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Geospatial Distribution Pattern of *Xanthostemon* F. Muell. Species (Iron Wood) in the Philippines Based on Updated Literature and Internet Digital Checklist Platforms

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A B S T R A C T

Unsustainable harvesting, land conversion, and mining activities have raised conservation concerns about the remaining stands of vulnerable to critically endangered Philippine *Xanthostemon* in its natural habitat and with restricted distribution. Mapping the current distribution is essential in developing conservation strategies and protecting these threatened species. This paper generated the distribution patterns of *Xanthostemon* in the Philippine islands by data mining from published and digital checklist platforms and translated them into distribution maps using Quantum Geographic Information System (QGIS). The data comprised 20 reported provincial occurrences of *Xanthostemon* species in the Philippines. Three endemic *Xanthostemon* species are widely distributed in selected provinces, and two have a restricted distribution pattern, making them more vulnerable to threats. Additional distribution of a possible introduced species, *X. chrysanthus* was reported in Agusan del Norte. The morphological description of the six *Xanthostemon* species reported was described based on the available data. The provinces of Leyte, Samar, Agusan del Norte, and Surigao del Sur obtained the highest number, having three species per province based on the number of reported occurrences. As per the island scale, Mindanao has the highest number of occurrences having ten provinces with four and one unidentified *Xanthostemon* species, naming it as the center of *Xanthostemon* in the country. Areas rich in heavy metals are a growing preference for ironwood and have been exploited for mining, which has been concluded for the threatened conservation status. The generated distribution map will significantly benefit from addressing intervention between local agencies and different sectors regarding the conservation and management of the natural population of *Xanthostemon*, especially in mining exploited areas, and could also serve as insight for further research into the collection of ironwoods for morphological, taxonomic, ecological, and molecular studies.

Keywords: *conservation, data mining, GIS, magkono, ultrabasic areas*

1 Introduction

The genus *Xanthostemon* F. Muell. (Myrtaceae) comprises approximately 50 recognized species in the world which are native and distributed in Australia, New Caledonia, the Solomon Islands, Papua New Guinea, Indonesia, and the Philippines (Wilson and Co 1998; Wilson and Pitisopa 2007; IPNI 2023). Currently, five unique *Xanthostemon* species are endemic to the Philippines, including *Xanthostemon verdugonianus* Náves, *Xanthostemon fruticosus* Peter G. Wilson & Co, *Xanthostemon speciosus* Merr., *Xanthostemon bracteatus* Merr., and *Xanthostemon philippinensis* Merr, which are categorized as either vulnerable to critically endangered under the International Union for Conservation of Nature Red List of Threatened Species (IUCN 2022). The five native *Xanthostemon* species have a limited distribution range and usually grow as shrubs. Only a few develop into tall and large trees in their natural environments, almost thriving in ultramafic areas rich in heavy metals, significantly affecting their threatened conservation status (Malabrigo and Gibe 2020; Lillo et al. 2019).

In the Philippines, *Xanthostemon* or ironwoods are of great economic importance because of their durability and high-quality hardwood, making it a highly-priced timber with great demand locally (Merrill 1904). Usually, the harvested wood is used for construction materials, mainly carved furniture used to decorate houses, posts, salt-water piling, tool handles, and bowling balls (Gerry 1952). However, the increasing demand for *Xanthostemon* wood as a marketable resource has more recently raised conservation concerns due to the possibility of unsustainable harvesting along with unregulated activities, including land conversion and mining, which could threaten the remaining stands and lead to habitat loss, especially since there is an overlapping of resources of mineral production and preferable growth of the natural population of *Xanthostemon* species in forest vegetation over ultramafic soils rich in heavy metals (Malabrigo and Gibe 2020). In addition, limited literature describes the Philippine *Xanthostemon* species regarding its distribution, habitat, medicinal properties, morphological variations, and taxonomic aspects.

Distribution mapping of species based on the relevant available dataset is an increasingly important application in biodiversity assessment and habitat management (Velásquez-Tibatá et al. 2019). Distribution mapping using GIS can predict the suitable areas species distribution, richness, abundance, and species-habitat relationship, which are vital in understanding the potential habitat for a respective plant species within a community (Franklin 2010; Jumawan 2022). Information based on the generated data from GIS could also be effectively utilized in evaluating the species' conservation status and planning and developing conservation strategies, including efforts to conserve threatened species (Sofaer et al. 2019; Jumawan and Macandog 2021). Thus, it is essential to consolidate and generate a distribution map to locate areas with *Xanthostemon* species in the Philippines. Conservation and management approaches are crucial as the species are threatened by logging, agricultural conversion, and large-scale mining that can potentially deteriorate the remaining stands of the Philippine *Xanthostemon* with restricted distribution. The general objective of this paper is to generate geospatial distribution patterns of *Xanthostemon* species in the Philippine islands. Based on available literature and digital platforms, the study specifically aimed to create species distribution maps and describe the taxonomic traits of *Xanthostemon* species in the Philippines.

2 Materials and Methods

Data Mining

The geographical occurrences of *Xanthostemon* spp. in the Philippine islands were obtained from published articles and appropriate online websites by data mining. It was explored using search terms in Google Scholar, Co's Digital Flora of the Philippines website (https://www.philippineplants.org/), and Facebook pages that have been created to encourage participants to post photographs of plants observed in the Philippines like Co's Digital Flora of the Philippines (https://www.facebook.com/groups/260276987384309), Eastern Visayas Native Tree Enthusiasts (https://www.facebook.com/groups/628975971248761/about), and Nabunturan Native Tree Enthusiasts (https://www.facebook.com/groups/761053897684600/about). The terms entered in various search engines mentioned above were: "*Xanthostemon* in the Philippines", "Mangkono in the Philippines", "Ironwood in the Philippines", "Mangkono", "*Xanthostemon*", "Bagoadlau", and "Mapilig". Available data associated with the occurrence of *Xanthostesmon* were downloaded and recorded, including the authors' names, GPS coordinates, taxonomic description, habit form, and habitat preference. Only reported occurrences from the wild or its natural habitat were included to ensure distribution truthfulness. Gathered data without GPS coordinates was searched online based on the location per province. Overall datasets were encoded in Microsoft Excel and utilized for analysis.

Data Mapping

Collected data from published articles and online websites were utilized to generate the distribution pattern depicted as maps of *Xanthostemon* species in the Philippines. The distribution map was categorized to the provincial level only since most of the available data specify the location at the provincial level. Geographic Information System (GIS) software called Quantum GIS (QGIS) version 3.24 was used in this study. The administrative boundary shapefile of the Philippines was acquired from DIVA-GIS, a free computer program for mapping and geographic data analysis. The GPS coordinates based on the occurrences of different *Xanthostemon* species were then entered as a comma delimited (.csv) file along with the administrative boundary shapefile in QGIS. Geospatial distribution map layouts of *Xanthostemon* spp. per province were generated as outputs.

3 Results and Discussion

Morphological Description of Xanthostemon Species in the Philippines

There are five endemic *Xanthostemon* species and one potentially introduced species in the Philippines. The comparative morphological description based on the habit, leaves, flower and fruit characteristics are presented in Table 1. These species are: *Xanthostemon verdugonianus* Náves, *Xanthostemon fruticosus* Peter G. Wilson & Co, *Xanthostemon speciosus* Merr., *Xanthostemon bracteatus* Merr., *Xanthostemon philippinensis* Merr., and *Xanthostemon chrysanthus* (F. Muell.) Benth.

Xanthostemon verdugonianus Náves or locally called 'magkono' is a large tree-growing plant that mostly thrives in areas where soil and rock type are rich in heavy metals including nickel, aluminum, and iron, where mining-related activities are also present (Sarmiento and Demetillo 2017; Sarmiento 2020; Ocon et al. 2018). This species bears a bright red flower with plenty of stamens (Figure 1B) and is also known to produce flowers and fruits at a younger stage (Figure 1A), similar to *X. fruticosus* and *X. speciosus* (Malabrigo and Gibe 2020), making them hard to identify sometimes due to their similarities. The hypanthium is cup-shaped somewhat similar to *X. fruticosus*. However, *X. verdugonianus* can grow taller, reaching 50 m, than *X. fruticosus* (Merrill 1904). This species of ironwood has been recognized as an efficient material for construction (salt-water piling, furniture, and posts) due to its hardness and high-density wood.

Xanthostemon fruticosus Wilson & Co, a red-bearing flower that produces fruit at an early stage similar to *X. verdugonianus* and *X. speciosus* but can be differentiated by its longer pedicel (6.5-10 mm) (Malabrigo and Gibe 2020). The species also resembles *X. verdugonianus* having a cup-shaped hypanthium but can be categorized by their habit form, lamina, and petiole sizes. The three red-bearing *Xanthostemon* species have an obovate-ovate lamina shape, which is hard to identify without their reproductive organs. It grows as a shrub (about 1 m high) which was then derived from its epithet *fruticusos* (a Latin word) meaning 'shrubby' (Wilson and Co, 1998), however, there are sightings reported by Malabrigo and Gibe (2020) that *X. fruticosus* can grow into a mature tree.

Xanthostemon speciosus Merr. is another red-producing flower of the three Philippine endemic *Xanthostemon* species. It grows as a tree up to 10 m high (Merrill 1904) and produces fruit at an early growth stage similar to *X. fruticosus* and *X. verdugonianus*. Although *X. speciosus* and *X. fruticosus* have similar features, the distinct characteristics of *X. speciosus* can be distinguished by having a larger flower, shorter calyx tubes but broader in dimension, crimson filaments, and larger petals (Merrill 1094).

Xanthostemon bracteatus Merr., is a unique species and the only *Xanthostemon* species in the Philippines that have a white color flower (Figure 1C&D). The species have the smallest fruit among the five Philippine endemic ironwood (Malabrigo and Gibe 2020). It grows as a tree approximately 14 m tall and has quality hardwood (Merrill 1917). Petioles are shorter compared to the rest of the Philippine ironwood. Leaf arrangement alternate similar to *X. verdugonianus, X. speciosus,* and *X. philippinensis* and have an oblong-ovate lamina. It is locally called as "diricalin" in the Province of Camarines and "bagoadlao" in the Province of Samar.

Xanthostemon philippinensis Merr., locally called "bagoadlau" and "canacanala", and also

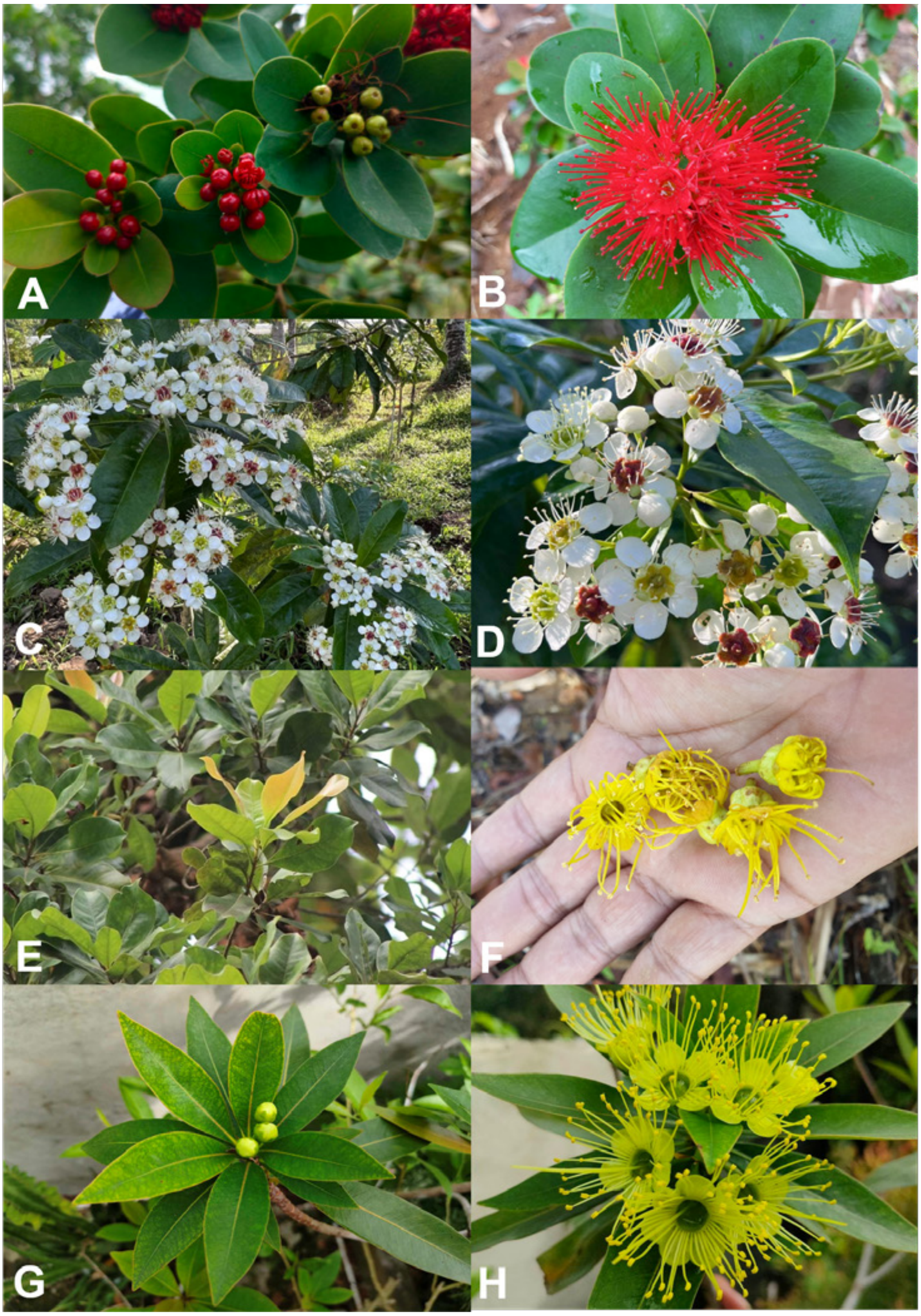

Figure 1. Photographs of some *Xanthostemon* species in the Philippines. Developing flower buds (red) and lobed mature fruit (green) captured in the terminal branches (A) while fully developed inflorescence (B) of *Xanthostemon verdugonianus* Náves found in Dinagat Islands. The oblong-ovate leaves (C) and distinct white petals (D) of *Xanthostemon bracteatus* Merr. found in Davao Oriental. The elliptical leaves (E) and noticeable yellow flowers (F) of *Xanthostemon philippinensis* Merr. found in Surigao del Sur. The whorled shiny-green leaves (G) and bright yellow flowers (H) of *Xanthostemon chrysanthus*, an introduced species found in Agusan del Norte. (Photo credits: Angie Abucayon for Fig. 1 A&B and Carlo Ancla for Fig. 1 C-F).

Table 1. Comparative taxonomic description of the five endemic and one potentially introduced *Xanthostemon* species in the Philippines

Taxonomic Characters	*X. verdugonianus*	*X. fruticosus*	*X. speciosus*	*X. bracteatus*	*X. philippinensis*	*X.chrysanthus*
Habit	large tree (26-50 m tall) [1,2]	shrub (1 m)1- tree[5]	tree (about 5-10m high)[1,2]	tree (14 m tall)[3]	large tree (20 m tall)[3]	tree[4]
Inflorescence						
Color	red	red	red	white[3]	yellow[3]	yellow[4]
Position	terminal	axillary[1]	terminal[2]	axillary[3]	terminal racemes[3]	axillary[4]
Peduncles and Pedicels	-	long (5-9 mm and 6.5-10 mm, respectively)[1]	pedicel 2-3 mm long[2]	pedicel 5 mm long or less[3]	pedicel 10 mm long[3]	-
Hypanthium	cup-shaped[1]	cup-shaped[1]	broader dish-shaped with distinct vesicles[1]	-	-	cup-shaped[4]
Leaves						
Arrangement	alternate	spiral[1]	alternate[2]	alternate[3]	alternate[3]	alternate[4]
Petiole	4-7 mm long[1]	7-10 mm long and 2.5-3 mm wide[1]	10 mm long[2]	5 mm long[3]	up to 10 mm long[3]	up to 10 mm long[4]
Lamina	obovate (3-7 cm long and 1-3.5 cm wide)[1]	obovate (6-8 cm long and 3.5-4 cm wide)[1]	ovate or obovate (6-8 cm long and 3-4.5 cm wide)[2]	oblong to ovate (11-18 cm long and 4-8 cm wide)[3]	elliptic to obovate-elliptic (4-7 cm long and 2.5-3.5 wide)[3]	lanceolate to oblanceolate (10-15 cm long and (3-4.5 cm wide)[4]
Calyx	lobe-shaped calyx	5 equal lobes, triangular[1]	calyx-tube, 5 lobes, triangular, spreading[2]	calyx-tube shallow, lobes spreading[3]	calyx-tube cup-shaped, 5 lobes[3]	yellowish, triangular[4]
Ovary	superior	inferior (2-3 locular)[1]	ovary 3-celled[2]	ovary 3-celled[3]	superior, ovoid, and 3-celled[3]	nearly superior, 3 locular[4]
Fruit	dehiscent, 2-3 lobes	depressed-globular (6.5 mm long and 8 mm wide)[1]	large fruits[5]	small capsule (1 cm diameter)[3]	3 large fruit (> 2 cm diameter)[5]	9-15 mm diameter[4]

[1]Wilson and Co (1998); [2]Merrill (1904); [3]Merrill (1917); [4]Wilson (1990); [5]Malabrigo Jr and Gibe (2020).

called as "bano" in local communities of Surigao del Sur. The only Philippine ironwood that produces a yellow flower and stamen (Merrill 1917; Malabrigo and Gibe 2020). This species has the largest fruit among *X. verdugonianus, X. fruticosus, X. speciosus,* and *X. bracteatus*. This species can be found in lowland primary forests, growing approximately 20 m high, and resembles another yellow -producing flower *X. chrysanthus* (endemic in Australia and potentially introduced in the Philippines), but can be differentiated by its larger fruit and elliptic to obovate-elliptic lamina.

Xanthostemon chrysanthus (F. Muell.) Benth., a potentially introduced species in the Philippines which this species is endemic in Queensland Australia. *X. chrysanthus* has similar features to our endemic *X. philippinensis* having a yellow color flower with plenty of stamens (Figure 1G&H), alternate leaf arrangement, up to 10 mm long petioles, and a superior ovary but has a distinct characteristic including a shorter length of stamen and smaller discs than *X. philippinensis*. However, its type of cultivation locality is still unknown in the Philippines. Hence, further assessment of this species is highly needed.

Number of reported occurrences per species and province

The gathered data comprised 20 reported provincial occurrences of *Xanthostemon* species in the Philippines. Reported data obtained five species that are Philippine Endemics and are classified as Vulnerable to Critically Endangered, one potentially introduced species which is also endemic in Australia, and two unidentified *Xanthostemon* species found in Mindanao (Table 2).

In total, there were 11 provincial occurrences of the natural population of *X. verdugonianus* reported from published articles and different websites, including the Province of Romblon in Luzon; Provinces of Leyte, Palawan, and Samar in Visayas; and the Province of Dinagat island, Surigao del Sur, Surigao del Norte, Agusan del

Sur, Agusan del Norte, Zamboanga, Misamis Oriental in Mindanao. These records made it one of the ironwood species with a wide distribution pattern and occurred in the three islands of the Philippines (Figure 3A). In terms of the number of occurrences of *X. verdugonianus* per island, the island of Mindanao obtained the highest occurrences having seven provinces recorded and known to be abundant as a shrub to tree in the Province of Dinagat islands (Figure 2), and Surigao del Norte, the northeastern section of Mindanao. The *X. verdugonianus* has been assessed as Vulnerable in the International Union for Conservation of Nature (IUCN) Red List of Threatened Species and classified as endangered under DAO 2017-11. Its population in the wild is still decreasing especially tree-type forms, due to unregulated harvesting and anthropogenic activities.

Xanthostemon fruticosus can be found in coastal low scrub communities where it is exposed to an ultrabasic substrate (Wilson 1998; Malabrigo and Gibe 2020). This species has a restricted distribution and occurs only in the northeastern part of the Sierra Madre Mountain Range and in ultrabasic areas in the Province of Isabela (Figure 3B), naming it Sierra Madre mangkono. As of date, *X. fruticosus* is classified by the IUCN as Endangered and Critically Endangered under the DAO 2017-11, which led to its current threatened conservation status due to its restricted distribution and the vast decline of population in the wild.

X. speciosus, locally it is called the 'Palawan mangkono' due to its restricted distribution pattern that can only be found in the province of Palawan (Figure 3C), southwesternmost of the archipelago, including Puerto Princessa, Narra, Roxas, Bataraza, Quezon, El Nido, Basuanga, Caluit, Snake island, Islands of Pangalusian, Busuanga, Culion, Calauit, Uson, Apo, and Dinanglet. Similar to the previous *Xanthostemon* species mentioned, *X. speciosus* can also be found in the selected ultramafic type of habitat in Palawan (De Castro et al. 2020; Malabrigo and Gibe 2020). The conservation status is Near Threatened as per the assessment of the IUCN and was assessed as Vulnerable under DAO 2017-11.

Xanthostemon bracteatus can be observed in three major islands in the Philippines, including in the Province of Camarines Norte, Albay, Aurora, Nueva Ecija, and Catanduanes in Luzon; Province of Leyte and Samar in Visayas; and Province of

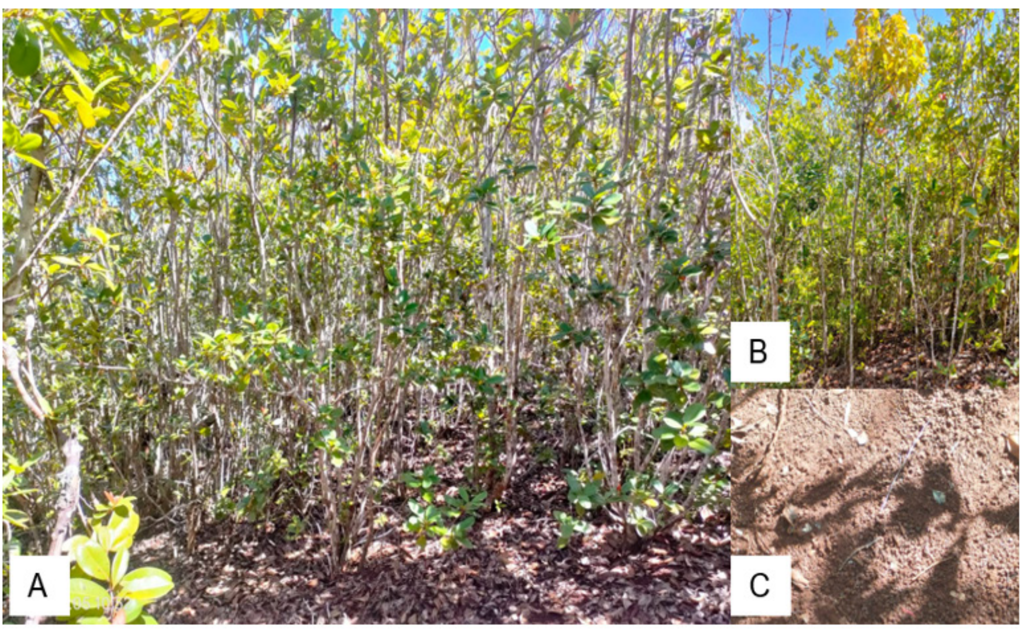

Figure 2. The abundance of a shrub-type natural population of *Xanthostemon verdugonianus* in the Municipality of Loreto, Dinagat Islands. A-B) the upper portion of the area, approximately 700 m away from the shore observed with dominant population, gwrowing over the distinct reddish brown soil color (C) where the magkono is abundant.

Dinagat Island, Surigao del Sur, Compostella Valley, Davao Oriental, and Agusan del Norte in Mindanao (Figure 3D). It is one of the well-distributed ironwood species that can be observed in three major islands of the Philippines but only in selected provinces, similar to *X. philippinensis*. This species is assessed as Vulnerable and Critically Endangered under the IUCN Red List Status and DAO 2017-11, respectively.

Available literature documented *X. philippinensis* in selected provinces in the Philippines, including the Province of Camarines Norte, Isabela, and Aurora in Luzon; Province of Samar and Leyte in Visayas; Province of Surigao del Sur and Misamis Oriental in Mindanao (Figure 4A). Currently, the species is categorized as Vulnerable under the IUCN Red List Status and Critically Endangered under the DAO 2017-11.

Xanthostemon chrysanthus, is a potentially introduced species whose type of cultivation locality is still unknown; however, it is reported to occur in Agusan del Norte, the northeastern side of Mindanao, and other provinces in the Philippines (Figure 4B).

Two unidentified species of *Xanthostemon* were also recorded in Mindanao (Figure 4C). *Xanthsotemon* sp. 1 was reported by Amoroso et al. (2009) in Mt. Hamiguitan, Davao Oriental, the southern portion of Mindanao. *Xanthostemon* sp. 2 was reported by Zaragoza et al. (2016) in

Table 2. Summary of the distribution and literatures of the reported *Xanthostemon* species in the Philippines

Scientific Name	Common Name	Distribution	Endemicity	Conservation Status		References
				IUCN 2022-2	DAO (2017-11)	
Xanthostemon verdugonianus Náves	Mangkono	Romblon (Sibuyan Island), Leyte, Samar (Eastern and Western), Palawan (Busuanga), Dinagat Island, Surigao del Sur (Hinatuan, Carrascal, Cantilan), Surigao del Norte (Bucas Grande, Siargao, Placer, Claver, Sohoton), Agusan del Sur (Ezperanza), Agusan del Norte (Tubay, Cabadbaran), Misamis Oriental, Zamboanga City	PE	VU	EN	Malabrigo Jr and Gibe 2020; Houdkova et al. 2020; Gregorio et al. 2011; Langerberger et al. 2006; Romeroso et al. 2021; Fernando 2017; Lilio et al. 2019; Pelser & Barcelona 2015; Sarmiento and Demetillo 2017; Merrill 1904; Ocon et al. 2018; Galolo et al. 2021; Garcia et al. 2017; Pabalan and Aquino 2020; Sarmiento 2020; Lador 2016; Sarmiento et al. 2022; Ramos et al. 2020; Guadalquiver et al. 2019; Mukul et al. 2020.
Xanthostemon bracteatus Merr.	Bagoadlau or Diridcalin or Mapilig	Camarines Norte, Samar, Aurora, Nueva Ecija, Albay (Manito), Catanduanes, Leyte, Dinagat Island, Surigao del Sur, Davao Oriental, Compostella Valley, and Agusan del Norte.	PE	VU	CR	Malabrigo Jr and Gibe 2020; Lilio et al. 2019; Pelser & Barcelona 2015.
Xanthostemon philippinensis Merr.	Bagoadlau or Canacanala	Camarines Norte (Paracale), Samar (Paranas), Isabela, Aurora (Baler), Surigao del Sur (Bislig City, Lianga), Misamis Oriental (Gingoog City), Leyte (Babatngon)	PE	VU	CR	Malabrigo Jr and Gibe 2020; Madera et al. 2021; Coracero and Malabrigo 2020a; Coracero and Malabrigo 2020b; Pelser & Barcelona 2015; Nabunturan Native Tree Enthusiasts; Eastern Visayas Native Tree Enthusiasts.
Xanthostemon fruticosus Peter G.Wilson & Co	Sierra Madre Mangkono	Isabela (Dinapique, Palanan Wilderness, Northern Sierra Madre Natural Park)	PE	EN	CR	Malabrigo Jr and Gibe 2020; Wilson and Co 1998; Co 2011.
Xanthostemon speciosus Merr.	Palawan Mangkono or Bungan	Palawan (Puerto Princessa, Narra, Roxas, Bataraza, Quezon, El Nido, Basuanga, Caluit, Snake Island, Islands of Pangalusian, Busuanga, Culion, Calauit, Uson, Apo, Dinanglet)	PE	NT	VU	Malabrigo Jr and Gibe 2020; Merrill 1904; Marler et al. 2017; De Castro et al. 2020; Pelser & Barcelona 2015.
Xanthostemon chrysanthus (F.Muell.) Benth.	Golden Penda	Agusan del Norte	Potentially Introduced	NE	-	This study
Xanthostemon sp 1	-	Davao oriental	-	-	-	Amoroso et al. 2009
Xanthostemon sp. 2	-	Lanao del Norte	-	-	-	Zaragoza et al. 2016

Note: PE = Philippine Endemic, NE = Not Evaluated, VU = Vulnerable, NT = Nearly Threatened, EN = Endangered, CR = Critically Endangered

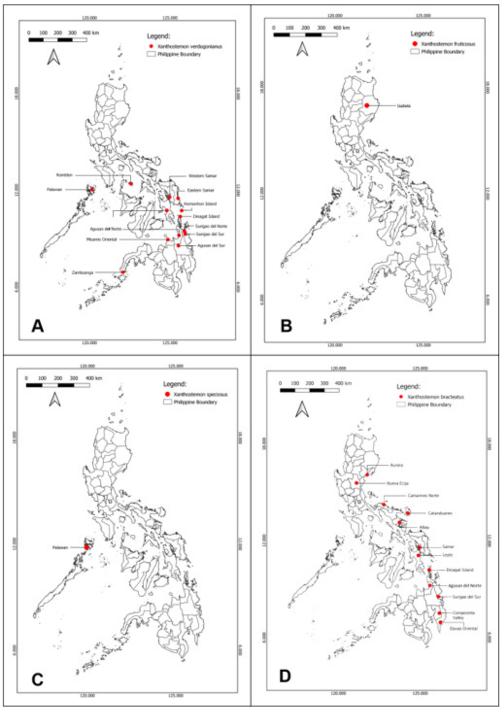

Figure 3. Species distribution of *Xanthostemon* species on a provincial scale: A. *Xanthostemon verdugonianus* Náves, B. *Xanthostemon fruticosus* Wilson & Co, C. *Xanthostemon speciosus* Merr., and D. *Xanthostemon bracteatus* Merr

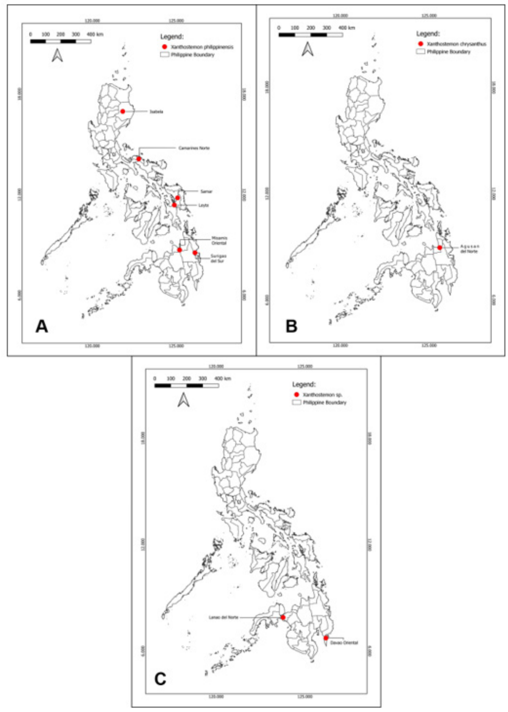

Figure 4. Species distribution of *Xanthostemon* species on a provincial scale: A. *Xanthostemon philippinensis* Merr., B. *Xanthostemon chrysanthus* (F. Muell.) Benth., C. *Xanthostemon* sp.

Kapatagan, Lanao del Norte, northwestern part of Mindanao. Unidentified species might either be unknown due to a lack of critical taxonomic traits like its reproductive organ, which was only identified at the genus level. The observed unidentified could be an additional distribution record in the area upon verification and could serve as insights for an updated distribution of *Xanthostemon* and is essential for future research on ironwoods in the area.

Overall, an additional distribution of *Xanthostemon* was recorded from the gathered data including *X. verdugonianus, X. bracteatus, X. philippinensis, X. chrysanthus*, and two unidentified species of *Xanthostemon* (Figure 5). Previous study by Malabrigo and Gibe (2020) reported the occurrences of *X. verdugonianus* in the provinces of Sibuyan Island, Leyte, Homonhon Island, Dinagat Island, Hinatuan, Bucas Grande, Siargao, Mindanao, Eastern, and Western Samar. However, an additional report was sporadically recorded in Agusan del Norte, Agusan del Sur, Misamis Oriental, Zamboanga, and Palawan. Moreover, an additional distribution report of *X. bracteatus* in Agusan del Norte and *X. philippinensis* in the Provinces of Misamis Oriental and Leyte. Furthermore, a potentially introduced species *X. chrysanthus* was reported in Agusan del Norte, and two unidentified species in Davao Oriental and Lanao del Norte. Generally, *Xanthostemon* species are primarily associated with ultramafic soils, but their sporadic distribution was not classified as ultramafic soil substrates. This observation needs further assessment as it appears that *Xanthostemon* species are not obligately thriving on ultramafic soils. The distribution data of *Xanthostemon* species in the Philippines tend to cluster in the eastern side of the Visayas and northern Mindanao islands, particularly in the Province of Samar, Province of Leyte, and Caraga Region.

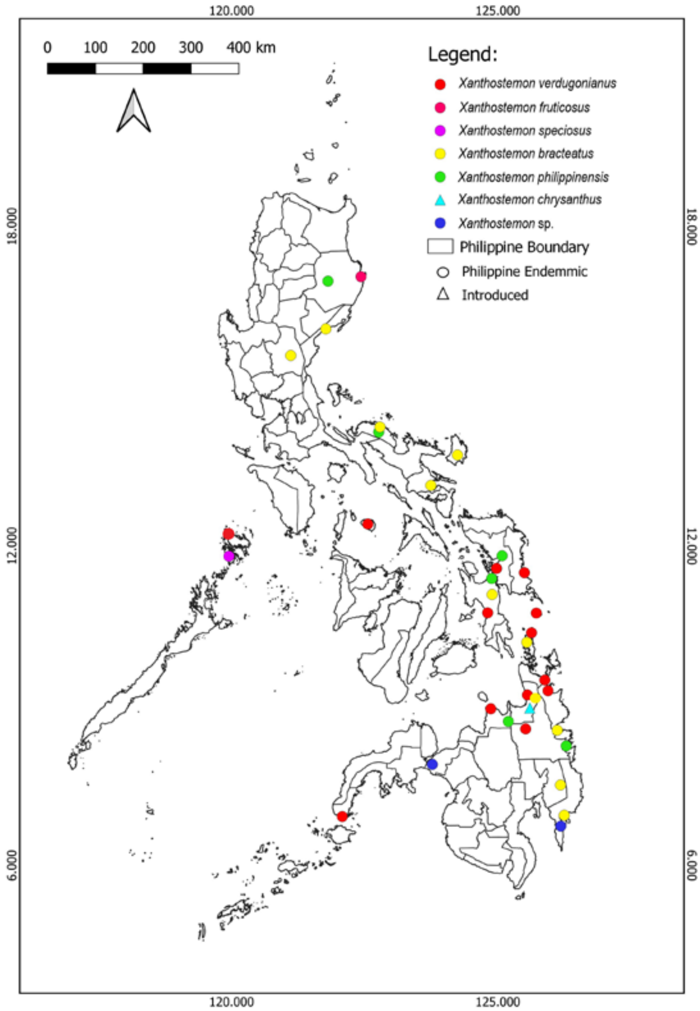

Figure 5. The overall distribution map of *Xanthostemon* species in the Philippines on a provincial scale

The number of provinces where *Xanthostemon* is reported and the number of *Xanthostemon* species per province (Table 3 and Figure 6). Based on the available data, *X. bracteatus* and *X. verdugonianus* are the widely distributed Philippine ironwood found in 12 and 11 provinces in Luzon, Visayas, and Mindanao. The *X. philippinensis* follow this with seven provincial occurrences in the three major islands of the Philippines. Two species, *X. fruticosus* and *X. speciosus* have a restricted distribution and can only be found in selected areas in Isabela and Palawan, making them more vulnerable to threats. According to Verbeck (2011), species with restricted geographical distribution tend to become extinct more than those with a broader distribution. This suggests the importance of species with limited distribution as noteworthy for conservation actions of the two species and all native ironwood species in the country. Regarding the number of reported *Xanthostemon* species per province, Leyte, Samar, Agusan del Norte, and Surigao del Sur obtained the highest number of reported *Xanthostemon*, having three species each

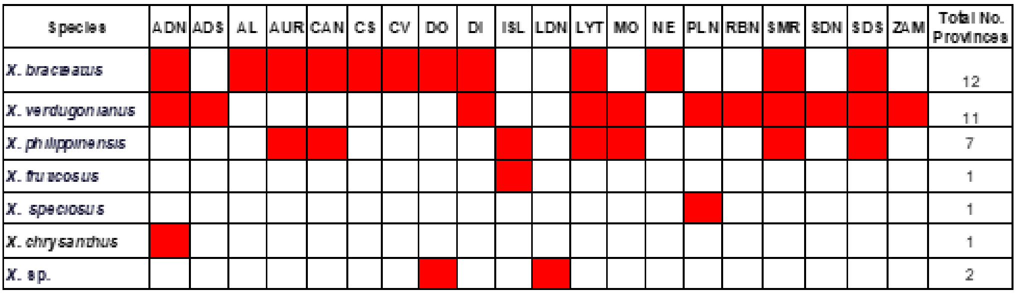

Figure 6. A total number of provinces where the *Xanthostemon* species are reported. Notes: AND = Agusan del Norte; ADS = Agusan del Sur; AL = Albay; CAN = Camarines Norte; CS = Catanduanes; CV = Compostela Valley; DO = Davao Oriental; DI = Dinagat Island; ISL = Isabela; LDN = Lanao del Norte; LYT = Leyte; MO = Misamis Oriental; NE = Nueva Ecija; PLN = Palawan; RBN = Romblon; SMR = Samar; SDN = Surigao del Norte; SDS = Surigao del Sur; and ZAM = Zamboanga.

Table 3. The total number of reported *Xanthostemon* species per province

Province	No. of Species Reported	Species
Agusan del Norte	3	*X. verdugonianus, X. bracteatus, X.chrysanthus*
Agusan del Sur	1	*X. verdugonianus*
Albay	1	*X. bracteatus*
Aurora	2	*X. bracteatus; X. philippinensis*
Camarines Norte	2	*X. bracteatus; X. philippinensis*
Catanduanes	1	*X. bracteatus*
Compostela Valley	`1	*X. bracteatus*
Davao Oriental	2	*X. bracteatus.; Xanthostemon* sp.
Dinagat Island	2	*X. verdugonianus; X. bracteatus*
Isabela	2	*X. philippinensis; X. fruticosus*
Lanao del Norte	1	*Xanthostemon* sp.
Leyte	3	*X. philippinensis; X. bracteatus; X. verdugonianus*
Misamis Oriental	2	*X. verdugonianus; X. philippinensis*
Nueva Ecija	1	*X. bracteatus*
Palawan	2	*X. speciosus, X. verdugonianus*
Romblon	1	*X. verdugonianus*
Samar	3	*X. verdugonianus; X. bracteatus; X. philippinensis*
Surigao del Norte	1	*X. verdugonianus*
Surigao del Sur	3	*X. verdugonianus; X. bracteatus; X. philippinensis*
Zamboanga	1	*X. verdugonianus*

namely: *X. verdugonianus, X. bracteatus,* and *X. philippinensis.* Two species were reported in Isabela, Aurora, Camarines Norte, Palawan, Davao Oriental, Dinagat Islands, and Misamis Oriental (Figure 7). As per the island scale, Mindanao has the highest number of occurrences having ten provinces with four and two unidentified *Xanthostemon* species, naming it as the center of *Xanthostemon* in the country. They were followed by Luzon and Visayas, with seven and three provincial occurrences, respectively. However, habitat destruction associated with logging, agricultural conversion, and large-scale mining could deteriorate the remaining stands of *Xanthostemon* and other flora and fauna species in the country. According to Fernando (2001), the country's forest genetic resources are threatened by overexploitation for commercial purposes, habitat fragmentation, and land conversion (logging and shifting cultivation). The Philippines

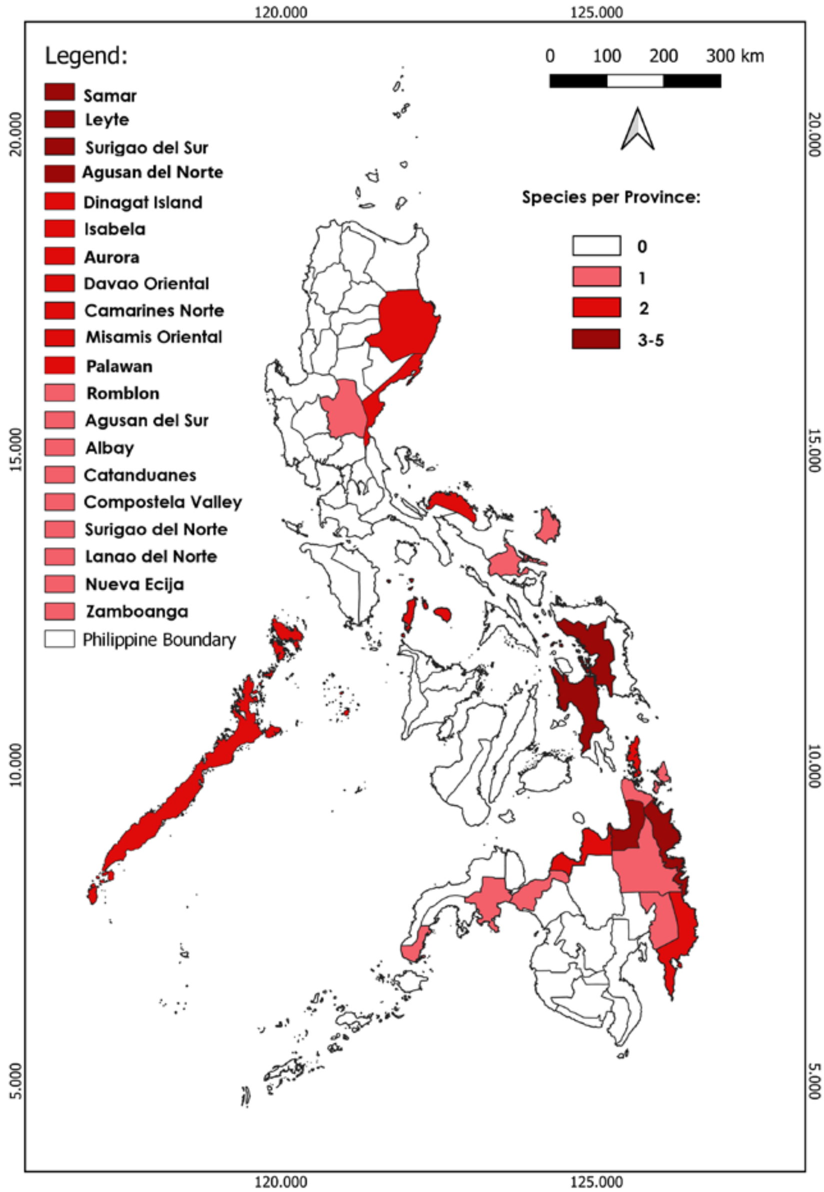

Figure 7. Map showing the number of reported *Xanthostemon* species per province in the Philippines based on the available data online.

is among the top nickel producers globally, with 48 registered metallic mines, and 23 of these are located in Caraga Region in Mindanao, where 20 are engaged in nickel mining operations (DENR-MGB 2018). Areas with rich in heavy metals are the growing preference for ironwood which has been exploited for mining. These areas are associated with preferential growth of most *Xanthostemon* species, clustered in Mindanao, specifically in Caraga Region, with mining productions of the largest nickel in the country. Four reported *Xanthostemon* species in Caraga Region forming dominant vegetation populations that could be threatened by anthropogenic activities. Areas with mineral deposits forming habitat-dependent vegetation species like Philippine Ironwood are thriving, especially in Surigao del Sur, Surigao del Norte, Dinagat Island, and also other provinces like Camarines Norte, Palawan, and Isabela, where natural populations of *X. verdugonianus, X. bracteatus, X. philippinensis, X. fruticosus,* and *X. speciosus* are located. In addition, unsustainable harvesting of *Xanthostemon* wood due to high demand and the high price is also the root cause of the decreasing population of *Xanthostemon* species. Hence, Philippine ironwood should be carefully monitored and managed. Coordination and intervention between local agencies and different sectors regarding the conservation and management of *Xanthostemon* in its natural habitat are essential. Areas that overlap with the natural population of *Xanthostemon* species and mining activities require further research and discussion with stakeholders to improve and provide appropriate policies for its implementation.

4 Conclusion and Recommendations

The study provided a geospatial distribution map of *Xanthostemon* species based on reported occurrences in literature and available online resources. The Philippines has five native and endemic ironwoods, one possibly an introduced species, and two unidentified species, and most are categorized as endangered to critically endangered distributed across 20 provinces. Three species, namely *X. verdugonianus, X. bracteatus,* and *X. philippinensis,* are widely distributed in 12, 11, and seven selected provinces, respectively. At the same time, *X. fruticosus,* and *X. speciosus* have a restricted distribution and can be found nowhere else. Mindanao is considered the center of *Xanthostemon* in the country, having ten provincial occurrences with four and one unidentified species. They were followed by Luzonand Visayas, with seven and three provincial occurrences, respectively. The distribution map is based on reports provided in the published papers, secondary sources, and technical reports and some of the distribution of this species needs to be further studied. Generally, the updated distribution map will greatly benefit from addressing intervention between local agencies and different sectors regarding the conservation and management of the natural population of *Xanthostemon*, especially in mining exploited areas. The study could also serve as insight for further research into the collection of ironwoods for morphological, taxonomic, ecological, and molecular studies.

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Statement of Conflict of Interest

The co-author, JH Jumawan, an Associate Editor of JESEG, did not participate, and abstained in the review process.

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