoming scaly. The edge is fibrous, beige to light yellow with lighter vertical stripes that darken rapidly, and composed of several superimposed layers (laminated structure). The leaves are simple alternate with 5 (or 7) more or less marked lobes, and with 5 to 7 main basilar veins (10-20 x 10-25 cm). The petiole is often 3-10-(15) cm long. The stipules drop off quickly but leave a conspicuous ring scar at the node. The inflorescences are short (up to 5 cm), in the leaf axils and composed of large, fragrant, 5-petalled white and purple deciduous flowers about 1 cm long. The fruits are winged (samaras) and clustered in groups of 5, with an elongated, strongly ribbed membranous wing with a straight edge on one side and a rounded edge on the other (4-6 x 1-2 cm).

- **Assessment Rationale**

Triplochiton scleroxylon, is a widespread tall tree in African dense humid evergreen and semi-deciduous guineo-congolian forest, long-lived, pioneer and usually gregarious species, which prefers fertile soils (rich in exchangeable bases) and associating its roots with arbuscular mycorrhizal fungi. It is distributed from Guinea to Democratic Republic of the Congo. Based on a 2 x 2 km cell size, the AOO of this species is estimated as 532 km^2, with a minimum of 36 locations (number of forest management units of different logging companies in Central Africa). This species is not “Vulnerable” status under criterion B2. The EOO is calculated as 2 356 848 km^2, above the upper threshold for “Vulnerable” status under criterion B1.

Commonly known as Ayous, it is among the most exploited forest species in tropical Africa, highly sought after for the quality of its wood. The minimum cutting diameter (MCD) in Central Africa varies from 60cm to 80 cm and in West Africa (Ivrory Coast and Ghana) it varies from 60 cm to 90 cm. These values are close to the regular fruiting diameter (RFD) of 90 cm DBH, which can locally compromise the availability of seed trees. Therefore, the DYNAFAC collective recommends the adoption of an MCD of 100 cm in Central Africa (DYNAFAC, 2022). The population structure of this species showed a curve in "bell-shaped" suggesting poor regeneration in mature forests with a density of 1.07 $stems.ha^{-1}$ (dbh ≥ 20 cm) in Central Africa (see Supplementary Material) and 2 stems.ha-1 (dbh ≥ 20 cm) in West Africa (Akinnagbe, 2008). Given its stem density and the mean annual increment of 0.78 ± 0.66 cm/year in Central Africa (see Supplementary Material), we estimate the number of mature individuals over 10 000 across the distribution range, well above the threatened category under criteria C and D.

The most serious long-term threat is the conversion of the forest to agriculture, and illegal logging. However, the species is not considered severely fragmented as 209 known occurrences represent more than 50 localities (sensu Comité des normes et des pétitions de l’UICN, 2019). Considering the species' generation length (120 years), an inference of three generations in the past goes back around 1700 before the period characterised by high regeneration of light-demanding trees species, resulting from gardening activities of local populations in the forest, creating scattered large openings (Biwolé et al., 2015; Morin-Rivat et al., 2017). So the species would certainly not be threatened according to the A2 and A1 criteria. Based on simulations of the expected population reduction on its distribution range including protected areas, non - permanent forest areas and production forest (logging concessions), we estimated population reduction of 34.8 to 38.9 % in the next 100 years below the threshold to be considered threatened under criterion A3 (see Supplementary Material). An assessment of the population reduction according to criterion A4 considering one to two generations back and one to two generations forward would likely introduce high levels of uncertainty due to the lack of data to efficiently model the reduction of population size in the past. No quantitative analysis of the probability of extinction in the wild was conducted, and therefore criterion E does not apply.

Considering (i) poor regeneration, (ii) the incompatibility between MCD and RFD, and (iii) the reduction of population in the future across the distribution range within the threshold for Vulnerable, the species is assessed as Vulnerable (VU), A3cd.

Reasons for change

Reason(s) for Change in Red List Category from the Previous Assessment:

Triplochiton scleroxylon was previously assessed as "Least Concern" by the IUCN (https://www.iucnredlist.org/species/32174/9684953) at the African Regional Workshop (Conservation & Sustainable Management of Trees, Zimbabwe, July 1996), 1998, following the A1cd criterion. During the last few years, important data have been produced on the self-ecology, population dynamics (growth, recruitment, mortality) of the species. Moreover, a new version of the IUCN guidelines is available (from version 2.3 to 3.1). Given all these information, it was necessary to produce a new assessment of the species.

● Distribution

● Geographic Range

Triplochiton scleroxylon is widely distributed from Guinea to Democratic Republic of the Congo, mainly in forest at low and medium altitudes in the monsoon equatorial forest belt. It is commonly planted in its native range (e.g. Ivory Coast, Ghana and Nigeria), and occasionally elsewhere in the world, e.g. the Solomon Islands. The extent of occurrence (EOO) in native area is estimated as 2 356 848 km^2 across its distribution range.

● Area of Occupancy (AOO)

Estimated area of occupancy (AOO) - in km2	Justification
532	The AOO has been estimated using ConR based on the 2 × 2 km cell size of 209 occurrences from CJB (Conservatoire et Jardin botaniques de Genève) and RAINBIO

Continuing decline in area of occupancy (AOO)	Qualifier	Justification

Yes	Inferred	The species has suffered from reduction in area of occupancy, due to habitat degradation and deforestation in West Africa forest (Vancutsem et al., 2021).

- Extent of Occurrence (EOO)

Estimated extent of occurrence (EOO)- in km2	EOO estimate calculated from Minimum Convex Polygon	Justification
2 35 6848	true	Calculated using ConR based on 209 known occurrences from CJB (Conservatoire et Jardin botaniques de Genève) and RAINBIO

Continuing decline in extent of occurrence (EOO)	Qualifier	Justification
Yes	Observed	The species has certainly undergone an extent of occurrence reduction in West Africa, linked to the reduction in forest area (Vancutsem et al., 2021).

- Locations Information

Number of Locations	Justification
30-100	More than 36 localities. Based on the most serious plausible threat (conversion of its habitat) and illegal logging across the distribution range.

Continuing decline in number of locations	Qualifier	Justification
Yes	Inferred	The main threat remains the reduction of the forest area in West Africa.

Extreme fluctuations in the number of locations	Justification
No	

- Very restricted AOO or number of locations (triggers VU D2)

Very restricted in area of occupancy (AOO) and/or # of locations	Justification

No	-

- ## Elevation / Depth / Depth Zones

Elevation Lower Limit (in metres above sea level): 0

Elevation Upper Limit (in metres above sea level): 900

- ## Map Status

Map Status	Use map from previous assessment	How the map was created, including data sources/methods used:	Please state reason for map not available:	Data Sensitive?	Justification	Geographic range this applies to:	Date restriction imposed:
Done	-	Qgis. The dataset was created from a compilation of Rainbio and CJB	-	-	-	-	-

- ## Biogeographic Realms

Biogeographic Realm: Afrotropical

- ## Occurrence

- ## Countries of Occurrence

Country	Presence	Origin	Formerly Bred	Seasonality
Benin	Extant	Native	-	Resident
Cameroon	Extant	Native	-	Resident
Central African Republic	Extant	Native	-	Resident
Republic of Congo	Extant	Native	-	Resident
Democratic Republic of the Congo	Extant	Native	-	Resident
Côte d'Ivoire	Extant	Native	-	Resident
Equatorial Guinea	Extant	Native	-	Resident
Gabon	Extant	Native	-	Resident
Ghana	Extant	Native	-	Resident
Guinea	Extant	Native	-	Resident
Liberia	Extant	Native	-	Resident
Nigeria	Extant	Native	-	Resident

Sierra Leone	Extant	Native	-	Resident
Togo	Extant	Native	-	Resident

• Population

Triplochiton sceroxylon is a Guineo-Congolian species, widely distributed from Guinea to Democratic Republic of the Congo. Its average density is 1.07 stems.ha^{-1} (dbh ≥ 20 cm) in Central Africa (see Supplementary Material) and 2 stems.ha-1 (dbh ≥ 20 cm) in West Africa (Akinnagbe, 2008). This density can locally reach 6.9 stems.ha-1 (all diameters considered) in some regions of Cameroon (Le Garrec, 2020), 4 stems.ha-1 (dbh ≥ 240 cm) in Ghana and Nigeria (Hall and Bada, 1979), and more than 16.6 stems.ha-1 (dbh ≥ 40 cm) in Central Africa Republic (Palla and Louppe, 2002).

The average diameter diameter growth is 0.78 ± 0.66 in Central Africa (see Supplementary Material), some variation can be observed according to the forest type (Ligot et al., 2022). In West Africa also, diameter growth variations are observed, up to 2.5 cm in Nigeria and 1.4 cm in Ghana (Bosu and Krampah, 2005; Palla and Louppe, 2002). Under natural conditions, saplings from seedlings can reach a height of 15 m with a diameter of 15 cm at the age of 4 years (Bosu and Krampah, 2005). The species performs well in plantations, given its high growth rate and success level of vegetative multiplication, the species is widely planted in mixed stands in Ivory Coast (1967 to 1995, about 3000 ha were planted), Ghana, Nigeria (in agroforestry complexes in association with cocoa) and in several logging concessions in Central Africa (Palla and Louppe, 2002).

The legal minimum cutting diameter “MCD” (60 cm in Central Africa Republic and Ivory Coast, 80 cm in Cameroon and Democratic Republic of Congo, 90 cm in Liberia and 90 cm in Ghana) (Adam et al., 2006; DYNAFAC, 2022), is lower than the regular fruiting diameter (RFD) estimated at 90 cm in Cameroon. Additionally, almost half of the pollinator trees are between 90 and 110 cm in DBH, and half of the females producing quality seeds are between 100 and 130 cm in DBH (Le Garrec, 2020) and the minimum fertility diameter was observed at 65 cm in Central Africa (see Supplementary Material). This situation may strongly be damageable for the natural regeneration of the species across distribution range. However, based on almost 40 years of monitoring forest dynamics in Central Africa, the DYNAFAC collective recommends a MCD of 100 cm (DYNAFAC, 2022).

Using the Red List criterion A3, the projected population reduction (PPR) to be met in the future (100 years because the generation length of the species is 120 years) of the *T. sceroxylon* population was assessed across its distribution range. Because *T. sceroxylon* is a widespread species in West and Central Africa, the PPR was estimated for each region.

In Central Africa, three different PPR were thus estimated: PPRpa in protected areas, PPRpf in production forests and PPRnp in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas. First, protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). The population of the species in protected areas covering its range was kept stable in the future over 100 years, suggesting that the PPR in protected areas was 0%. Second, the evolution of the *T. sceroxylon* population was simulated using an Usher matrix model to estimate the PPR of production forests (logging concessions, PPRpf). The simulations were initialised using the density (number of trees.ha^{-1}) per diameter class (from 65 cm diameter, mature individuals) from forest management inventories of logging companies. The evolution of this initial population depended on several demographics (recruitment, mortality, and growth rate) and logging parameters (minimum cutting diameter, cutting and damage rate) that were adjusted using data of permanent tree plot monitoring. Thus, the density of *T. sceroxylon* in 100 years was predicted with a logging event every 25 years, which corresponds to the average cutting cycle in Central Africa. PPRpf was then calculated as the difference between initial and final number of trees. Third, the major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Illegal logging and the habitat lost from deforestation rate have been both activities that allowed estimating the PPRnp in non-permanent domains.

In West Africa, the forest areas were subject to a constant annual deforestation rate of 1.20% year-1 (Vancutsem et al., 2021). Taking this rate of deforestation as constant over the next 100 years, when it is expected to decline, is a reasonable precautionary measure.

We thus had two different PPR: PPRC in Central Africa and PPRW in West Africa. The global PPR was then computed after weighting the two values by their relative forest areas. The global PPR result was found to be from 34.8 to 38.9 %, higher than 30%.

- **Population Information**

Current Population Trend: Decreasing

Extreme fluctuations? (in # of mature individuals)	Justification
No	-

Severely fragmented?	Justification
No	-

Continuing decline in mature individuals?	Qualifier	Justification

Continuing decline % in mature individuals within 3 generations or 10 years, whichever is longer (up to max. of 100 years in the future)	Qualifier	Justification

Extreme fluctuations in the number of subpopulations	Justification
No	-

Continuing decline in number of subpopulations	Qualifier	Justification
No	-	-

All individuals in one subpopulation: No

Number of Subpopulations	Justification	Subpopulation Details	Subpopulation description	Number of mature individuals	Subpopulation trend	Qualifier	Location type	Number of Subpopulations	Location bounding box	Location coordinates	Notes
0	-	-	-	-	-	-	-		-	-	-

- **Population Reduction - Past**

Percent Change in past	Reduction or Increase	Qualifier	Justification

Basis?

Reversible?
Yes

Understood?
Yes

Ceased?
No

- **Population Reduction - Future**

Percent Change in future	Reduction or Increase	Qualifier	Justification
34.8-38.9 %	Reduction	Projected	Using the Red List criterion A3, the projected population reduction (PPR) to be met in the future (100 years because the generation length of the species is 120 years) of the *T. sceroxylon* population was assessed across its distribution range. Because *T. sceroxylon* is a widespread species in West and Central Africa, the PPR was estimated for each region.

In Central Africa, three different PPR were thus estimated: PPRpa in protected areas, PPRpf in production forests and PPRnp in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas. First, protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). The population of the species in protected areas covering its range was kept stable in the future over 100 years, suggesting that the PPR in protected areas was 0%. Second, the evolution of the *T. sceroxylon* population was simulated using an Usher matrix model to estimate the PPR of production forests (logging concessions, PPRpf). The simulations were initialized using the density (number of trees.ha^{-1}) per diameter class (from 65 cm diameter, mature individuals) from forest management inventories of logging companies. The evolution of this initial population depended on several demographics (recruitment, mortality, and growth rate) and logging parameters (minimum cutting diameter, cutting and damage rate) that were adjusted using data of permanent tree plot monitoring. Thus, the density of *T. sceroxylon* in 100 years was predicted with a logging event every 25 years, which corresponds to the average cutting cycle in Central Africa. PPRpf was then calculated as the difference between initial and final number of trees. Third, the major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Illegal logging and the habitat lost from deforestation rate have been both activities that allowed estimating the PPRnp in non-permanent domains.

In West Africa, the forest areas were subject to a constant annual deforestation rate of 1.20% year-1 (Vancutsem et al., 2021). Taking this rate of deforestation as constant over the next 100 years, when it is expected to decline, is a reasonable precautionary measure.

We thus had different PPR: PPRC in Central Africa and PPRW in West Africa. The global PPR was then computed after weighting the two values by their relative forest areas. The global PPR result was found to be from 34.8 to 38.9 % higher than 30%.

Basis?
b) an index of abundance appropriate for the taxon, d) actual or potential levels of exploitation

- **Population Reduction - Ongoing**

Both: Percent Change over any 10 year or 3 generation period, whichever is longer, and must include both past and future, future can't go beyond 100 years	Reduction or Increase	Number of years for this period	Qualifier	Justification

Basis?

Reversible?
Yes

Understood?
Yes

Ceased?
No

- **Habitats and Ecology**

Triplochiton scleroxylon is a large tree reaching 50 m in height and 2 m in diameter. It is a long-lived, gregarious pioneer species, characteristic of the dense semi-deciduous secondary rainforests of West and Central Africa. It is distributed up to 900 m altitude in areas with up to 3000 mm annual rainfall, but is most abundant at 200-400 m altitude and in areas with annual rainfall between 1100 to1800 mm with two rainy seasons. Trees normally occur in clusters of 10 or more and isolated trees are very rare. It prefers fertile soils (rich in exchangeable bases) by associating its roots with arbuscular mycorrhizal fungi. It regenerates in large openings such as the fallow lands of slash and burn agriculture. Its current old stands are therefore the result of old grubbing activities (anthropophilic species) and are destined to disappear. Its young stems are extremely rare and its regeneration is often very deficient (Bosu and Krampah, 2005; Gorel, 2012; Meunier et al., 2015; Morin-Rivat et al., 2017).

Triplochiton scleroxylon bears hermaphrodite flowers. In Ghana, Ivory Coast and Liberia, flowering occurs during the dry season from December to January (Bosu and Krampah, 2005). First flowers are observed at a minimum 28 cm in northern Republic of Congo (Ouédraogo et al., 2018). It is a pterochorous species whose seeds are wind dispersed (Leakey et al., 1981). In Cameroon and the Northern Republic of the Congo, the fruiting period is respectively between March-May, October-November (-February) (Daïnou et al., 2021). While in Liberia the fructification period is from January to March (Bosu and Krampah, 2005; Daïnou et al., 2021). Trees bear first fruits at 56 cm and become regular and abundant at 90 cm in Central Africa (Daïnou et al., 2021). However, fruiting is quite rare, mature fruits are usually observed every 5-7 years (Daïnou et al., 2021). Cross-pollination is necessary for the production of viable seeds, with little or no self-fertilisation observed in the species (Lapido et al., 1994; Le Garrec, 2020). This situation might compromise the reproductive capacity of the species in case of strong fragmentation of the populations. However, the species is highly genetically diverse and shows long-distance seed and pollen dispersal (DYNAFAC, 2022; Le Garrec, 2020). In favourable conditions (high winds), the fruits can be transported up to 200 m from the mother tree (Le Garrec, 2020).

- **IUCN Habitats Classification Scheme**

Habitat	Season	Suitability	Major Importance?
1.6. Forest -> Forest - Subtropical/Tropical Moist Lowland	Resident	Suitable	Yes

- **Continuing Decline in Habitat**

Continuing decline in area, extent and/or quality of habitat?	Qualifier	Justification
Yes	Observed	Despite the annual deforestation rate of 0.35% and 1.2% in Central and West Africa respectively (FAO, 2015). The species can colonise savannah and other open habitats.

- **Life History**

Generation Length	Justification	Data Quality
120	Minimum estimate of generation length for the species from the average growth rate, and the mean diameter of mature individuals (see Supplementary Material).	good

Age at maturity: female or unspecified
84 Years

Age at Maturity: Male
84 Years

Size at Maturity (in cms): Female
65

Size at Maturity (in cms): Male
65

Reproductive Periodicity
Annual

Annual Rate of Population Increase

Natural Mortality
1% (Ligot et al. 2022)

- **Systems**

System: Terrestrial

- **Plant / Fungi Specific**

Wild relative of a crop? No

Plant and Fungal Growth Forms
Tree - large

- **Use and Trade**

- **General Use and Trade Information**

Triplochiton scleroxylon is among the most exploited forest species in Central Africa (Eba'a Atyi et al., 2022), and was once the most timber species in West Africa (Bosu and Krampah, 2005).

At industrial level, *T. scleroxylon* is used for interior joinery, paneling, moldings, furniture, boxes and crates, sculpture, matches, pencils, peeled and sliced veneers for interior and exterior layers of plywood, fiberboard and particleboard, and laminated panels. It is very important for house construction, for beams, posts and planks, and is also used to make shingles. The wood from the buttresses is used to make doors, dishes, bowls and sandal soles, and the trunk is used to make dugouts. The pulp can be used for the production of medium quality paper (Bosu and

Krampah, 2005). In the 1970s, Ivory Coast exported over 1 million m³ of logs, Ghana, Nigeria and Cameroon together 400 000 m³ of logs and 40 000 m³ of sawn timber (Bosu and Krampah, 2005). However, a decline in production has been observed in recent decades. In the 2000s, it was economically the most important timber species in Ghana and Cameroon, accounting respectively for about 35% and 70% of the volume of timber products exported. In 2010, it was the 3rd most exploited species (De Wasseige et al., 2012), with around 900 000 m3/year, while in Cameroon it has fallen to 9th place since (Eba'a Atyi et al., 2022). In 2016, Central Africa produced 803 548 m^3 representing 14% of the total volume of timber harvested (FRMi, 2018) and 74 479 m³ of log in 2018 (Eba'a Atyi et al., 2022).

In Ivory Coast and Benin, *T. scleroxylon* leaves are used in cooking as a boiled vegetable or as a sauce. The bark is used to cover the roofs and walls of huts, and is used in traditional medicine to treat edema and as an analgesic. The leaves of *T. scleroxylon* are used as food for the silkworm *Anaphe venata*, whose caterpillars are a good source of protein, and are commonly eaten. The sawdust is used for the production of edible mushrooms (*Pleurotus* spp.). Trees are often preserved in cocoa farms to serve as shade trees (Bosu and Krampah, 2005).

Subsistence:	Rationale:	Local Commercial:	Further detail including information on economic value if available:
Yes	-	Yes	-

National Commercial Value: Yes

International Commercial Value: Yes

Is there harvest from captive/cultivated sources of this species? Yes

Trend in level of total offtake from wild sources: Stable

Trend in level of total offtake from domesticated sources: Unknown

- **Non- Consumptive Use**

Non-consumptive use of the species? true

- **Threats**

The main threats in the non-permanent domain across the species' distribution range, are mainly related to habitat loss due to the destruction of natural environments as a result of population explosion and urbanisation, the expansion of agriculture, fuelwood collection, illegal logging and the abusive harvesting of plant parts requested as non-wood forest products (Bradshaw et al., 2009). In Central Africa, illegal logging accounts for nearly 46% of total log production (FRMi, 2018).This production generally comes from unallocated forest areas (non-permanent forest domain).

Triplochiton scleroxylon is exploited in Central Africa. In West and East Africa, forests are generally not managed in concessions, and the large part of the rainforest has been transformed into cultivated areas (Nix, 2019).

- **Threats Classification Scheme**

No past, ongoing, or future threats exist to this species. false

Threat	Timing	Scope	Severity	Impact Score
1.1. Residential & commercial development -> Housing & urban areas	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4
2.1.1. Agriculture & aquaculture -> Annual & perennial non-timber crops -> Shifting agriculture	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
2.2.2. Agriculture & aquaculture -> Wood & pulp plantations -> Agro-industry plantations	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
2.3.2. Agriculture & aquaculture -> Livestock farming & ranching -> Small-holder grazing, ranching or farming	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4
3.2. Energy production & mining -> Mining & quarrying	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 5
4.1. Transportation & service corridors -> Roads & railroads	Past, Likely to Return	Minority (<50%)	Slow, Significant Declines	Low Impact: 4
5.3.1. Biological resource use -> Logging & wood harvesting -> Intentional use: (subsistence/small scale) [harvest]	Ongoing	Minority (<50%)	Slow, Significant Declines	Low Impact: 4
5.3.2. Biological resource use -> Logging & wood harvesting -> Intentional use: (large scale) [harvest]	Ongoing	Minority (<50%)	Slow, Significant Declines	Medium Impact: 6
7.1.3. Natural system modifications -> Fire & fire suppression -> Trend Unknown/Unrecorded	Ongoing	Minority (<50%)	Negligible declines	Low Impact: 4

• Conservation

Triplochiton scleroxylon is known to occur in protected areas and in at least 10 *ex situ* collections (BGCI, 2022). In certified forest concessions where the species is exploited, trails and or permanent forest plots are usually installed. These plots provide important data for (i) quantifying population dynamics processes at the stand level: mortality, growth and recruitment; (ii) phenological studies to determine the regular fruiting diameter (RFD). These tails and plots are managed in collaboration with forest concessions grouped within the DYNAFAC collective (see here for more information https://www.dynafac.org/fr/p/130/installation-de-dispositifs-de-suivi-de-la-dynamique-forestiere). Compilation of these data will provide important additional information for targeted silvicultural measures for the sustainable management of this species. First summaries have provided information on important parameters such as: mortality, growth etc. (DYNAFAC, 2022; Ligot et al., 2022). Based on almost 40 years of monitoring forest dynamics in Central Africa, the DYNAFAC collective recommends a MCD of 100 cm in Central Africa to maintain optimal gene flow and optimal regeneration (DYNAFAC, 2022; Le Garrec, 2020). DYNAFAC also recommends the preservation of additional seed trees or the implementation of regeneration support techniques to ensure the long-term maintenance of populations. *T. scleroxylon* is also monitored in nurseries and planted in various forest concessions. The irregular seed production can be largely compensated for by relatively inexpensive methods of vegetative propagation, which offers increased possibilities in planting. Its high growth rates, allow a relatively short cutting rotation, generally good bole shape and the possibility of planting it in a mixture with other timber species make it a good choice for planting. Literature shows that the extent of past human disturbance in the forests of the Congo Basin has a positive impact on the abundance of pioneer species such as *T. scleroxylon* (Daïnou et al., 2016; Morin-Rivat et al., 2017; Van Gemerden et al., 2003). Keeping the environment open would ensure good regeneration of the species.

Logging in Central Africa is subject to strict legislation, species can only be harvested above a certain diameter and measures must be taken to ensure the renewal of the resource (Fargeot et al., 2004). Indeed, management plans for tropical rainforests require the determination of a minimum cutting diameter (MCD) to ensure a minimum renewal rate at the end of a rotation period (duration between two cuts on the same cutting base), the minimum reconstitution rate (40-50% depending on the country) as well as the rotation duration, being imposed by forestry legislation (Durrieu de Madron and Forni, 1997).

In addition, it will also be necessary to :

- Ensure the implementation of the recommendations of the Dynafac collective, including the establishment of a system for monitoring the populations of commercial species in the different forest types defined in a consensual manner;
- Set up monitoring and support systems for the regeneration of commercial species, prioritising species with regeneration deficits;
- Set up programmes to guarantee the phenotypic quality of commercial species populations: seed banks, seed stands, plus trees, seed orchards, conservation plantations;
- Consider threatened species in the delimitation of conservation series and in the identification of High Conservation Values;
- Update conservation statuses on a five-yearly basis, in particular by setting up a system of "green statuses";
- Define red lists adapted to regional or national contexts;
- Evaluate the status of cryptic species or species close to commercial species evaluated during this workshop.

- **Conservation Actions In- Place**

Conservation Actions In- Place

Action Recovery Plan	Note

Yes	Reforestation within forest concessions and others in forest gaps, old parks, quarries, and large logging roads.

Systematic monitoring scheme	Note
Yes	The species is monitored in permanent plots installed within forestry companies in Central Africa (see here for more information https://www.dynafac.org/fr)

Occur in at least one PA	Note
Yes	The species may appear in at least 100 protected areas considering it distribution range

Percentage of population protected by PAs (0-100)	Note
1-10	Considering protected area across species distribution range

Area based regional management plan	Note
Unknown	-

Invasive species control or prevention	Note
No	-

Harvest management plan	Note
Yes	In legal forest concessions, the species is exploited according to a management plan.

Subject to ex-situ conservation	Note
Yes	-

Included in international legislation	Note
No	-

Subject to any international management/trade controls	Note

- **Important Conservation Actions Needed**

Conservation Actions	Note
3.1.1. Species management -> Species management -> Harvest management	-
3.1.2. Species management -> Species management -> Trade management	-
3.4.2. Species management -> Ex-situ conservation -> Genome resource bank	-

- **Research Needed**

Research	Note
1.2. Research -> Population size, distribution & trends	-
3.1. Monitoring -> Population trends	-
3.2. Monitoring -> Harvest level trends	-
3.3. Monitoring -> Trade trends	-

• Ecosystem Services

- **Ecosystem Services Provided by the Species**

	Importance:	Geographic range of benefit:
1. Water Quality	2 - Important	Global
3. Flood Control	2 - Important	Global
4. Climate Regulation	2 - Important	Global
5. Landscape	2 - Important	Global
6. Air Quality	2 - Important	Global
7. Nutrient Cycling	2 - Important	Global
8. Habitat Maintenance	2 - Important	Global
9. Provision of Critical Habitat	2 - Important	Global

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• SUPPLEMENTARY MATERIAL

Triplochiton scleroxylon - K.Schum

• IUCN status using criterion A3

We adopted the criterion A3 to assess the projected population reduction (PPR) to be met in the future (up to a maximum of 100 years) of *Triplochiton scleroxylon*. To quantify the projected population reduction, simulations must be performed on mature individuals and three generations with a maximum of 100 years according to **criterion A3**. We estimated mature individuals and generation length, as recommended by the IUCN guidelines.

A **mature individual** is an individual that can reproduce, able to bear flowers or seeds (fertile in plant kingdom). To quantify the mature individuals for each species, we used phenological data of DYNAFAC network[33] from a combined dataset of 493 trees belonging to eight sites in three countries (Cameroun, Central African Republic, and Republic of Congo). Minimum and maximum sampled diameters ranged from 10 to 150 cm (median 63 cm). The monitoring period ranged from 2015 to 2021. We assumed that the monitoring period was long enough to capture at least one reproductive event per tree such that trees without observed flowering/fruiting events were considered non-reproductive (56 percent of all monitored trees were non-reproductive). We used the methodology for the size at reproduction of canopy tree species in Central Africa (Ouédraogo et al., 2018): the **diameter of a mature individual** was obtained after fitting logistic regressions and the level of 50% of the probability to produce the flower or fruit was adopted for this species. Using this approach, the diameter of a mature individual was obtained after setting the 50% probability to produce flowers or fruits. The minimum diameter of mature individuals for this species was **65 cm**.

The **generation length** was the report between the mean diameter of mature individuals considering population structure and the mean increment. Given that the minimum diameter of mature individuals was 65 cm, we weighted the total number of trees by their diameter from 65 cm to 125 cm to compute the number of mature individuals. The mean diameter of mature individuals was **93 cm**. The **mean increment** of the species was **0.775 cm**, obtained from 882 observations of published data (Ligot et al., 2019, 2022) and unpublished data in three countries (Cameroon, Central African Republic, and Republic of Congo). Thus, the **generation length** was 93 cm / 0.775 cm = **120 years**. The age at maturity (**84 years**) has been estimated as the report between the **minimum diameter of mature individuals (65 cm**) and the **mean increment (0.775 cm)**.

• Estimation of the projected population reduction (PPR)

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We adopted the criterion A3 to assess the projected population reduction (PPR) to be met in the future (up to a maximum of 100 years). *Triplochiton scleroxylon*, is found in Guineo–Congolian rainforest species, widely distributed mainly from Guinea-Bissau to Democratic Republic of Congo. The geographic range of species was in two regions (Central Africa and West Africa) characteristic of two biogeographical regions across the tropical African forests (Fayolle et al., 2014). According to each region, different data (deforestation annual rate, growth, mortality, recruitment, forest inventory, etc.) have been used with logging data in Central Africa. Thus, the PPR was estimated for each region and the global PPR was then computed after weighting the two values by their relative forest areas.

- **PPR in Central Africa**

In this region, forest management follows three different modalities: protected areas, production forests (logging concessions) and non-permanent forest domain. Based on occurrences, the natural range of this species includes countries in Central Africa (Figure 1). The total natural area is estimated at 113 052 844.6 ha. Within this area, there are 33 798 381.6 ha (29.9%) for production forests, 8 879 496.21 ha (7.9%) for protected areas, and 70 374 966.74 ha (62.2%) for the non-permanent domain.

Three different PPR were thus estimated: PPR_{pa} in protected areas, PPR_{pf} in production forests and PPR_{np} in non-permanent domain. These three different PPR estimates were weighted by their relative forest areas and then added to estimate the PPR_C in Central Africa.

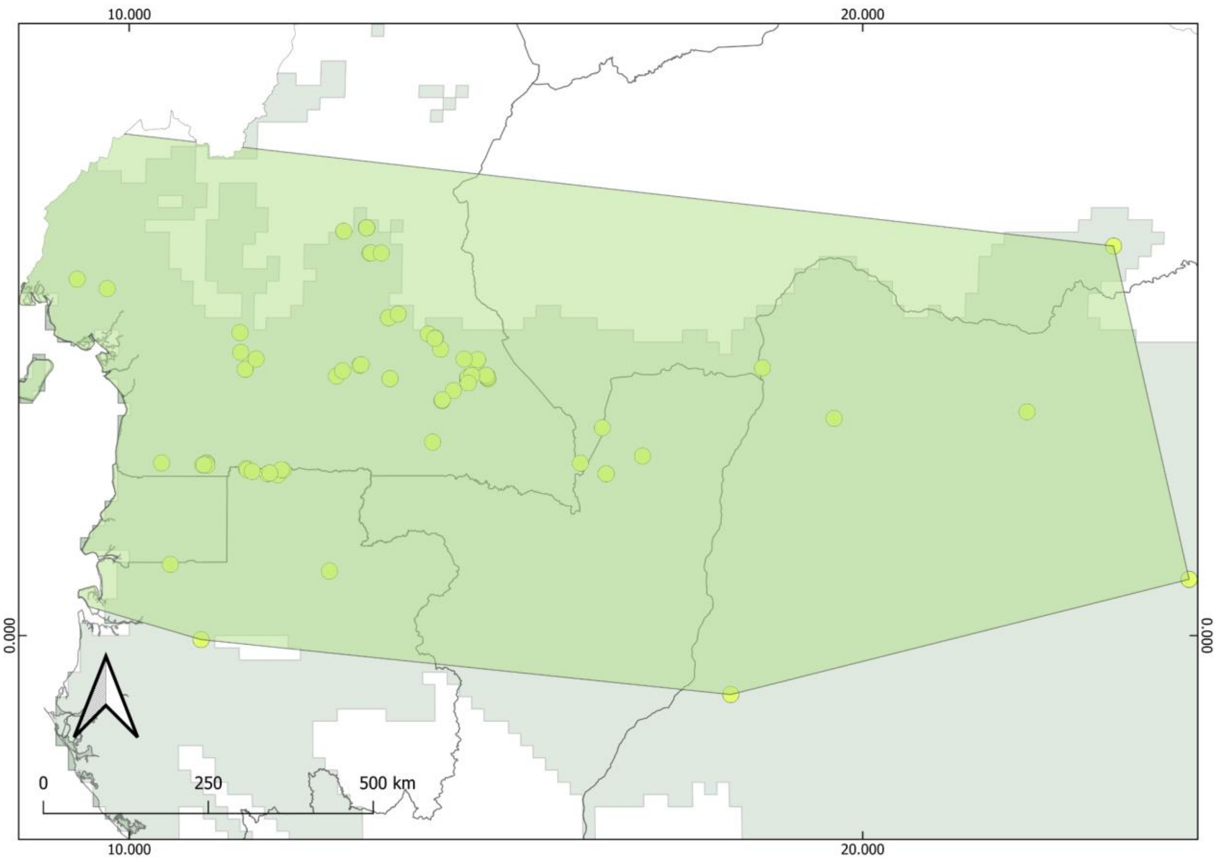

Figure 1. The range of *Triplochiton scleroxylon* in Central Africa estimated from RAINBIO and CJB data, validated in December 2022 during a workshop with a group of experts in Gabon.

- **PPR in protected areas**

Central Africa countries have allocated a higher proportion of their land to conservation than any other tropical regions, with relatively higher conservation success (Laurance et al., 2012). Indeed, most protected areas have resisted the attribution of extractive industry permits, land conversion, and village-based hunting intrusion that have been the main agents of forest degradation across the region (Abernethy et al., 2016). They are currently representing a large part of forest and tree species conservation in Central Africa. Thus, the population of each species in protected areas (according to FRMI, 2018) covering its range was kept stable in the future over 100 years. **In these conditions, it was hypothesized that the PPR in protected areas for each species is 0%, suggesting no population reduction in the present and future.**

- **PPR in production forests**

To quantify the evolution of the population of each timber species, matrix population models are widely used to study population dynamics (Picard & Liang, 2014). The population of this species was described at time t by a vector N_t corresponding to the density (number of trees ha^{-1}) in each diameter class (from 20 cm diameter to more than 120 cm). The density per diameter class was estimated using data from forest inventories that were carried out in 36 forest management units (FMU) of different logging companies in four countries (Cameroon, Central African Republic, Gabon, and Republic of the Congo). Most logging companies followed a standardized inventory protocol (Réjou-Méchain et al., 2011). These forest inventory data covered about 8 million ha (Table 1), that are representative of 25% of Central Africa's production forests of this species. The number of trees sampled in Central Africa was 8 985 770 with a density of 1.07 tree ha^{-1}. Large-scale commercial inventories have already been found useful in the identification of large-scale patterns in Central Africa (Réjou-Méchain et al., 2011). Using large-scale data from commercial forest inventories, Réjou-Méchain et al. (2021) jointly model the distribution in the abundance of the most dominant tree species and produce continuous maps of the floristic and functional composition of central African forests.

Table 1. Forest management units (FMU) sampled in Central Africa (Cameroon, CAR: Central African Republic, DRC: Democratic Republic of the Congo, EG: Equatorial Guinea, Gabon and RCongo: Republic of the Congo).

	Sampling	
Country	FMU	Area (ha)
Cameroon	20	2 042 206.98
CAR	7	2 165 837
DRC	-	-
EG	-	-
Gabon	1	180 822
RCongo	8	4 005 312
Total	36	8 394 177.98

The Usher matrix model was used to simulate the evolution of the recovery rate of all population and the exploitable stock of each species after logging in Central Africa. According to the Usher assumption, between *t* and *t*+1, an individual can either stay alive in the same class, stay alive and move up to the next class, or die; it cannot move up by more than one class or move backwards, i.e., the individual is free from diameter shrinkage (Picard et al., 2012). The Usher matrix model (U) considers three parameters (mortality, recruitment and growth rate that are constant in time) to estimate the transition probabilities:

$$U = \begin{pmatrix} q_1 + g_1 & g_2 & \cdots & \cdots & g_I \\ p_1 & q_2 & 0 & \cdots & 0 \\ 0 & \ddots & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & p_{I-1} & q_I \end{pmatrix}$$

where q_i is the probability for an individual to stay alive in class i between two consecutive time steps, p_i is the upgrowth transition rate (the probability for an individual to grow up from class i to class i +1), and g_i is the recruitment rate (Picard & Liang, 2014).

Tree mortality, recruitment and growth are three central processes for predicting the dynamics of tropical rainforests and estimating these three processes requires long-term monitoring in difficult field conditions (Picard & Gourlet-Fleury, 2008). These processes determine the evolution of the species population in the forest stand. The natural mortality is defined as the number of standing dead trees, and few studies have reported estimates of mortality rates in Central Africa. Data about tree mortality are still scarce and it does not allow to precisely model the mortality rate for each species and size class. Given the current state of knowledge, it appears reasonable to use a fixed mortality rate of 1% for all species and size classes, in agreement with the results of Ligot et al. (2022) on 21,180 trees belonging to 42 timber species of Central Africa annually monitored from one to seven years.

The recruitment integrates fruiting and seed dispersal from mother trees, and the survival of plant juveniles until they reach a size threshold where they are included in the stand. The recruitment term in the model is the average annual input of new individuals into the first size class from 20 cm. The recruitment events, like mortality events, are infrequent and thus difficult to model (Karsenty & Gourlet-Fleury, 2006). The population structure showed a single-mode curve with a good representation of the small stems suggesting a good regeneration (Figure 2). Simulations in production forests were performed using the minimum diameter of mature individuals. For this species, the minimum diameter of mature individuals was 65 cm. Since trees recruited from 20 cm with a diameter growth of 0.77 cm per year, it takes 84 years for these trees to reach 65 cm to be considered in the simulation. Given that the simulation has been performed over 100 years, there was a low recruitment effect in the PPR results in production forests. This low recruitment effect will not change the results regarding the IUCN status of the species. To model the recruitment, we tested two approaches for each species. The first hypothesis considered that the recruitment rate was 1%, i.e., the same value as the mortality rate. It is the most pessimistic hypothesis as only the trees that die naturally are replaced by new recruited trees. The harvested trees are not replaced between two successive logging operations. Thus, the population of each species decreased in size between two successive logging operations. The second hypothesis was defined as the recruitment rate that would maintain a constant number of trees in the first diameter class. Claeys et al. (2019) projected the future forest dynamics up to the end of the century and they showed that projected mortality and recruitment rates in 2099 could not differ from the ones observed today. Thus, the hypothesis on the recruitment and the mortality rate is used in the future (up to 100 years) as they do today.

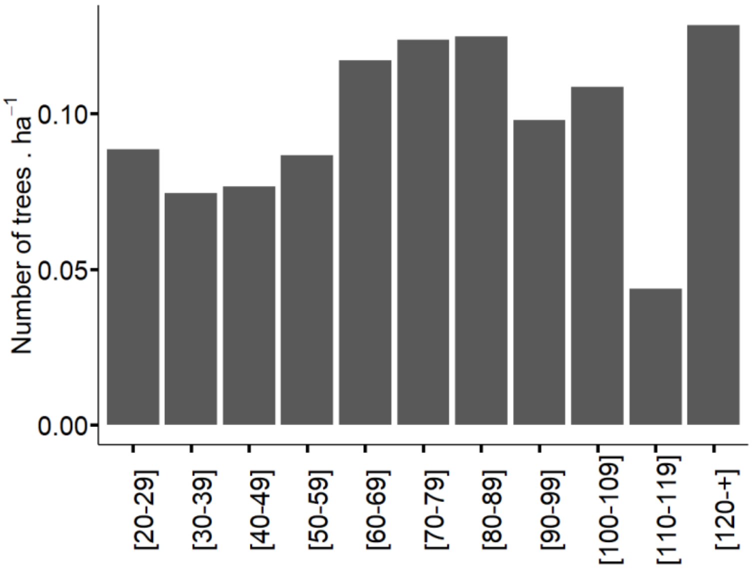

Figure 2. Population structure of *Triplochiton scleroxylon* (Ayous) defined using the number of trees per ha and per diameter class (from 20 cm of 36 logging concessions covering an area of 8 394 177.98 ha in Central Africa).

Since the mid-1900s, periodic tree monitoring and tree ring analyses have been carried out to study variability in tree growth across species in Central Africa (Durrieu de Madron, Nasi, et al., 2000; Ligot et al., 2019, 2022). We fitted growth models for each species using data from logged and unlogged areas of permanent tree plot monitoring from the DYNAFAC[34] network covering the five Central African countries. From the combined dataset, we identified 882 trees belonging to 8 sites in three countries (Cameroun, Central African Republic, and Republic of Congo). Minimum and maximum sampled diameters ranged from 10 to 150 cm. The monitoring period ranged from 1984 to 2017. The mixed second-degree polynomial models (with a random site effect) were fitted for species monitored in several sites. Because of all estimated coefficients from the mixed model was not significant, the mean of increment (0.775) has been used in the simulation in order to estimate the diameter growth (Table 2).

Table 2. Estimated coefficients (a, b and c) of growth models between the increment (ac in cm year^{-1}) and the initial diameter (D in cm). The sample including the number of trees (n) and the number of sites (site) are also given. ^{ns} non-significant (p-value > 0.050)

species	n	site	model	a	b	c
Ayous	882	8	$ac \sim D + D^2 + (1\|site)$	0.688^{ns}	0.002^{ns}	0.00001^{ns}

The transition probabilities of three parameters (mortality, growth, and recruitment rate) allowed making the harvested matrix. The logging operations have been modeled using the logging parameters (minimum cutting

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diameter, cutting and damage rate). The minimum cutting diameters were obtained from decrees of application of the forestry administrations (MCD_A) at the country level and the one used in the management plan (MCD_M, with $MCD_M \geq MCD_A$) at the logging company level. At the Central Africa level, we weighted the MCD_A and MCD_M values to the occupied area (**MCD_A = 65 cm** and **MCD_M = 90 cm**). The cutting rate (CA), which defines the proportion of harvested trees (trees with a diameter greater than MCD_A or MCD_M), was given by logging companies, and it was also weighted at the Central Africa level with a value of 82%. Given the current state of knowledge, it appears reasonable to use a fixed damage rate caused by logging of 7% of the initial population that disappears (Durrieu de Madron, Fontez, et al., 2000). The average cutting cycle (i.e. the period between two successive logging operations) is 28 years (FRMI, 2018), but we used 25 years to simplify computation of four simulations reaching 100 years (25, 50, 75 and 100 years), as requested by IUCN criterion A.

The Figure 3 shows the PPR in production forests for the *Triplochiton scleroxylon*. The reduction in the population of each species was then calculated as the difference between the initial numbers of mature individuals and the predicted numbers of mature individuals predicted after 100 years. The PPR in production forest was from **– 91.99 % (MCD_A) to -80.89% (MCD_M)** for the recruitment of 1% and from **– 85.14 % (MCD_A) to -76% (MCD_M)** for the constant recruitment over 100 years.

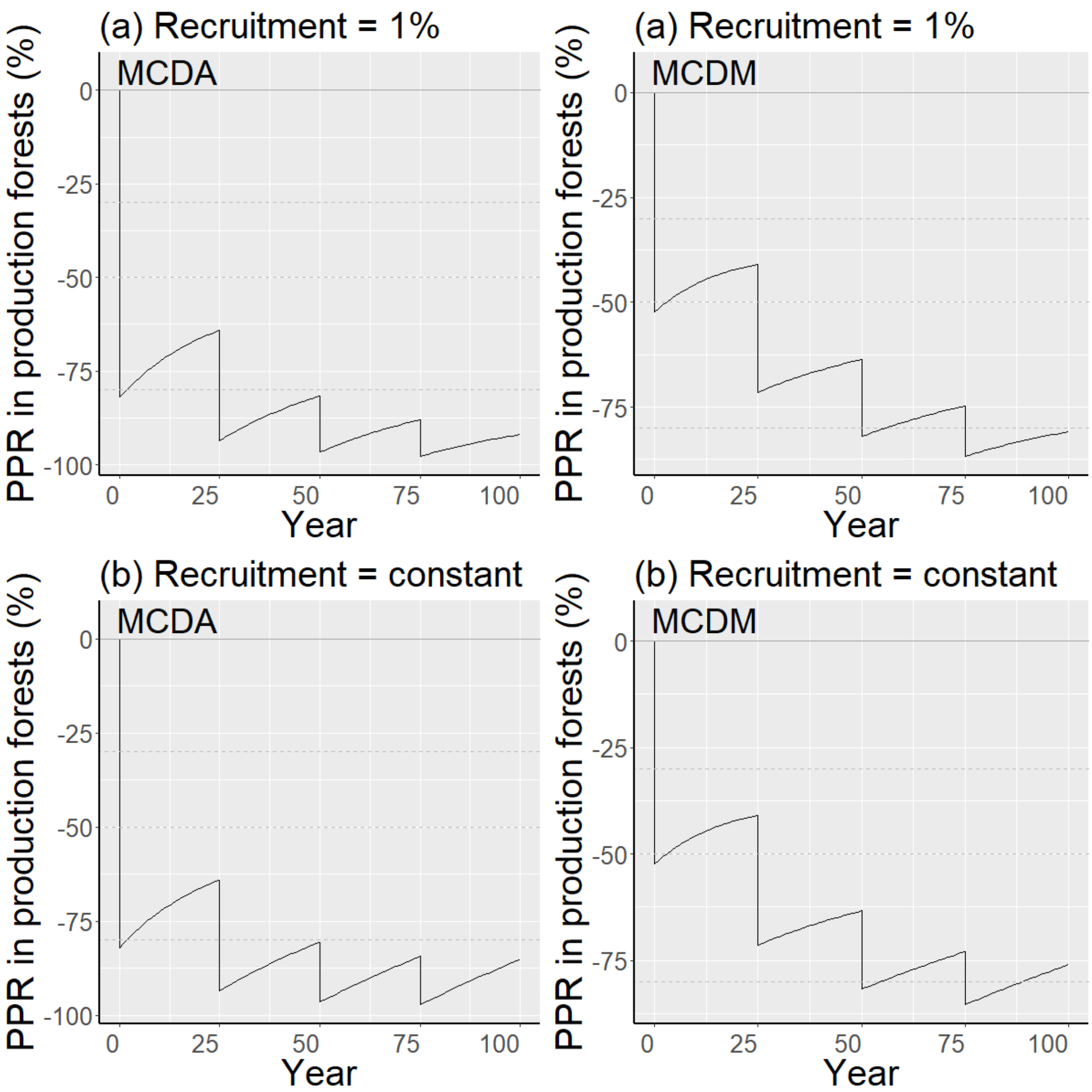

Figure 2. Simulations showing the projected population reduction (PPR) from the diameter of mature individuals (65 cm) in production forests for the *Triplochiton scleroxylon* over 100 years.

- **PPR in the non-permanent forest domain**

The major threats in the non-permanent domain are the habitat loss due to the destruction of natural environments because of population growth and urbanization, the expansion of agriculture, fuelwood collection, illegal logging, and the overharvesting of non-timber forest products (Bradshaw et al., 2009). Based on the large range of this species in Central Africa, the harvested volume from illegal logging and legal logging are 46% and 54%, respectively (FRMI 2018). In this condition, it was hypothesized that there is 54% of PPR from production forests and 46% of PPR from illegal logging in 100% PPR due to forest logging. Given that the PPR of production forests associated with its forest area was known, we deduced the PPR and forest area of illegal logging from those of the production forests. As a result, 28 791 214 ha were affected for the illegal logging for this species. The non-permanent domain area (70 374 966.74 ha) was considered as the area which was related to today's deforestation rate of 0.35% $year^{-1}$ in Central Africa (Vancutsem et al., 2021). This is a conservative value since it will probably decrease in the future (Swamy et al., 2018).

The PPR in Central Africa by considering the PPR in production forest, protected area and non-permanent domain was from **– 47.7 % (MCD_A) to -42.0% (MCD_M)** for the recruitment of 1% and from **– 44.1 % (MCD_A) to -39.4% (MCD_M)** for the constant recruitment over 100 years.

- **PPR in West Africa**

In this region, forests are generally not managed in concessions, and the large part of the rainforest has been transformed in cultivated areas (Nix, 2019). Given the high degree of anthropization in this area, the main threats are the habitat loss due to the destruction of natural environments and illegal logging, and the trees are frequently felled in fields. Applying the deforestation rate related to agricultural production can be considered as a proxy for tree removal. Thus, the forest areas in West Africa (15 600 000 ha) were subject to a constant annual deforestation rate of 1.20% $year^{-1}$ (Vancutsem et al., 2021). Taking this rate of deforestation as constant over the next 100 years, when it is expected to decline, is a reasonable precautionary measure incorporating illegal logging.

- **PPR global**

We thus had two different PPR: PPR_C in Central Africa and PPR_W in West Africa. The global PPR was then computed after weighting the two values by their relative forest areas:

$$PPR = \frac{(S_C \times PPR_C) + (S_W \times PPR_W)}{S_C + S_W}$$

where S_C and S_W are forest areas in Central and West Africa, respectively.

The criterion A3 based on (c) a decline in area of occupancy (AOO), the extent of occurrence (EOO), and/or habitat quality; and (d) potential levels of exploitation, has been computed as follows: (i) 30%≤PPR<50%, the species is considered as Vulnerable (VU); (ii) 50%≤PPR <80%, the species is considered as Endangered (EN), and PPR ≥ 80%, the species is considered as Critically Endangered (CR).

The PPR global in distribution range of the *Triplochiton scleroxylon* was from **– 42.0 % (MCD_A) to -37.0% (MCD_M)** for the recruitment of 1% and from **– 38.9 % (MCD_A) to -34.8% (MCD_M)** for the constant recruitment over 100 years. This PPR is > 30% and < 50%, suggesting that this species is threatened under the status of **Vulnerable (VU)** in its geographic area.

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