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A global checklist of the genus *Callicarpa* L. (Lamiaceae) in the 21st century

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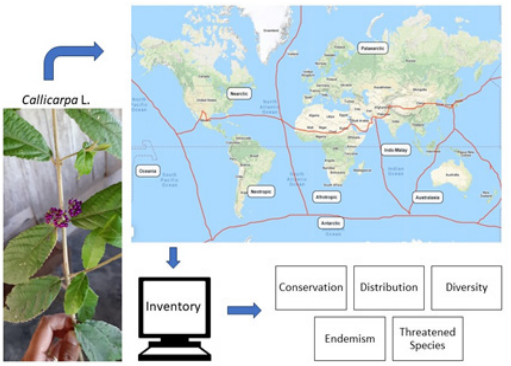
Graphical Abstract



Abstract

The genus *Callicarpa* L. is one of the most diverse vascular plants in the family of Lamiaceae. However, its biodiversity has greatly changed due to various ecological and anthropogenic disturbances, while knowledge of its overall distribution and conservation is becoming more inadequate. Herein, a global checklist of *Callicarpa* species is presented by integrating the past with the most recent collections through online databases. This checklist contains 148 species, 98 (66.0%) of which are endemic, mostly from Cuba, Indonesia, the Philippines, China, Vietnam, and Malaysia. *C. americana* is the most abundant species (36.8%), while 138 species represent the scarcest taxa (<2%) from all species sampled. The most species-rich country is China (44 spp.), while the Indo-Malayan region is the most species-rich biogeographic region (101 spp.) Moreover, 64 species (43%) were assessed in the 2022 IUCN Red List of Threatened Species which includes 33 species (23%) Least Concern (LC), 9 species (6%) Vulnerable (VU), 12 species (8%) Endangered (EN), 6 species (4%) Critically Endangered (CR), 1 species (<1%) Near Threatened and 3 species (2%) Data Deficient. This paper represents a step toward *Callicarpa* species conservation, especially of highly threatened species to address species conservation in a global context.

Keywords: conservation; distribution; diversity; endemism; threatened species

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Introduction

Callicarpa L. is among the largest genus of the family Lamiaceae, with approximately 170 species worldwide [1, 2, 3, 4]. The genus is derived from the Greek *callos*, meaning beauty, and *carpos*, meaning fruit, which is typically in brightly colored exocarp making it notably called a "beauty berry" [5]. Species of *Callicarpa* are shrubs and small trees that occur in temperate and tropical regions of the Mediterranean and Southwestern and Central Asia, Sub-Saharan Africa, Madagascar, China, Australia, South America, North America, including Mexico, and Indomalaysia [2]. According to Moldenke [6], there are two key centers of *Callicarpa*, which include the Philippines and Cuba representing the Old and the New World, respectively, noted for their diversity and endemicity.

Species of *Callicarpa* are common in many secondary forests, especially in parts of the Malesian region, wherein 51 species of *Callicarpa* were distributed across the region [7]. On the other hand, *Callicarpa* in North America, Central America, and South America which are known to be part of the New World was composed of 33 recognized species, mostly originating from Cuba [8]. Munir [9] Chen et al. [10], Leeratiwong et al. [11], and Bramley [3, 7, 12] have provided an inventory of *Callicarpa* species with taxonomic descriptions in Australia, Taiwan, Thailand, Borneo, Philippines, and the species distribution in the Malesian region, respectively. Most of the specimens used in these studies were collected in the early 20th century and updates in the recent collections of the 21st century were not included in the list.

Recent studies on morphology, palynology, phytochemistry, and molecular phylogeny have caused large-scale modifications in species classification, resulting in outdated data of the *Callicarpa* species [3, 13, 14, 15, 16, 17, 18]. Likewise, newly discovered species have greatly increased their diversity worldwide. Among these includes *C. argentii* Bramley, *C. coriacea* Bramley, *C. subequalis* Bramley and *C. teneriflora* Bramley from Borneo [3], *C. anosodonta* Bramley, *C. mendumiae* Bramley, and *C. pseudoverticillata* Bramley from Sulawesi [19], and *C. bachmaensis* Soejima and Tagane from Central Vietnam [20], while replacement names continued to modify *Callicarpa* nomenclature, e.g., *C. peichieniana* W. Y. Chun & S. L. Chen ex W. Z. Fang [21] from China. Moreover, increasing rate of introduced species in the new environment, e.g., the existence of *C. dichotoma* (Lour.) K.Koch and *C. japonica* Thunb, a native of China, Vietnam, Korea, and Japan [1] but occupied distant places like New York and New Jersey, USA have caused a huge adjustment in the species distribution [22].

The economic importance of *Callicarpa* includes food from *C. pentandra* Roxb., *C. pedunculata* R.Br., *C. bicolor* Juss. and *C. erioclona* Schauer [12, 23], medicine [13, 24] and construct [25] which are derived from the twigs, roots, fruits, and leaves of *Callicarpa*. Likewise, due to their ornamental properties, several taxa were cultivated for horticulture. Numerous species were cultivated and well-known in gardens, including the well-known *C. japonica*, *C. americana* L., *C. dichotoma*, and *C. bodinieri* var. *giraldii* (Hesse ex Rehder) Rehder [12, 26] which became widespread in many countries. Human pressure on plant resources like in *Callicarpa* species has led to the depletion of these resources while increasing potentials of invasive species have become uncontrollable.

For the first time, an overview of the current list of all known *Callicarpa* species by scientific name, country, and biogeographic distribution collected based on an online database is hereby presented. This study aims to present an updated floristic inventory of *Callicarpa* species and describe its distribution patterns based on the past to the most recent collections. This study will serve as a representation for regional and international investigations of *Callicarpa* species to answer questions concerning the distribution in its ecological and geographical context. Additionally, this study aims to collect significant and knowledge-based information required for action towards better conservation and sustainable management of *Callicarpa* species in a larger context.

Materials and Methods

This work provides a global preliminary species list (Table 1) of the genus *Callicarpa* by scientific name and country-level distribution, including biogeographic areas (Figure 1), in which all information was obtained through recognized online herbaria and open-access databases to biodiversity data (Table 2). Data on available and accepted *Callicarpa* species were checked and collected from several international online plant databases (Table 2). Samples were based primarily on the preserved specimen through herbarium collections contributed by numerous botanists who have focused their floristic studies on *Callicarpa* species. To make the data from the digital database more comparable, only taxonomically accepted names were included, while taxa with synonymous and doubtful taxonomic status and undefined places of collection were omitted. Online species descriptions were downloaded in the Global Biodiversity Information Facility (GBIF) using the 'Darwin Core Archive' format, which contains the URLs of the information while collections from online databases of recognized herbaria were consulted for the final compilation of samples. Moreover, the resulting species list was then compared to the international standard taxonomic checklist prioritizing those species that are listed in Plants of the World Online [27] and Catalogue of Life [28] to verify species distribution and classifications.

Figure 1. The biogeographic realms of the world [29] used in the study of *Callicarpa* species (Map: www. scribblemaps.com)

Table 1. Checklist of *Callicarpa* species worldwide based on the available digital herbarium and databases.

Species	No. of occurrences	Country	IUCN status	Biogeographic Region	Endemic
C. aculeolata Schauer	17	DO, JM, CU	NE	NT	DO
C. acuminata Kunth	2293	BO, BR, BZ, CO, CR, EC, GT, HN, IN, MX, NI, PA, PE, VE	LC	NT, IM	---
C. acutidens Schauer	7	VN	NE	IM	VN
C. acutifolia C.H.Chang	9	CN, PH	NE	PA, IM	---
C. albidotomentella Merr.	3	PH	EN	IM	PH
C. alongensis Dop	1	VN	NE	IM	VN
C. americana L.	21771	BE, BM, BR, CN, CU, DE, ES, FR, GB, GE, JM, MX, PR, RU, US	LC	NE, NT, PA	---
C. ampla Schauer	52	PR, US, V	CR	NE, NT	PR
C. angusta Schauer	40	PH, TH, VN	NT	IM	---
C. angustifolia King & Gamble	87	ID, KH, MY, TH, VN	LC	IM	---
C. anomala (Ridl.) B.L.Burtt	6	ID, MY	EN	IM	ID
C. apoensis Elmer	18	ID, PH	CR	IM	PH
C. arborea Roxb.	526	BD, BT, CN, ID, IN, KH, LA, MM, MY, NP, PG, PH, PK, TH, US, VN	LC	AS, IM, NE, PA	---
C. areolata Urb.	13	CU	NE	NT	CU
C. argentii Bramley	9	ID, MY	EN	IM	ID
C. bachmaensis Soejima & Tagane	1	VN	EN	IM	VN
C. badipilosa S.Atkins	2	BN	LC	IM	BN
C. barbata Ridl.	22	ID, MY	LC	IM	ID
C. basilanensis Merr.	19	PH	VU	IM	PH
C. basitruncata Merr. ex Moldenke	5	CN	NE	PA	CN
C. baviensis Moldenke	1	VN	NE	IM	VN
C. bodinieri H.Lév.	1022	AU, BE, CN, DE, ES, GE, NL, RU, SE, TH, TW, US, VN	NE	AS, IM, NE, PA	---
C. borneensis Moldenke	1	ID	LC	IM	ID
C. bracteata Dop	4	VN	NE	IM	VN
C. brevipes (Benth.) Hance	173	CN, HK, IN, TH, VN	LC	IM, PA	---
C. brevipetiolata Merr.	15	ID	NE	IM	ID
C. brevistyla Munir	65	AU	NE	AS	AU
C. bucheri Moldenke	7	CU	NE	NT	CU
C. candicans (Burm.f.) Hochr.	1205	AU, BR, CN, FM, GU, ID, IN, KH, LA, MP, MU, MY, PG, PH, PW, TH, TL, US, VN	LC	AS, OC, AT, NE, NT, IM, PA	---
C. cathayana C.H.Chang	628	BE, CA, CN, DE, KR, VN	NE	IM, PA	---
C. caudata Maxim.	207	AU, ID, PG, PH, SB, US	LC	AS, IM, NE	---
C. cinnamomea (Hallier f.) Govaerts	19	ID	EN	IM	ID
C. collina Diels	13	CN	NE	PA	CN
C. coriacea Bramley	3	MY	DD	IM	MY
C. crassinervis Urb.	28	CU	NE	NT	CU
C. cubensis Urb.	89	CU, MX	NE	NT	CU
C. cuneifolia Britton & P.Wilson	12	CU	NE	NT	CU
C. denticulata Merr.	3	PH	CR	IM	PH
C. dentosa (H.T.Chang) W.Z.Fang	10	CN	NE	PA	CN
C. dichotoma (Lour.) K.Koch	2,106	BE, CA, CN, DE, DK, EE, ES, FR, GB, IN, JP, KP, KR, RU, TW, US, VN	NE	IM, NE, PA	---
C. dolichophylla Merr.	237	PH	LC	IM	PH
C. endertii (Moldenke) Bramley	7	ID	CR	IM	ID
C. erioclona Schauer	183	CN, FM, ID, MP, MY, PG, PH, PW, PW, VN	LC	AS, IM, OC, PA	---
C. erythrosticta Merr. & Chun	14	CN	NE	PA	CN
C. fasciculiflora Merr.	4	PH	DD	IM	PH
C. ferruginea Sw.	73	CU, JM	NE	NT	EA
C. flavida Elmer	38	PH	VU	IM	PH
C. floccosa Urb.	5	CU	NE	IM	CU

Table 1. Checklist of *Callicarpa* species worldwide based on the available digital herbarium and databases. ***(cont'd)***

Species	No. of occurrences	Country	IUCN status	Biogeographic Region	Endemic
C. fulva A.Rich.	62	CU, JM	NE	IM, NT	CU
C. fulvohirsuta Merr.	21	MY, ID	LC	IM	---
C. furfuracea Ridl.	29	ID, MY, TH	LC	IM	CU
C. giraldii Hesse ex Rehder	523	CN, DE, EE	NE	PA	---
C. glabra Koidz.	78	JP, MP	NE	AS, PA	JP
C. glabrifolia S.Atkins	28	BN, ID, MY	LC	IM	---
C. gracilipes Rehder	10	CN	NE	PA	CN
C. grandiflora (Hallier f.) Govaerts	3	ID	NE	IM	ID
C. grisebachii Urb.	28	CU	NE	NT	CU
C. havilandii (King & Gamble) H.J.Lam	109	BN, ID, MY, PG	LC	AS, IM	---
C. heterotricha Merr.	1	VN	NE	IM	VN
C. hispida (Moldenke) Bramley	23	MY	LC	IM	MY
C. hitchcockii Millsp.	31	BS, CU	NE	NT	WI
C. homoeophylla (Hallier f.) Govaerts	3	ID	NE	IM	ID
C. hypoleucophylla T.P.Lin & J.L.Wang	92	CN, TW	NE	IM, PA	---
C. inaequalis Teijsm. & Binn. ex Bakh.	17	ID	NE	IM	ID
C. integerrima Champ. ex Benth.	83	CN, HK, TW	NE	IM, PA	---
C. involucrata Merr.	78	BN, ID, MY	LC	IM	---
C. japonica Thunb.	11694	BE, CA, CN, DE, DK, ES, FR, GB, ID, JP, KP, KR, LA, MY, LA, NZ, PH, PK, PT, PW, RU, SE, TH, US	NE	AS, IM, NE, PA	---
C. kerrii Leerat. & A.J.Paton	1	TH	LC	IM	TH
C. kinabaluensis Bakh. & Heine	13	ID, MY	LC	IM	MY
C. kochiana Makino	668	CN, HK, JP, TW	NE	IM, PA	---
C. kwangtungensis Chun	191	CN, KR, TW, US	NE	IM, NE, PA	---
C. laciniata H.J.Lam	1	ID	NE	IM	ID
C. lamii Hosok.	17	GU, JP, MP	NE	AS, OC, PA	---
C. lancifolia Millsp.	39	BS, CU, PH	NE	IM, NT	CU
C. leonis Moldenke	5	CU	NE	IM	CU
C. lingii Merr.	13	CN	NE	PA	CU
C. loboapiculata Metcalf	14	CN, HK, VN	NE	IM, PA	---
C. longibracteata C.H.Chang	1	CN	NE	PA	CN
C. longifolia Lam.	1482	AU, BD, BN, BT, CA, CN, CX, HK, ID, IN, KH, LA, MM, MY, NL, PG, PH, RU, SG, TH, TW, US, VN	LC	AS, IM, NE, PA	---
C. longipes Dunn	93	CN, TW, VN	NE	IM, PA	---
C. longipetiolata Merr.	25	PH	EN	IM	PH
C. luteopunctata C.H.Chang	44	CN, VN	NE	IM, PA	---
C. macrophylla Vahl	390	AU, BD, BR, BT, CN, ES, ID, IN, LA, LK, MM, NP, PG, PK, RE, TH, US, VN	LC	AS, AT, IM, NE, PA	---
C. madagascariensis Moldenke	10	MG	NE	AT	MG
C. magnifolia Merr.	2	PH	EN	IM	PH
C. maingayi King & Gamble	58	MY, SG, TH	LC	IM	---
C. membranacea C.H.Chang	225	CN	NE	PA	CN
C. mendumiae Bramley	1	ID	LC	IM	ID
C. micrantha S.Vidal	132	PH	NE	IM	---
C. mollis Siebold & Zucc.	2965	BE, CN, DK, JP, KP, KR, PH, RU	NE	IM, PA	---
C. nipensis Britton & P.Wilson	3	CU	NE	NT	CU
C. nudiflora Hook. & Arn.	250	BR, CN, HK, IN, JP, LK, SG, VN	LC	IM, NT, PA	---
C. oblanceolata Urb.	88	CU	NE	NT	CU
C. oligantha Merr.	2	CN	NE	PA	CN
C. oshimensis Hayata	165	ID, JP, TW	NE	IM, PA	---
C. pachyclada Quisumb. & Merr.	6	PH	EN	IM	PH

Table 1. Checklist of *Callicarpa* species worldwide based on the available digital herbarium and databases. ***(cont'd)***

Species	No. of occurrences	Country	IUCN status	Biogeographic Region	Endemic
C. paloensis Elmer	17	PH	VU	IM	PH
C. parvifolia Hook. & Arn.	18	JP	NE	PA	JP
C. pedunculata R.Br.	3510	AU, CN, HK, ID, JP, LK, PG, PH, RE, SB, TH, TL, TW, US, VN	LC	AS, AT, IM, PA	---
C. peichieniana H.Ma & W.B.Yu	65	CN	NE	PA	CN
C. pentandra Roxb.	996	BN, ID, MY, PG, PH, SB, SG, TH	LC	AS, IM	---
C. petelotii Dop	9	VN	NE	IM	VN
C. pilosissima Maxim.	307	CN, TW	NE	IM, PA	---
C. platyphylla Merr.	8	PH	VU	IM	PH
C. plumosa Quisumb. & Merr.	7	PH	DD	IM	PH
C. prolifera C.Y.Wu	3	CN	NE	PA	CN
C. pseudorubella C.H.Chang	1	CN	NE	PA	CN
C. pseudoverticillata Bramley	3	ID	EN	IM	ID
C. psilocalyx C.B.Clarke	4	IN	VU	IM	IN
C. ramiflora Merr.	10	PH	VU	IM	PH
C. randaiensis Hayata	403	CN, TW	NE	IM, PA	---
C. remotiflora T.P.Lin & J.L.Wang	86	CN, TW	NE	IM, PA	---
C. remotiserrulata Hayata	292	CN, JP, TW	NE	IM, PA	---
C. resinosa C.Wright & Moldenke	17	CU	NE	NT	CU
C. reticulata Sw.	6	JM	NE	NT	JM
C. revoluta Moldenke	4	CU	NE	NT	CU
C. ridleyi S.Moore	2	ID	NE	IM	ID
C. roigii Britton	22	CU, JM, US	NE	NE, NT	CU
C. rubella Lindl.	1299	AU, BT, CN, HK, ID, IN, LA, MM, MY, NZ, TH, TL, TW, US, VN	LC	AS, IM, NE, PA	---
C. rudis S.Moore	8	ID	NE	IM	ID
C. saccata Steenis	25	ID, MY	LC	IM	MY
C. salicifolia C.Pei & W.Z.Fang	9	CN	NE	PA	CN
C. scandens (Moldenke) Govaerts	21	BN, ID, MY	VU	IM	---
C. selleana Urb. & Ekman	6	HT	CR	NT	HT
C. sessilifolia Wall., 1829	1	BD	NE	IM	BD
C. shaferi Britton & P.Wilson	12	CU, JM	NE	NT	CU
C. shikokiana Makino	112	JP, KR, US	NE	NE, PA	---
C. shirasawana Makino	151	CA, JP, KR, RU, US	NE	PA	---
C. simondii Dop	1	VN	NE	IM	VN
C. siongsaiensis Metcalf	2	CN	NE	PA	CN
C. sordida Urb.	16	DO, JM	NE	NT	DO
C. stapfii Moldenke	34	ID, MY	LC	IM	MY
C. subaequalis Bramley	5	ID, MY	CR	IM	ID
C. subalbida Elmer	17	PH	EN	IM	PH
C. subintegra Merr.	16	PH	EN	IM	PH
C. subpubescens Hook. & Arn.	264	JP, US	LC	NE, PA	---
C. superposita Merr.	11	ID, MY	VU	IM	---
C. surigaensis Merr.	7	PH	EN	IM	PH
C. teneriflora Bramley	15	ID, MY	VU	IM	ID
C. thozetii Munir	14	AU	NE	AS	AU
C. tikusikensis Masam.	92	CN, TW	NE	IM, PA	---
C. tingwuensis C.H.Chang	4	CN	NE	PA	CN
C. tomentosa (L.) L.	233	IN, LK	LC	IM	---
C. tosaensis Makino	4	JP, US	NE	NE, PA	---
C. vansteenisii Moldenke	1	ID	NE	IM	ID

Table 1. Checklist of *Callicarpa* species worldwide based on the available digital herbarium and databases. ***(cont'd)***

Species	No. of occurrences	Country	IUCN status	Biogeographic Region	Endemic
C. vestita Wall. ex C.B.Clarke	8	BT, IN, NP, US	NE	IM, NE	---
C. woodii Merr.	2	MY	LC	IM	MY
C. wrightii Britton & P.Wilson	4	CU	NE	NT	CU

Note: IUCN Red List 2022 Version 2022-2. (Abbreviations: LC: Least Concern; VU: Vulnerable; EN: Endangered; CR: Critically Endangered; NT: Near Threatened; DD: Data Deficient). Occurrences and endemicity by country, following the ISO 3166 country names standard (Alpha-2 code); (---) not endemic to any country; Biogeographic regions (Abbreviations: OC: Oceania; NE: Nearctic; NT: Neotropical; AT: Afrotropical; AN: Antarctic; PA: Palearctic; AS: Australasia; IM: Indo-Malay [29].

Information gathered based on country-level distribution was recorded following the ISO 3166 country names standard. The country distributions were also matched to eight biogeographic regions: Oceania, Neotropical, Nearctic, Afrotropical, Antarctic, Palearctic, Australasia, and Indo-Malay, following Olson et al. [29] (Figure 1). Data acquired from the digital database were compiled to detail the quantitative information, biogeographic diversity, and conservation status of each species.

Results and Discussion

A total of 59,074 recorded occurrences of *Callicarpa* species representing the botanical exploration of several botanists in different parts of the world from data matrices of recognized herbaria. These collections represent 148 species of *Callicarpa*, showing the highest recorded occurrences of *C. americana* (36.8%), *C. japonica* (19.8%), *C. pedunculata* (5.9%), *C. mollis* Siebold & Zucc (5.0%), *C. acuminata* Kunth (3.9%), *C. dichotoma* (3.6%), *C. longifolia* Lam. (2.5%), *C. rubella* Lindl. (2.5%), *C. candicans* (Burm.f.) Hochr. (2.0%) and *C. bodinieri* (2%) (Figure 2A). Almost all these taxa are globally abundant and likely to have wide distribution ranges, except *C. mollis* where most of its collections were restricted to the limits of South Korea and Central and Southern Japan (Table 1).

C. americana is the most abundant species which comprised 36.8% out of all occurrences of *Callicarpa* species collected, while 138 *Callicarpa* species represent the scarcest taxa of less than 2% of the total collection (Figure 2A). *C. japonica* is the most widely distributed species, found in 24 countries of Australasia, Indomalayan, Nearctic, and Palaearctic region. However, *C. candicans* (Burm.f.) Hochr. was regarded as the most widely distributed species based on biogeographic region, as species occurred in seven biogeographic regions (Table 1). This result suggests that these species may have better dispersal capabilities and/or less habitat specificity across the region.

The most species-rich country showing the highest number of scientifically accepted species of *Callicarpa* is China (44 spp.), with *C. kochiana* Makino and *C. giraldii* as the most abundant collected species. Other species-rich countries include Indonesia (41 spp.), Philippines (30 spp.), Malaysia (27 spp.), Vietnam (24 spp.), Cuba (21 spp.), United States of America (18 spp.) and Taiwan (16 spp.). Furthermore, Bray-Curtis distance-based analysis showed 11% similarity in terms of species occurrence in all biogeographic regions (Figure 3). Between Palaearctic and Indomalayan regions and the Nearctic and Australasian regions are shown to be similar in terms of species composition with values of 37% and 49%, respectively. While the Afrotropical and Oceanic region shows a similarity index of 28%.

Table 2. Global databases used for compiling the checklist of *Callicarpa* species.

Database	Source
Co's Digital Flora of the Philippines	http://www.philippineplants.org
Catalogue of Life	http://www.catalogueoflife.org/annual-checklist/2021
Global Biodiversity Information Facility (GBIF)	http://www.gbif.org.occurrence
International Plant Names Index (IPNI)	http://www.ipni.org
Kew World Checklist of Selected Plant Families (WCSP)	http://wcsp.science.kew.org/home.do
Plant of the World Online (POWO)	http://plantsoftheworldonline.org
Tropicos	http://www.tropicos.org/Home.aspx

On the other hand, the Neotropical region is the most unique in terms of species composition wherein 19 species (83%) are endemic, mostly from Cuba, Puerto Rico, Greater Antilles, West Indies, Jamaica, Haiti, and Dominican Republic.

The country with the highest level of endemic species of *Callicarpa* is Cuba (19 spp.), followed by Indonesia (18 spp.), the Philippines (17 spp.), China (14 spp.), Vietnam (8 spp.), and Malaysia (6 spp.). Other countries including Australia, Dominican Republic, and Japan have two endemics each while Bangladesh, Greater Antilles, Haiti, India, Jamaica, Madagascar, Puerto Rico, Thailand, and West Indies are represented by one endemic species of *Callicarpa* each (Figure 2B).

Countries were also classified according to biogeographic regions, with Indo-Malay regions having the highest number of accepted *Callicarpa* species (101 spp.), followed by the Nearctic region (26 spp.), Neotropical and Australasia (10 spp. each), Palaearctic (7 spp.), Afrotropical (4 spp.) and Oceania (2 spp.). However, no *Callicarpa* species were occurring in the Antarctic region (Figure 5).

In addition, 64 species (43%) were assessed in the 2022 International Union for Conservation of Nature's Red List of Threatened Species [30], while 84 species (57%) were not assessed (Figure 4). The conservation status of the defined *Callicarpa* species includes 33 species (23%) Least Concern (LC), 9 species (6%) Vulnerable (VU), 12 species (8%) Endangered (EN), 6 species (4%) Critically Endangered (CR), 1 species (<1%) Near Threatened and 3 species (2%) Data Deficient.

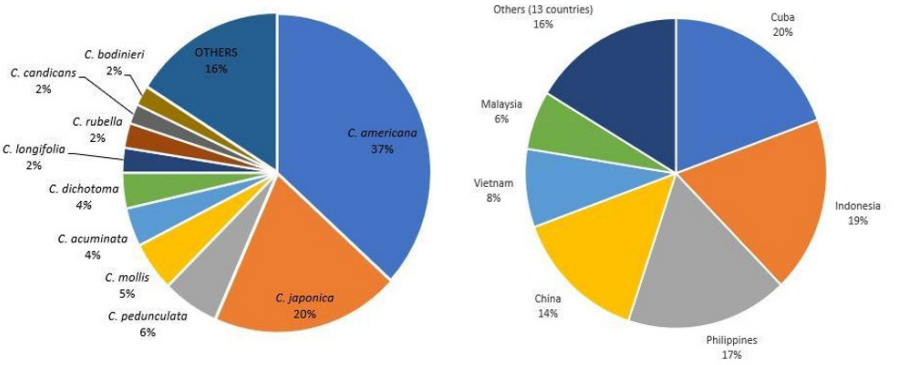

Figure 2. (A) Percentage number of occurrences (species abundance) per *Callicarpa* species. **(B)** The proportion of endemic *Callicarpa* species by country.

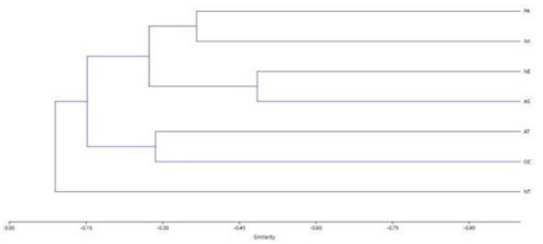

Figure 3. Bray-Curtis distanced-based species similarity analysis of *Callicarpa* species across different biogeographical regions based on species occurrence. (Note: Antarctica is excluded in the analysis).

The occurrences of *Callicarpa* species have quadrupled that of the collections in the past centuries. Almost 30% of the recognized *Callicarpa* species were originated in China (Figure 2A). However, 77% of its collections are not evaluated under the IUCN Red List of Threatened Species. It also shows that the two most dominant *Callicarpa* species, *C. americana*, and *C. japonica* constitute 56.6% of the global collection.

Moreover, most of the samples used in this study were documented to occur in a disturbed habitat which may indicate the importance of a disturbance in the existence and diversity of species [31]. According to Mott [32], species show a higher rate of adaptability to environmental conditions including anthropogenic disturbance, then these species may display a higher chance of survival. In this study, *C. bodinieri* and *C. candicans* were recorded to thrive in a wide range of biogeographical settings, thus more chance of species survival (Table 1). Likewise, the dominance of *C. americana* and *C. japonica* compared to low-dense *C. shikokiana* Makino and *C. shirasawana* Makino could also signal higher rates of survival because they can outcompete other species. On the other hand, species showing higher restriction to habitat like in the case of *C. ampla* Schauer were found originally in the Virgin Islands and Puerto Rico but currently became restricted only in the Palo Colorado forest region of the Luquillo Mountains [30] may experience a higher risk of extinction.

Indeed, the high rate of species richness and endemism in the Indo-Malayan Realm is owing to its highly variable and diverse tropical forests (Figure 5). However, various studies [12, 33, 34, 35] stated that most countries have been gradually losing the natural habitat of many plants causing biodiversity loss. In the Philippines, tropical forests originally covered almost 93% of its total land area, but according to figures published by Revilla [36], the remaining tropical forest decreased to 22% due to human disturbances. In the previous study conducted by Bramley [12] of *Callicarpa* species in the Philippines, 27 species were recognized while 16 are endemic but most recent collections from the year 2000 up to the present showed that current collections of *Callicarpa* species in the Philippines decreased by 50% [37] GBIF Occurrence Download https://doi.org/10.15468/dl.8c9mdp).

Aside from the Philippines, several countries in the Indo-Malayan region including Malaysia, Indonesia, and Taiwan were also at a grave threat of forest loss due to climate change, unsustainable logging, land conversion, and forest fires, e.g., major fires in Sumatra and Kalimantan in Indonesia, Brazil, and Australia, which serves as important repositories of *Callicarpa* species, destroyed large forest areas affecting species diversity [34, 39]. Furthermore, according to the report given by Millennium Ecosystem Assessment [34], more than half of the 14 biomes have experienced a 20-50% increase in human-related pressures during the past 50 years. Also, Temperate and Mediterranean forests and temperate grasslands were affected by land conversion, being highest in tropical forests. Based on the reports of The Catalogue of Seed Plants of the West Indies [8], Cuba has 22 *Callicarpa* species (19 endemics), however, current statistics collected in the online database show that Cuba had decreased their collection to an alarming rate of 85% [38] GBIF Occurrence Download https://doi.org/10.15468/dl.d598ja). Currently, only three species, *C. cuneifolia* Britton & P. Wilson, *C. fulva* A. Rich, and *C. americana* have been collected from the year 2000 up to the present with one occurrence per species [40, 41]. Indeed, the low species rate is a result of human and other environmental disturbances. Two endemic *Callicarpa* species, *C. apoensis* Elmer, and *C. ampla* are considered critically threatened as it is restricted to Mt. Apo, Philippines, and Puerto Rico, respectively, and both are currently facing a high risk of extinction due to the continued forest and habitat degradation (Table 1) [12, 41].

Threatened species, generally was used to refer to the three categories (vulnerable, endangered, and critically endangered species) [31] of the *Callicarpa* species' current conservation status. Based on this study, the Indo-Malayan region was relatively highest in the number of threatened species, 25 (93%) out of 27 threatened *Callicarpa* species worldwide, where nine VU, 12 EN, and four CR (Figure 3). As the frequency of species extinction increases, the distribution of species is becoming more homogenous, thus, resulting in a lack of biodiversity [42, 43]. When species decline especially in endemic species resulting from anthropogenic disturbance, they are replaced by a smaller number of expanding species that can grow and thrive in the human-altered environment and later develop species homogeneity [44].

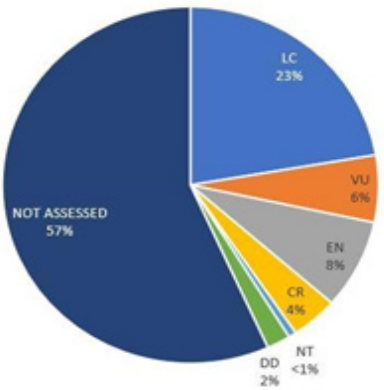

Figure 4. Conservation status of *Callicarpa* species based on the International Union of Conservation of Nature [30].

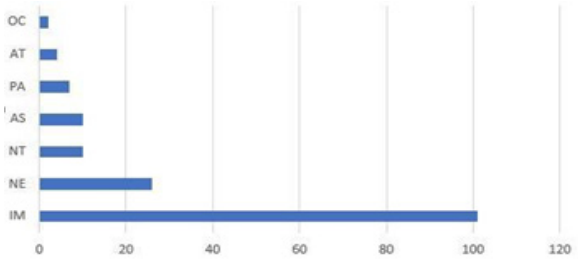

Figure 5. The number of *Callicarpa* species per biogeographic region. (Abbreviations: AT: Afrotropical; AS: Australasia; PA: Palaearctic; OC: Oceanic; NE: Nearctic; NT: Neotropical; IM: Indo-Malay).

These species tend to reproduce and exceed population size, while native and endemic species' strong potential to become extinct is becoming high [45]. Introduced species attempt to increase biodiversity in some areas where diversity is low, e.g., *Callicarpa* species show new records of introduced species in the Palaearctic region, including *C. dichotoma* and *C. japonica* in Belgium, *C. bodinieri* in Taiwan, and *C. shikokiana* in the USA. This study shows that Belgium and the US have no endemics of *Callicarpa* while Taiwan has four, which is fewer than other Indo-Malayan countries. These species were most likely introduced as ornamental plants; however, these species have been reported to spread invasively [22] as shrubs of these *Callicarpa* species also reseed largely due to animal dispersion.

Conclusion

The result of the preliminary checklist of the *Callicarpa* species in a global context uncovers the current status of the species of *Callicarpa*. Current collections of *Callicarpa* revealed that the genus is losing its biodiversity due to human and environmental disturbances. The two key centers of *Callicarpa*, Philippines, and Cuba, have shown a 50% and 85% decrease in their specimen collection, respectively, while other species-rich countries were experiencing the same problem in biodiversity. To summarize, the collection of *Callicarpa* species revealed that China (30%) is the most specious country, the Indo-Malayan region (68%) is the most specious biogeographic region, Cuba (19%) is the most numbered endemics country, *C. japonica* is the most widespread species, *C. americana* (36.8%) is the most abundant species while 18% of the *Callicarpa* species are threatened. This paper represents a step toward *Callicarpa* species conservation, especially of highly threatened species, and it stimulates further studies to address species conservation in a global context. However, data availability is considered an important factor in developing an extensive species checklist. In this case, there will still inevitably be poorer data collection for some localities and data may not be sufficient for establishing a final assessment. This suggests that further research is needed to bridge the gap in the investigation of the distribution and conservation of species especially of elusive taxa of *Callicarpa*.

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Conflict of Interest

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Author Contributions

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References

[1] Chen, SL & Gilbert MG. Verbenaceae. In Wu Zheng-Yi & P.H. Raven (eds). Flora of China 17: 1–49. Science Press, Beijing & Missouri Botanical Garden, St. Louis, **1994**. Available from: http://www.efloras.org/florataxon.aspx?flora_id=2&taxon_ id=10941 (accessed 5 November 2021).

[2] Harley RM, Atkins S, Budantsey AL, Cantino PD, Conn BJ, Grayer R, Harley MM, Kok R De, Krestovskaja T, Morales R, Paton AJ, Ryding O & Upson T. Labiatae. In: Kadereit J.W. (eds) Flowering Plant Dicotyledons. The Families and Genera of Vascular Plants, Vol 7. Springer, Berlin, Heidelberg **2004**.

[3] Bramley GLC. The genus *Callicarpa* (Lamiaceae) on Borneo. Botanical Journal of the Linnean Society **2009**. 159(3), 416–455.

[4] Li B & Olmstead RG. Two new subfamilies in Lamiaceae. Phytotaxa, 313(2), 222 **2017**; doi:10.11646/phytotaxa.313.2.9

[5] Valkenburg JLCHV & Bunyapraphatsara N. PROSEA Medicinal Plants. PlantUse English **2016**.

[6] Moldenke HN. A monograph of the genus *Callicarpa* as it occurs in America and in cultivation. Repertorium Novarum Specierum Regni Vegetabilis, 39(10-25) **1936**; 288–317.

[7] Bramley GLC. Distribution patterns in Malesian *Callicarpa* (Lamiaceae). Garden's Bulletin Singapore **2011**; 63(1&2):287-298.

[8] Acevedo-Rodríguez P & Strong MT. Catalogue of seed plants of the West Indies Smithsonian Contributions to Botany **2012**; 98: 1–192.

[9] Munir J. A Taxonomic Revision of the genus *Callicarpa* in Australia. J. Adelaide Bot. Gard **1982**; 6: 5 – 39.

[10] Chen TT, Chaw SM &Yang YP. A revision on *Callicarpa* (Verbenaceae) of Taiwan. Taiwania **1998**; 43: 330 – 345.

[11] Leeratiwong C & Chantaranothai P, Paton A. Notes on the genus *Callicarpa* (Lamiaceae) in Thailand. Thai. For. Bull., Bot. **2009**; 35: 73 – 79.

[12] Bramley GLC. The genus *Callicarpa* (Lamiaceae) in the Philippines. Kew Bulletin **2013**; 68(3), 369–418.

[13] Jones WP & Kinghorn AD. Biologically Active Natural Products of The Genus *Callicarpa*. Current Bioactive Compounds **2008**; 4(1), 15–32.

[14] Li B, Cantino PD, Olmstead RG, Bramley GLC, Xiang CL, Ma ZH & Zhang DX. A large-scale chloroplast phylogeny of the Lamiaceae sheds new light on its subfamilial classification. Scientific Reports **2016**; 6(1). doi:10.1038/srep34343

[15] Ma Z, Bramley GLC, Zhang D. Pollen morphology of *Callicarpa* L. (Lamiaceae) from China and its systematic implications. Plant Systematics & Evolution **2016**; 302 (1), 67-88

[16] Ma Z & Su Z. The identity of *Callicarpa minutiflora* Y. Y. Qian (Lamiaceae) and taxonomic synonym of *C. longifolia* Lamarck. PhytoKeys **2016**; 75: 13 18. https://doi.org/10.3897/phytokeys.75.10704

[17] Danila JS, Alejandro GJD. Pollen morphology and infrageneric classification of selected *Callicarpa* species (Lamiaceae) from the Philippines and Borneo. Biodiversitas **2020**; 21 (12): 5736-5746. DOI: 10.13057/biodiv/d211234.

[18] Danila JS, Alejandro GJD. Leaf geometric morphometric analyses of *Callicarpa* and *Geunsia* (Lamiaceae) in the Malesian region. Biodiversitas **2021**; 22: 4379-4390.

[19] Bramley GLC. Three new species of *Callicarpa* (Lamiaceae) from Sulawesi. Kew Bulletin, 67(2), 213–223 **2012**; doi:10.1007/s12225-012-9359-3

[20] Soejima A, Tagane S, Van NN, Duy CN, Huong NT & Yahara T. *Callicarpa* bachmaensis Soejima & Tagane (Lamiaceae), a new species from Bach Ma National Park in Thua Thien Hue Province, Central Vietnam. PhytoKeys **2016**; (62), 33–39. https://doi.org/10.3897/phytokeys.62.7974

[21] Ma H, Jiang N, Yu WB & Li ZH. Valid publication of the name *Callicarpa peichieniana* (Lamiaceae). Nordic Journal of Botany **2011**; 29(2), 224–226. doi:10.1111/j.1756-1051.2010.01006.x

[22] Atha DM, Gunderson M, Whitaker E, Alvarez RA &Young M. First report of *Callicarpa dichotoma* and *Callicarpa japonica* (Lamiaceae) spontaneous and potentially invasive in New York and New Jersey. Phytoneuron **2019**; 2019-17: 1–3. ISSN 2153 733X

[23] Brown WH. Minor products of Philippine Forests, Medicinal Uses of Plants 3. Department of Agriculture and Natural Resources Bureau of Forestry Bulletin No. 22. Bureau of Printing, Manila **1921**.

[24] Tu Y, Sun L, Guo M & Chen W. The medicinal uses of *Callicarpa* L. in traditional Chinese medicine: An ethnopharmacological, phytochemical and pharmacological review. Journal of Ethnopharmacology **2013**; 146(2), 465–481. doi:10.1016/j.jep.2012.12.051

[25] Tsai LM. Biomass Production and Biomass Relationship of Young *Callicarpa pentandra*. Pertanika **1991**; 14 (3). pp. 281-285.

[26] Atkins S. Plate 363. *Callicarpa japonica*. Curtis's Botanical Magazine **1999**; 16(2), 79–83. doi:10.1111/1467-8748.00201

[27] POWO. "Plants of the World Online. Facilitated by the Royal Botanic Gardens, Kew **2023**; Published on the Internet; http://www.plantsoftheworldonline.org/ Retrieved 15 August 2023."

[28] Bánki O, Roskov Y, Vandepitte L, Dewalt R, Remsen D, Schalk P, Orrell T, Keping M, Miller J, Aalbu R, Adlard R, Adriaenssens E, Aedo C, Aescht E, Akkari N, Alonso-Zarazaga M, Alvarez B, Alvarez F & Anderson G. Catalogue of Life Checklist (Version 2021-08-25). Catalogue of Life **2021**; https://doi.org/10.48580/d4sg

[29] Olson DM, Dinerstein E, Wikramanayake ED, Burgess ND, Powell GVN, Underwood EC, & Kassem KR. Terrestrial ecoregions of the world: A new map of life on Earth. Bioscience **2001**, 51 (11), 933–938. doi:10.1641/0006-3568(2001)051[0933:TEOTWA]2.0.CO;2

[30] IUCN. The IUCN Red List of Threatened Species. Version **2022**-2. https://www.iucnredlist.org. Downloaded on [20 August 2023].

[31] Tobgay, Jamtsho T & Sridith K. The resilience of Rubiaceae to anthropogenic factors: a case study from the Himalayan range of Western Bhutan. Environmental Protection and Natural Resources **2021**; 32(1) 13-20. https://doi.org/10.2478/oszn-2021-0003

[32] Mott CL. Environmental Constraints to the Geographic Expansion of Plant and Animal Species. Nature Education Knowledge **2010**; 3(10):72

[33] John. Protected areas systems review of the Indo-Malayan Realm **1997**.

[34] [MA] Millennium Ecosystem Assessment. Ecosystems and Human Well-being: Biodiversity Synthesis. World Resources Institute, Washington, DC **2005**.

[35] [FAO] Food and Agriculture Organization of the United Nations. Global Forest Resources Assessment 2020: Main report. Rome **2020**.

[36] Revilla AV. Fifty-year development program for the Philippines. In: Proceedings of the Seminar on the Fifty-Year Forestry Development program of the Philippines. Philippine Institute for Development Studies and Forestry Development Center, University of the Philippines, Los Banos **1986**; Pp. 1-20.

[37] GBIF Secretariat (**2022**). GBIF Backbone Taxonomy. Checklist dataset https://doi.org/10.15468/39omei accessed via GBIF.org on 2022-02-26.

[38] [FAO] Food and Agriculture Organization of the United Nations. **2010**. Global forest resources assessment 2010: Main report. Rome: Food and Agriculture Organization of the United Nations.

[39] Orrell T, Informatics Office. NMNH Extant Specimen Records (USNM, US). Version 1.51. National Museum of Natural History, Smithsonian Institution. Occurrence dataset https://doi.org/10.15468/hnhrg3 accessed via GBIF.org on **2022**-03-05.

[40] Ramirez J, Watson K, Thiers B & Mcmillin L. The New York Botanical Garden Herbarium (NY). Version 1.44. The New York Botanical Garden **2022**. Occurrence dataset https://doi.org/10.15468/6e8nje accessed via GBIF.org on 2022-03-05.

[41] Natureserve. NatureServe Explorer [web application]. NatureServe, Arlington, Virginia **2022**; Available https://explorer.natureserve.org/. (Accessed: March 05, 2022).

[42] Daehler CC & Carino D. Hybridization between native and alien plants and its consequences. In: Lockwood JL, McKinney M (Eds). Biotic homogenization. Kluwer Academic/Plenum Publishing, New York: 81-102. doi: 10.1007/978-1-4615-1261-5_5

[43] Richardson DM & Pyšek P. Plant invasions: merging the concepts of species invasiveness and community invasibility. Progress in Physical Geography **2006**; 30(3), 409–431. doi:10.1191/0309133306pp490pr

[44] Yang Z, Liu X, Zhou M, Ai D, Wang G, Wang Y & Lundholm JT. The effect of environmental heterogeneity on species richness depends on community position along the environmental gradient. Scientific Reports **2015**; 5(1). doi:10.1038/srep15723

[45] Mcneely JA, Mooney HA, Neville LE, Schei P & Waage JK. A global strategy on invasive alien species. IUCN, Gland, Switzerland, and Cambridge, UK **2001**.