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Unveiling the prevalence of invasive alien plant species in multiple-use zone of Initao-Libertad Protected Landscape and Seascape, Misamis Oriental, Philippines

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Abstract. *Herbito Jr. LC, Guihawan JQ, Casal CMV, Polestico DLL, Torres AG. 2024. Unveiling the prevalence of invasive alien plant species in multiple-use zone of Initao-Libertad Protected Landscape and Seascape, Misamis Oriental, Philippines. Biodiversitas 25: 3286-3294.* Invasive Alien Plant Species (IAPS) threaten Protected Areas (PAs) globally, causing habitat degradation, biodiversity reduction, and ecosystem disruption. In the Philippines, data on invasive species in PAs is limited. This study aimed to investigate the prevalence, abundance, and diversity of IAPS in multiple-use zone of Initao-Libertad Protected Landscape and Seascape (ILPLS), Misamis Oriental, Philippines. Using belt-transect method, a total of 15 nested plots (20×20 m for trees, 5×5 m for herbs and shrubs, and 1×1 m for grasses and lianas) were established. Twenty-nine plant species from 18 families were identified, comprising 18 Native Species (NS), seven Non-Invasive Alien Species (NIAS), and four IAPS. The IAPS identified were *Gmelina arborea*, *Leucaena leucocephala*, *Lantana camara*, and *Swietenia macrophylla* which had the highest relative abundance of 96.83%. The Shannon-Weiner diversity indices showed very low to low diversity of 0.30 to 2.17, and an unbalanced to semi-balanced species evenness of 0.17 to 0.70. The Wilcoxon signed-rank test showed a significant difference in relative abundance between NS and IAPS ($p = 0.01576$). The Wilcoxon rank-sum test indicated significant differences in species diversity and evenness of $p = 0.03359$ and 0.03343, respectively. These findings are crucial for developing IAPS control strategies in the ILPLS in the future.

Keywords: Initao-Libertad Protected Landscape and Seascape, invasive alien plant, diversity, Sustainable Development Goal 15

Abbreviations: IAS: Invasive Alien Species; IAPS: Invasive Alien Plant Species; ILPLS: Initao-Libertad Protected Landscape and Seascape; NS: Native Species; NIAS: Non-Invasive Alien Species

INTRODUCTION

Biodiversity encompasses the variety of life on earth, including plants, animals, and microorganisms, which are crucial for sustaining ecosystems. It provides essential services like food production, pollination, disease regulation, cultural enrichment, influencing human health and well-being (Gora et al. 2023; Jain 2023). Despite its benefits, biodiversity is declining globally due to several factors, such as land and ocean use changes, climate change, pollution, overexploitation of organisms, and the introduction of Invasive Alien Species (IAS) (Brondizio et al. 2019), which is the main concern in this case. Invasive Alien Plant Species (IAPS), part of the IAS, are non-native plants that can outcompete native flora, reduce biodiversity, disrupt ecosystems, and cause economic and ecological harm. Key characteristics of IAPS include rapid growth, high reproductive capacity, effective seed dispersal mechanisms, and the ability to adapt to various environmental conditions (Dawson et al. 2017; Langmaier and Lapin 2020).

The proliferation of IAPS has become an urgent concern in managing Protected Areas (PAs) (Bomanowska et al. 2017; Foxcroft et al. 2017). PAs serve as sanctuaries for biodiversity, where natural ecosystems can flourish free from human disturbances and the encroachment of invasive species (Holenstein et al. 2021; Martínez-Vega and Rodríguez-Rodríguez 2022). However, several studies have unveiled a concerning trend of IAPS infiltrating the PAs globally, such as Braun et al. (2016), Padmanaba et al. (2017), Foxcroft et al. (2019), Paclibar and Tadiosa (2019), and Huda et al. (2022). Meanwhile, among the 18 mega-diverse countries, the Philippines ranks fifth in plant species diversity and hosts 5% of the world's flora, but is now one of the most threatened forest areas (Keong 2015; Ramachandran 2023; CBD 2024). Biodiversity decline in the country is driven by the introduction of IAS, habitat loss, climate change, overexploitation, and pollution (BMB-DENR 2016). In response, the government has created more than 240 PAs under Republic Act 11038, the Expanded National Integrated Protected Areas System (ENIPAS) Act, to safeguard and conserve the country's terrestrial and aquatic biodiversity. The country also established a National Invasive Species Strategy and Action Plan (NISSAP) 2020-2030 to mitigate IAS threats and reduce pressure on local biodiversity.

Only a few PAs in the Philippines have undergone assessments for IAPS like the ecological niche modeling of IAPS in Quezon Protected Landscape (QPL), Southern Luzon (Paclibar and Tadiosa 2019), and the distribution and management of *Swietenia macrophylla* G.King in Mt. Banahaw de Nagcarlan, Luzon Island (Coracero 2023). Additionally, the species richness of trees in Mt. Apo Natural Park, Mindanao Islands (Zapanta et al. 2019), the native and alien plant species inventory and diversity in Mt. Manunggal and Cebu Island (Garces 2019) also highlight the occurrence of IAPS within these PAs. Meanwhile, the biodiversity assessment of flora and fauna (Canencia and Daba 2015) revealed some IAPS in the Initao-Libertad Protected Landscape and Seascape (ILPLS).

There is no full account of the composition and diversity of IAPS in the ILPLS yet. Hence, this study is committed to assessing the prevalence of IAPS in the ILPLS. Specifically, this study aimed to identify the IAPS within the ILPLS and assess their abundance, diversity, and evenness. The findings from this study hold significance for Sustainable Development Goal (SDG) Target 15.8 - introduce measures to prevent invasive species and reduce their ecosystem impact, and serve as a useful guide by the Protected Area Management Board (PAMB) of the ILPLS and Municipal Environment and Natural Resources Office (MENRO) Initao for developing management strategies aimed at mitigating the proliferation of IAPS, preserving native biodiversity, and maintaining the ecological balance of the ILPLS.

MATERIALS AND METHODS

Entry protocol

The research proposal was submitted to the PAMB and MENRO Initao for approval. Subsequently, a gratuitous permit was obtained from the Department of Environment and Natural Resources (DENR) Region 10 Office in Cagayan de Oro City, Misamis Oriental, in compliance with Republic Act No. 9147 - Wildlife Resources Conservation and Protection Act.

Study area

The study was conducted in the multiple-use zone of the Initao-Libertad Protected Landscape and Seascape (ILPLS), Misamis Oriental, Philippines (Figure 1). ILPLS spans 1,425 ha, with 57 ha of landscape and 1,368 ha of seascape. It lies between Initao and Libertad, adjacent to Iligan Bay, at the coordinates 8.1846°N,124.2571°E on Mindanao Island, with 6.1 m above sea level (m asl.) (Canencia and Daba 2015). ILPLS is one of over 240 national parks and protected areas designated under Republic Act No. 11038 - Expanded National Integrated Protected Areas System (ENIPAS) Act of 2018.

Procedures

Field sampling and data collection

Field sampling took place from December 2023 to January 2024. Five 100-m transects were spaced roughly 100 m apart using a belt transect method, covering an area of 5 ha (50,000 m^2). Within each transect, three nested plots, totalling 15 nested plots were designated: 20×20 m for trees, 5×5 m for herbs and shrubs, and 1×1 m for grasses and lianas, following the study of Paclibar and Tadiosa (2020) with modification. Moreover, plant species frequency and height were recorded, photographed, and categorized as habitus, such as trees, shrubs, and lianas.

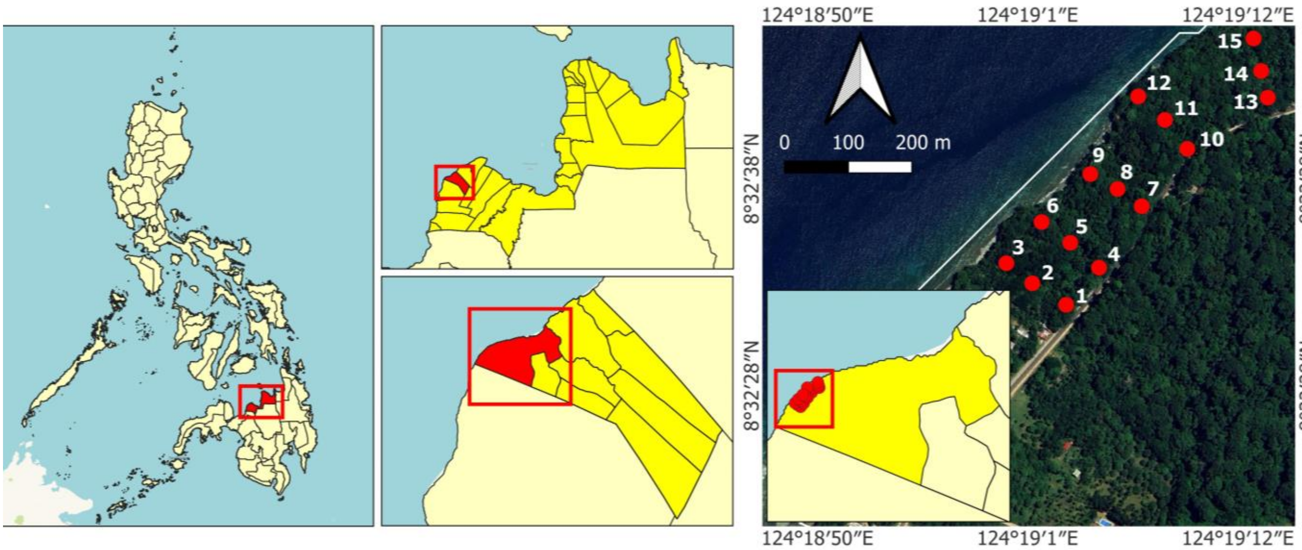

Figure 1. Map showing the Initao-Libertad Protected Landscape and Seascape (ILPLS), Misamis Oriental, Philippines. Note: Red dots are sampling plots

Identification and classification of invasive alien plant species

The identification of IAPS utilized data from the Global Invasive Species Database (GISD) (https://www.iucngisd.org/gisd/) and Global Register of Introduced and Invasive Species (GRIIS) (https://www.gbif.org/). Plant specimens were cross-checked with existing reports, scientific literatures, and websites such as Co's Digital Flora of the Philippines (https://www.philippineplants.org/), Catalog for Life (https://www.catalogueoflife.org/), and Plants of the World Online (https://powo.science.kew.org/) for further validation. Identified species were categorized into habitus: trees, shrubs, and lianas.

Size classes, height, and canopy cover of tree species

Tree species size classes are based on research by Coracero (2023). Tree species were analyzed for Diameter at Breast Height (DBH), height, and canopy cover using a transect tape and range finder. DBH, measured at 1.3 m above ground, approximates breast height. The diameter (in cm) was calculated by dividing the circumference (in cm) by 3.1416 (Yimam and Kifle 2020). Furthermore, the data were presented in tabular format.

Data analysis

Species richness and distribution were estimated using Shannon-Wiener Diversity Index described by Shannon (1948) as follows:

$$H' = \sum_{i=1}^{s} P_i \,(\ln P_i)$$

Where :

H' : Species Diversity Index

s : Number of species

pi : Proportion of (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N)

Whereas, evenly species and/or individuals distributed within a plot or quadrat were calculated using evenness index described by Pielou (1966) as follows:

$$E' = \frac{H'}{\ln S}$$

Where :

H' : Species Diversity Index

s : Number of species

Species diversity and evenness were calculated using PAST Software (v.4.03). Additionally, the descriptive values used are presented in Table 1.

Table 1. Descriptive value for plant species diversity and evenness indices (Napaldet 2023)

Diversity		Evenness	
Values	**Description**	**Values**	**Description**
>3.50	Very high	0.96-1.00	Balanced
3.00-3.49	High	0.76-0.95	Almost balanced
2.50-2.99	Moderate	0.51-0.75	Semi-balanced
2.00-2.49	Low	0.26-0.50	Less balanced
<1.99	Very low	0.00-0.25	Unbalanced

The relative abundance of IAPS was determined using the formula described by Achacoso et al. (2016) as follows:

$$Pi = \frac{n_i}{N} \times 100$$

Where :

P_i : Relative abundance

ni : Number of individuals of the same species

N : Total number of individuals for all species

The Wilcoxon signed-rank test, a non-parametric test, was used to compare the relative abundance between Native Species (NS) and Invasive Alien Plant Species (IAPS) across the 15 plots, with a significance level set at 0.05. Meanwhile, the Wilcoxon rank-sum test at a significance level of 0.05 was applied to assess differences in species diversity and evenness between NS and IAPS (Renner et al. 2011). Moreover, heatmaps were utilized to present and compare the species relative abundance, diversity, and evenness across plots.

RESULTS AND DISCUSSION

Species identification and classification

Twenty nine distinct species comprising 18 Native Species (NS), 7 Non-Invasive Alien Species (NIAS), and 4 Invasive Alien Plant Species (IAPS) in the Philippines are documented (Table 2). The four IAPS identified are mahogany (*S. macrophylla*), Gmelina (*Gmelina arborea* Roxb. ex Sm.), Ipil-ipil (*Leucaena leucocephala* (Lam.) de Wit), and Koronitas (*Lantana camara* L.) (Figure 2). These IAPS are further categorized into habitus, namely trees and shrubs. The IAPS categorized as trees are *S. macrophylla*, *G. arborea*, and *L. leucocephala*, while the shrub group is *L. camara*. Notably, no IAPS, NIAS, and NS belonging to the herb and grass groups are observed within the ILPLS.

In terms of conservation status, most of the identified Native Species (NS) were Least Concern (LC) based on the 2024 IUCN Red List of Threatened Species (https://www.iucnredlist.org/). Only two species, *Rhaphidophora korthalsii* Schott (Other Threatened Species (OTS)) and *Caryota mitis* Lour. (Near Threatened (NT)) have been evaluated locally based on the DENR Administrative Order (DAO) 2017-11. The *R. korthalsii* was designated with OTS status locally through DAO 2017-11. However, it has not yet been evaluated by the IUCN. Therefore, assessment of its conservation status using the IUCN Red List categories and criteria should be considered. Notably, no conservation status has been designated to NIAS and IAPS, as they are targeted for control and eradication rather than conservation.

Swietenia macrophylla, a member of the family Meliaceae indigenous to the Americas, including Mexico and South America, is renowned for its rapid growth and environmental adaptability. Its introduction to the Philippines dates back to 1911, primarily for reforestation and timber production (Pinol et al. 2018). The leaf litter of *S. macrophylla* is known to hinder the growth of native species (Galano and Rodriguez 2021). Moreover, due to its allelopathic property, *S. macrophylla* can suppress other plants' growth under its canopy (Mukaromah et al. 2016). The *G. arborea* is a fast-growing tree species belonging to the family Lamiaceae that is native to Pakistan, China, and northern Indo-China (Warrier et al. 2021). Its introduction to the Philippines aimed to bolster pulpwood and furniture manufacturing as early as 1960 (Pinol et al. 2018; Alipon et al. 2019). The species was categorized as a long-lived pioneer species, displaying opportunistic characteristics. It can potentially disturb the natural succession of ecosystems in areas where it spreads, thereby outcompeting native plant communities (Sandoval 2016).

The *L. leucocephala*, a legume species in the family Fabaceae, is native to Southern Mexico and Central America (Pinol et al. 2018; Kato-Noguchi and Kurniadie 2022). Its arrival in the Philippines can be traced back to natural dispersal and human-mediated introduction around 1910 (Pinol et al. 2018). The International Union for Conservation of Nature (IUCN) has identified it as one of the 100 worst invaders globally. This species has a negative impact on infrastructure and inhibits the growth and germination of other plants due to its allelopathic properties (Kato-Noguchi and Kurniadie 2022). Finally, *L. camara*, a flowering plant species from the family Verbenaceae native to the American tropics (Kumar et al. 2022), likely reached the Philippines through anthropogenic means as early as 1930 (Pinol et al. 2018). Known for its allelopathic properties, *L. camara* can disrupt the structure and composition of native plant vegetation (Singh et al. 2014). In addition, it also threatens livestock productivity due to its toxicity, especially in cattle and sheep (Ntalo et al. 2022).

Species diversity, evenness, and relative abundance

A total of 2,649 individual plants were identified in plots that had been designated at ILPLS, of which 1,429 individuals (53.94%) were NS, 54 individuals (2.04%) were NIAS, and 1,166 individuals (44.02%) were IAPS. Among the existing plots, plot 3 had the highest IAPS with 583 individuals, followed by plot 2 (451 individuals) and plot 14 (39 individuals), whereas no IAPS were recorded in plots 7 to 10 (Table 3). Among the identified IAPS, *S. macrophylla* was the most dominant species with a relative abundance of 96.83%, followed by *G. arborea* (2.14%), *L. leucocephala* (0.86%), and *L. camara* (0.17%) (Figure 3). Native species, although relatively abundant, showed varying degrees of distribution across plots. On the other hand, NIAS groups, although less numerous than natives, also showed their presence in some plots. Meanwhile, IAPS shows a large number of individuals recorded. These findings are consistent with research highlighting the widespread impact of invasive species on ecosystems (Galano and Rodriguez 2021).

The diversity values across all plots ranged from 0.30 to 2.17 wherein Plot 3 has the lowest and Plot 6 has the highest diversity index value. Based on the descriptive values provided (Napaldet 2023), Plot 3 is considered very low diversity, while Plot 6 is considered low diversity. Meanwhile, the species evenness values across all plots ranged from 0.17 to 0.70 wherein Plot 3 is the lowest, while Plot 11 is the highest. These values are considered unbalanced and semi-balanced, respectively (Napaldet 2023). The dominance of IAPS individuals, particularly *S. macrophylla,* resulted a very low diversity observed in plots 2 and 3. In contrast, the very low diversity values observed in other plots can be attributed to the dominance of large native trees, which limit the establishment and growth of other species in the region. Meanwhile, evenness values across plots may indicate an imbalance in the distribution of species abundances, with some species being much more abundant than others (Taiwo et al. 2021). Moreover, plots with higher proportions of IAPS exhibited lower diversity and evenness, indicating potential disruption to ecosystem stability (Pyšek and Richardson 2017).

Statistical analysis

The relative abundance of Native Species (NS), Non-Invasive Alien Species (NIAS), and Invasive Alien Plant Species (IAPS) in the 15 plots are shown in Figure 4. Notably, NS showed varying levels of abundance across plots, ranging from 4.9% to 100%. Plots 7 and 10 consist exclusively of NS. In contrast, NIAS and IAPS show different patterns. NIAS shows its presence sporadically, with values below 10%, indicating a small contribution to the overall abundance. In contrast, IAPS shows a wider distribution range from 0% to 94.8%. Plots 2 and 3, particularly, are distinguished by a marked dominance of IAPS. These plots were located on the perimeter of the ILPLS, and the large number of IAPS individuals recorded in these plots may have been influenced by the encroaching presence of several mature *S. macrophylla* trees near the area (outside the perimeter fence) from ILPLS, as highlighted by the parallel study of Herbito Jr. et al. (2024). This finding is consistent with other studies highlighting the invasiveness of *S. macrophylla*, which suppresses the growth of native plants through its allelopathic properties (Mukaromah et al. 2016; Coracero 2023). Moreover, further investigation is needed to explore the observed gaps. Therefore, to achieve this aim, a statistical test was conducted to ascertain if the median differences between the relative abundance of NS and IAPS, matched by the plot, significantly deviate from 0, with a significance level set at 0.05. Given the presence of outliers in the relative abundance observed in Plots 2, 3, 7, and 10, the Wilcoxon signed-rank test with continuity correction was employed. The resulting test statistic, $V = 103$, yielded a corresponding P-value of 0.01576. These results indicate a significant difference in the relative abundance between NS and IAPS across the sampled plots.

The species diversity and evenness distribution in the 15 plots are shown in Figure 5. Plots 2 and 3 showed the lowest diversity and evenness indices than the others. Furthermore, these plots had the highest prevalence of IAPS compared to the other plots (Table 3). Therefore, to investigate whether species diversity and evenness had the same distribution for NS and IAPS vegetation types, the Wilcoxon rank sum test was used at a significance level of 0.05 (Table 4).

Table 2. List of identified plants in Initao-Libertad Protected Landscape and Seascape, Misamis Oriental, Philippines

Family	Scientific name	Common name	Local name	Habitus	Conservation status DAO 2017-11	Conservation status IUCN Red List (2024)
Native Species (NS)						
Araceae	*Rhaphidophora korthalsii* Schott	Dragon tail plant	Tibatib	Liana	OTS	-
Arecaceae	*Caryota mitis* Lour.	Fishtail palm	Lubi-lubi	tree	NT	LC
Arecaceae	*Cocos nucifera* L.	Coconut	Lubi	tree	-	-
Apocynaceae	*Tabernaemontana pandacaqui* Lam.	Banana bush	Kampupot	shrub	-	LC
Burseraceae	*Garuga floribunda* Decne.	Garuga tree	Bogo	tree	-	LC
Calophyllaceae	*Calophyllum* sp.	-	-	tree	-	-
Capparaceae	*Crateva religiosa* G.Forst.	Spider tree	Banugan	tree	-	LC
Combretaceae	*Terminalia catappa* L.	Tropical almond tree	Talisay	tree	-	LC
Elaeocarpaceae	*Elaeocarpus monocera* Cav.	One-hundred quandong	Margapali	tree	-	-
Euphorbiaceae	*Macaranga tanarius* (L.) Müll.Arg.	Parasol leaf tree	Binunga	tree	-	LC
Euphorbiaceae	*Mallotus* sp.	-		tree	-	-
Euphorbiaceae	*Melanolepis multiglandulosa* (Reinw. ex. Blume) Rchb. & Zoll.	Chawan	Alim	shrub	-	LC
Malvaceae	*Pterocymbium tinctorium* (Blanco) Merr.	Winged boot tree	Taloto	tree	-	LC
Malvaceae	*Pterospermum* sp.	-		tree	-	-
Meliaceae	*Aglaia argentea* (Reinw.) Blume	Silver boodyara	Ilo-ilo	tree	-	LC
Moraceae	*Artocarpus blancoi* (Elmer) Merr.	Tipolo	Antipolo	tree	-	LC
Moraceae	*Streblus asper* Lour.	Siamese rough bush	Kalyos	tree	-	LC
Rhamnaceae	*Ziziphus* sp.	-	Malabayabas	tree	-	LC
Non-Invasive Alien Species (NIAS)						
Araceae	*Syngonium podophyllum* Schott	Arrowhead	-	liana		
Arecaceae	*Chrysalidocarpus lutescens* H.Wendl.	Golden cane palm	-	tree		
Bignoniaceae	*Tabebuia rosea* (Bertol.) Bertero ex A.DC.	Trumpet tree	-	tree		
Fabaceae	*Bauhinia purpurea* L.	Butterfly leaf	Alibangbang	tree		
Lamiaceae	*Tectona grandis* L.f.	Teak	Teak	tree		
Nyctaginaceae	*Bougainvillea glabra* Choisy	Paper flower	Bogambilya	shrub		
Sapotaceae	*Chrysophyllum cainito* L.	Star apple	Caimeto	tree		
Invasive Alien Plant Species (IAPS)						
Fabaceae	*Leucaena leucocephala* (Lam.) de Wit	River tamarind	Ipil-ipil	tree		
Meliaceae	*Swietenia macrophylla* G.King	Mahogany	Mahogany	tree		
Lamiaceae	*Gmelina arborea* Roxb. ex Sm.	Beechwood	Gmelina	tree		
Verbenaceae	*Lantana camara* L.	Coronet	Koronitas	shrub		

Table 3. Coordinates, vegetation composition, diversity, and species evenness in observed plots

Coordinates		Plot	NS	NIAS	IAPS	TI	H'	SE	Description by Napaldet (2023)	
Latitude (N)	Longitude (E)								H'	SE
8° 32' 31.815"	124° 19' 3.183"	1	345	1	20	366	1.46	0.43	VL	LB
8° 32' 33.014"	124° 19' 1.455"	2	81	14	451	546	0.80	0.19	VL	U
8° 32' 33.986"	124° 19' 0.109"	3	30	2	583	615	0.30	0.17	VL	U
8° 32' 33.755"	124° 19' 4.872"	4	112	1	6	119	1.55	0.34	VL	LB
8° 32' 35.052"	124° 19' 3.396"	5	80	20	10	110	2.03	0.45	L	LB
8° 32' 36.131"	124° 19' 1.919"	6	80	10	18	108	2.17	0.59	L	SB
8° 32' 36.959"	124° 19' 7.067"	7	188	0	0	188	1.42	0.59	VL	SB
8° 32' 37.853"	124° 19' 5.822"	8	91	2	0	93	1.46	0.48	VL	LB
8° 32' 38.638"	124° 19' 4.426"	9	88	1	0	89	1.95	0.64	VL	SB
8° 32' 39.948"	124° 19' 9.408"	10	90	0	0	90	1.88	0.66	VL	SB
8° 32' 41.460"	124° 19' 8.256"	11	62	0	4	66	1.95	0.70	VL	SB
8° 32' 42.683"	124° 19' 6.887"	12	55	0	3	58	1.19	0.55	VL	SB
8° 32' 42.624"	124° 19' 13.540"	13	22	1	16	39	1.21	0.67	VL	SB
8° 32' 44.012"	124° 19' 13.202"	14	54	2	39	95	1.16	0.46	VL	LB
8° 32' 45.711"	124° 19' 12.809"	15	51	0	16	67	1.81	0.68	VL	SB
Total			**1429**	**54**	**1166**	**2649**				

Note: NS: Native Species; NIAS: Non-Invasive Alien Species; IAPS: Invasive Alien Plant Species; TI: Total Individual; H': Diversity Index; SE: Species Evenness; VL: Very Low; L: Low; SB: Semi-Balanced; LB: Less Balanced; U: Unbalanced

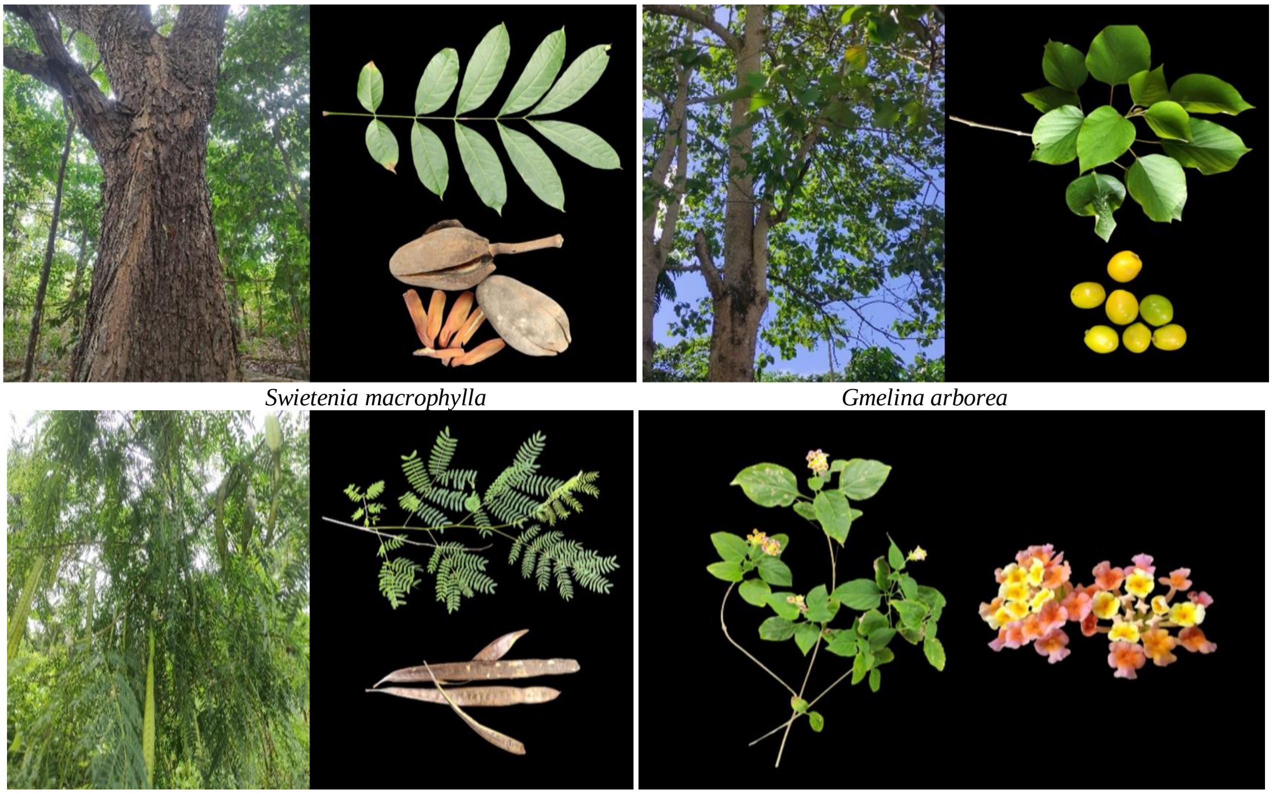

Figure 2. Invasive Alien Plant Species (IAPS) present in Initao-Libertad Protected Landscape and Seascape (ILPLS), Philippines

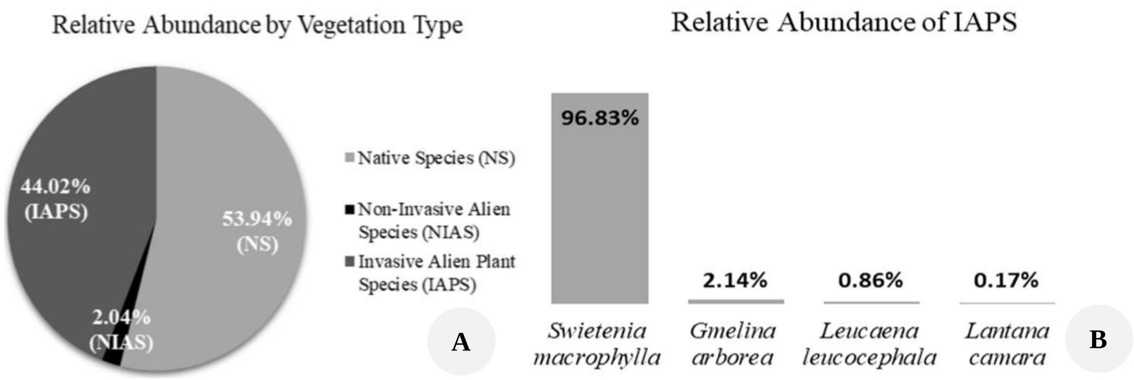

Figure 3. A. Relative abundance of different plant individuals; and B. Relative abundance of identified IAPS

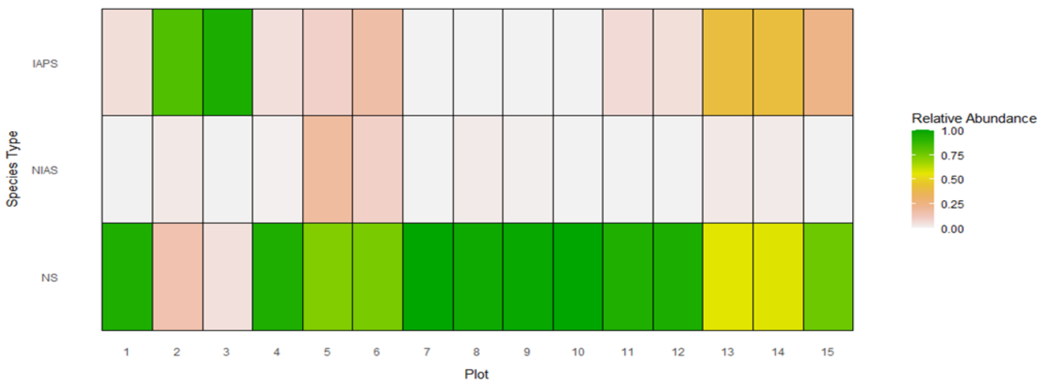

Figure 4. Relative abundance heatmap by vegetation type across the 15 plots

Table 4. Wilcoxon rank sum test results for Species Evenness Index (SE) and Diversity Index (H')

Variable	W Statistic	*P*-value
Diversity Index (H')	0*	0.03359
Species Evenness Index (SE)	0*	0.03343

Table 5. Size classes of IAPS categorized as trees

Size class	Diameter (cm)	*Swietenia macrophylla*	*Gmelina arborea*	*Leucaena leucocephala*
Seedlings/ Saplings	1≤Diameter<5	1,117	8	10
Poles	5≤Diameter<30	3	1	0
Adults	≥30	9	16	0
Total		1,129	25	10

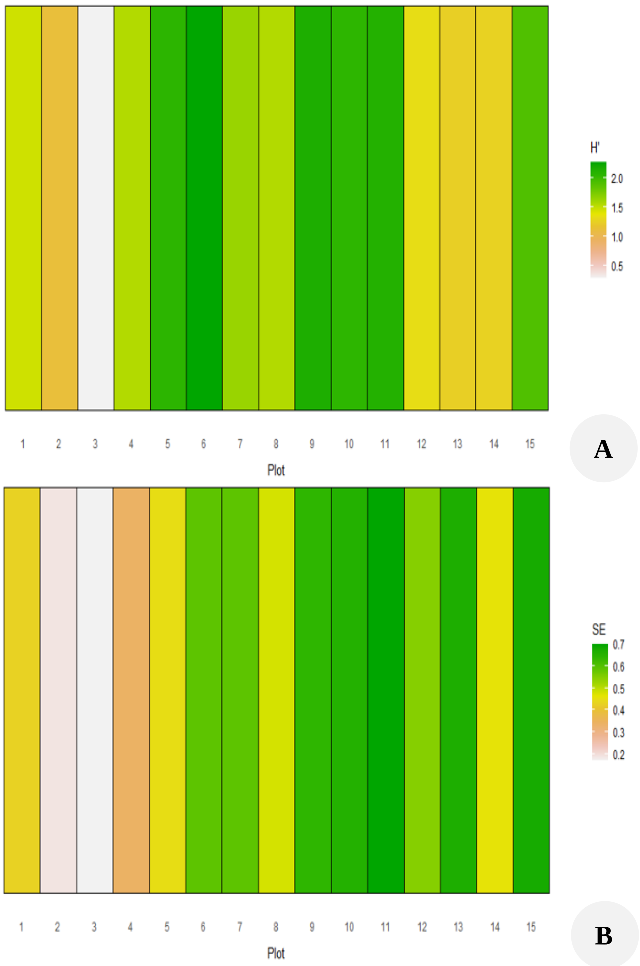

Figure 5. Heatmap by IAPS across the 15 Plots of: A. Species diversity; and B. Evenness

The results show with 95% confidence that there are significant differences in species diversity and evenness between IAPS and NS vegetation types. This could mean that plots predominantly occupied by IAPS show lower diversity and evenness values than plots dominated by NS. However, NS-dominated plots tended to show low levels of diversity, albeit with varying degrees of evenness, often showing signs of depression or instability in species evenness. The findings indicate that the high prevalence of IAPS can contribute to the reduction of biodiversity (Dawson et al. 2017; Pyšek and Richardson 2017; Langmaier and Lapin 2020), while diverse native plant communities may limit the invasion of IAPS on small-scale observations (Petruzzella et al. 2018).

Tree size classes, height, and crown cover of IAPS

The distribution of size classes for the three tree species is presented in Table 5. Most individuals of *S. macrophylla* are classified as seedlings/saplings (1,117 individuals), followed by adults (9 individuals) and poles (3 individuals). Meanwhile, *G. arborea* has the highest number of adults (16 individuals), with 8 seedlings/saplings individuals and just 1 pole. Moreover, *L. leucocephala* is solely represented by seedlings/saplings (10 individuals), with no individuals recorded in the pole or adult-size classes. Adult individuals of *S. macrophylla* have heights ranging from 13 to 18 m, with crown cover ranging from 4 to 7 m. In contrast, adults *G. arborea* exhibit heights ranging from 15 to 19.5 m, with crown cover varying from 2.3 to 9 m.

The predominance of seedlings/saplings in *S. macrophylla* indicates successful recruitment and regeneration processes in the area. This observation aligns with previous studies highlighting the species' ability to establish and thrive in various forest environments (Galano and Rodriguez 2021; Coracero 2023). Additionally, the widespread use of *S. macrophylla* in reforestation projects, such as the Philippine government's National Greening Program (NGP), has led to its prevalence within PAs. The *S. macrophylla* is the most planted tree in the country under NGP until 2011 (Torres 2018). Furthermore, the abundance of *S. macrophyll*a underscores its invasiveness, emphasizing the necessity for efficient management strategies to alleviate its impact on native biodiversity (Galano and Rodriguez 2021). Meanwhile, *G. arborea* has a notably higher number of adult individuals than *S. macrophylla*. This observation aligns with the fact that *G. arborea* is known for its rapid growth rate, making it a popular choice for reforestation programs in tropical and subtropical regions (Sandoval 2016). The broader range of heights and crown covers observed among adult *G. arborea* trees suggest greater variability in canopy structure and potential niche differentiation within the species (Hakamada et al. 2023). In contrast, only seedlings/saplings of *L. leucocephala* may indicate ongoing establishment and colonization by this species in the study area. The absence of individuals in the pole and adult size classes may suggest that *L. leucocephala* populations are in earlier stages of development or experiencing limitations in reaching maturity, possibly due to biotic or abiotic factors (Sharma et al. 2022).

Assessing the prevalence of invasive species in this region is a critical step in supporting the country's efforts to meet SDG 15.8, which focuses on preventing, controlling, and eradicating invasive alien species.

Moreover, policymakers and conservationists can identify the areas most affected, understand the species causing the greatest harm, and develop targeted management strategies. In conclusion, the multi-use zone of Initao-Libertad Protected Landscape and Seascape (ILPLS) has a variety of plant species, with 29 species consisting of 18 native species, seven non-invasive alien species, and four IAPS. Thus, 2,649 individual plants were identified, consisting of 1,429 native individuals, 54 non-invasive alien individuals, and 1,166 IAPS individuals. This shows the high prevalence of IAPS in ILPLS; *S. macrophylla* (Mahogany) was the most abundant IAPS, with a relative abundance of 96.83%. The Shannon-Wiener diversity index ranged from 0.30 to 2.17, indicating very low to low diversity. In contrast, the evenness value ranged from 0.17 to 0.70, indicating an unbalanced and semi-balanced species community and species abundance distribution. Relative abundance between native species and IAPS showed significant differences in species diversity and evenness. This indicates that plots dominated by IAPS showed lower levels of diversity and reduced evenness compared to plots dominated by native species. In recommendation, conservation efforts must prioritize controlling and eradicating IAPS to reduce its negative impacts on native ecosystems. Ongoing monitoring and research are also essential to track changes in vegetation dynamics within the area. Additionally, comprehensive assessments of IAPS in the landscape zone of ILPLS should be conducted to inform effective management strategies.

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REFERENCES

Achacoso SC, Walag AMP, Saab LL. 2016. A rapid assessment of foliage spider fauna diversity in Sinaloc, El Salvador City, Philippines: A comparison between habitats receiving different degrees of disturbance. Biodiversitas 17 (4): 156-161. DOI: 10.1080/14888386.2016.1258331.

Alipon MA, Bondad EO, Alcachupas PL, Cortiguerra EC. 2019. Properties and utilization of young-age yemane (*Gmelina arborea* Roxb.) for lumber production. Philipp J Sci 148 (2): 237-248.

BMB-DENR. 2016. Philippine Biodiversity Strategy and Action Plan (2015-2028): Bringing Resilience to Filipino Communities. In: Cabrido C (eds). Quezon City, Biodiversity Management Bureau (BMB) - Department of Environment and Natural Resources (DENR), United Nations Development Programme - Global Environment Facility, Foundation for the Philippine Environment, Manila.

Bomanowska A, Rewicz A, Wolski GJ, Krasoń K. 2017. Invasive alien plants in protected areas within city borders, Lodz, (Poland). Pak J Bot 49 (1): 311-316.

Braun M, Schindler S, Essl F. 2016. Distribution and management of invasive alien plant species in protected areas in central Europe. J Nat Conserv 33: 48-57. DOI: 10.1016/j.jnc.2016.07.002.

Brondizio ES, Settele J, Díaz S, Ngo HT. 2019. Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. IPBES secretariat, Paris, France. DOI: 10.5281/zenodo.3831673 .

Canencia OP, Daba BO. 2015. Biodiversity conservation and sustainability of Initao-Libertad Protected Landscape and Seascape in Misamis Oriental, Philippines. Asian J Biodivers 6 (1): 163-182. DOI: 10.7828/ajob.v6i1.701.

CBD. 2024. Decision adopted by the conference of the parties to the Convention on Biological Diversity (CBD). https://www.cbd.int/doc/decisions/cop-15/cop-15-dec-04-en.pdf.

Coracero EE. 2023. Distribution and management of the invasive *Swietenia macrophylla* King (Meliaceae) at the foot of a protected area in Luzon Island, Philippines. J Zool Bot Gard 4 (3): 637-647. DOI: 10.3390/jzbg4030045.

Dawson W, Moser D, van Kleunen M et al. 2017. Global hotspots and correlates of alien species richness across taxonomic groups. Nat Ecol Evol 1: 0186. DOI: 10.1038/s41559-017-0186.

Foxcroft LC, Pyšek P, Richardson DM, Genovesi P, MacFadyen S. 2017. Plant invasion science in protected areas: Progress and priorities. Biol Invasions 19: 1353-1378. DOI: 10.1007/s10530-016-1367-z.

Foxcroft LC, Spear D, van Wilgen NJ, McGeoch MA. 2019. Assessing the association between pathways of alien plant invaders and their impacts in protected areas. NeoBiota 43: 1-25. DOI: 10.3897/neobiota.43.29644.

Galano JB, Rodriguez LJV. 2021. Exotic mahogany leaf litter hinders growth of philippine native tree seedlings. Proc Natl Inst Ecol Repub Korea 2 (2): 76-81. DOI: 10.22920/PNIE.2021.2.2.76.

Garces JJC. 2019. Native and alien plant species inventory and diversity in disturbed forests and its economic value. Glob J Environ Sci Manag 5 (2): 249-264. DOI: 10.22034/gjesm.2019.02.10.

Gora MM, Mir MR, Mehraj S, Sharma RK, Hussain A, Nazim N, Khan IL. 2023. Biodiversity for Sustainable Development. 1st Edition. Taylor and Francis, London. DOI: 10.1201/9781003220398-25.

Hakamada R, Prados-Coronado J, Lages C, Vrechi A, Zuñiga-Grajeda V, Villota-Gonzalez FH, Sulbaran-Rangel B. 2023. Initial growth of *Gmelina arborea* and efficacy of RGB image to capture canopy area in a large range of stockings. Remote Sens 15 (19): 4751. DOI: 10.3390/rs15194751.

Herbito Jr. LC, Guihawan JQ, Casal CMV, Polestico DLL, Torres AG. 2024. Invasive alien plant management: Attitude and insights from Initao-Libertad Protected Landscape and Seascape, Misamis Oriental, Philippines. Environ Ecol Res 12 (3): 308-321. DOI: 10.13189/eer.2024.120308.

Holenstein K, Simonson WD, Smith KG, Blackburn TM, Charpentier A. 2021. Non-native species surrounding protected areas influence the community of non-native species within them. Front Ecol Evol 8: 625137. DOI: 10.3389/fevo.2020.625137.

Huda MK, Pasaribu N, Syamsuardi, Siregar ES. 2022. Diversity, risk and management feasibility of invasive alien plants in the border zone of Sicike-cike Nature Tourism Park, North Sumatra, Indonesia. Biodiversitas 23 (6): 3156-3165. DOI: 10.13057/biodiv/d230643.

Jain AK. 2023. Biodiversity, greens and cultural spaces. In: Jain AK (eds). Climate Resilient, Green and Low Carbon Built Environment. Green Energy and Technology. Springer, Singapore. DOI: 10.1007/978-981-99-0216-3_8.

Kato-Noguchi H, Kurniadie D. 2022. Allelopathy and allelochemicals of *Leucaena leucocephala* as an invasive plant species. Plants 11 (13): 1672. DOI: 10.3390/plants11131672.

Keong CY. 2015. Sustainable resource management and ecological conservation of mega-biodiversity: The Southeast Asian big-3 reality. Intl J Environ Sci Dev 6: 876-882. DOI: 10.7763/IJESD.2015.V6.715.

Kumar A, Singh S, Chand HB, Kumar R. 2022. Phenological documentation of *Lantana camara* L. using modified BBCH scale in relation to climatic variables. Plant Sci Today 9 (2): 376-385. DOI: 10.14719/pst.1481.

Langmaier M, Lapin K. 2020. A systematic review of the impact of invasive alien plants on forest regeneration in European temperate forests. Front Plant Sci 11: 524969. DOI: 10.3389/fpls.2020.524969.

Martínez-Vega J, Rodríguez-Rodríguez D. 2022. Protected area effectiveness in the scientific literature: A decade-long bibliometric analysis. Land 11 (6): 924. DOI: 10.3390/land11060924.

Mukaromah AS, Purwestri YA, Fujii Y. 2016. Determination of allelopathic potential in mahogany (*Swietenia macrophylla* King) leaf litter using sandwich method. Indones J Biotechnol 21 (2): 93-101. DOI: 10.22146/ijbiotech.16456.

Napaldet JT. 2023. Plant species and ecosystem diversity along national road in mountain sites: The case of Kennon Road in Cordillera Central Range, Philippines. Taiwania 68 (3): 339-348. DOI: 10.6165/tai.2023.68.339.

Ntalo M, Ravhuhali KE, Moyo B, Hawu O, Msiza NH. 2022. *Lantana camara*: Poisonous species and a potential browse species for goats in Southern Africa-A review. Sustainability 14 (2): 751. DOI: 10.3390/su14020751.

Paclibar GCB, Tadiosa ER. 2019. Ecological niche modeling of invasive alien plant species in a protected landscape. Glob J Environ Sci Manag 5 (3): 371-382. DOI: 10.22034/GJESM.2019.03.09.

Paclibar GCB, Tadiosa ER. 2020. Plant species diversity and assessment in Quezon Protected Landscape, Southern Luzon, Philippines. Philipp J Syst Biol 14 (3): 1-19. DOI: 10.26757/pjsb2020c14010.

Padmanaba M, Tomlinson KW, Hughes AC, Corlett RT. 2017. Alien plant invasions of protected areas in Java, Indonesia. Sci Rep 7 (1): 9334. DOI: 10.1038/s41598-017-09768-z.

Petruzzella A, Manschot J, van Leeuwen CHA, Grutters BMC, Bakker ES. 2018. Mechanisms of invasion resistance of aquatic plant communities. Front Plant Sci 9: 134. DOI: DOI: 10.3389/fpls.2018.00134.

Pielou EC. 1966. The measurement of diversity in different types of biological collections. J Theor Biol 13: 131-144. DOI: 10.1016/0022-5193(66)90013-0.

Pinol A, Perino E, Pollisco M, San Valentino HO, Pacho MV. 2018. A report on the stocktaking of National Forest Invasive Species (FIS) activities in the Philippines. Asia-Pacific Forest Invasive Species Network (APFISN). www.apfisn.net.com

Pyšek P, Richardson DM. 2017. Traits associated with invasiveness in alien plants: Where do we stand? In: Nentwig W (eds). Biological Invasions. Ecological Studies, vol 193. Springer, Berlin, Heidelberg. DOI: 10.1007/978-3-540-36920-2_7.

Ramachandran S. 2023. Building Back Biodiversity. UNDP Philippines. https://www.undp.org/philippines/blog/building-back-biodiversity.

Renner SC, Vanna N, Eames JC. 2011. Observations on the spread and extent of alien invasive plant species in six protected areas in Cambodia. Cambodian J Nat Hist 1: 40-48.

Sandoval J. 2016. *Gmelina arborea* (candahar). CABI Compendium. DOI: 10.1079/cabicompendium.2546.

Shannon CE. 1948. A mathematical theory of communication. Bell Syst Tech J 27 (3): 379-423. DOI: 10.1002/j.1538-7305.1948.tb01338.x.

Sharma P, Kaur A, Batish DR, Kaur S, Chauhan BS. 2022. Critical insights into the ecological and invasive attributes of *Leucaena leucocephala*, a tropical agroforestry species. Front Agron 4: 890992. DOI: 10.3389/fagro.2022.890992.

Singh HP, Batish DR, Dogra KS, Kaur S, Kohli RK, Negi A. 2014. Negative effect of litter of invasive weed *Lantana camara* on structure and composition of vegetation in the lower Siwalik Hills, northern India. Environ Monit Assess 186 (6): 3379-3389. DOI: 10.1007/s10661-014-3624-x.

Taiwo DM, Udoh SI, Olaoti-Laaro SO, Jeminiwa OR, Jeminiawa MS. 2021. Assessment of species diversity and distribution of woody species on selected plots in Olokemeji Forest Reserve, Ogun State, Nigeria. Ife J Sci 22 (3): 43-50. DOI: 10.4314/ijs.v22i3.3.

Torres J. 2018. Using mahogany in our reforestation programs may be ecological suicide. https://bluprint-onemega.com/mahogany-national-greening-program/.

Warrier RR, Priya SM, Kalaiselvi R. 2021. *Gmelina arborea* - An indigenous timber species of india with high medicinal value: A review on its pharmacology, pharmacognosy and phytochemistry. J Ethnopharmacol 267: 113593. DOI: 10.1016/j.jep.2020.113593.

Yimam YM, Kifle B. 2020. Tree inventory assessment in religious institution compound and its benefit for environmental management in the case of Addis Ababa, Ethiopia. Intl J Sci Res Biol Sci 7 (1): 51-61.

Zapanta BR, Achondo MJMM, Raganas AFM, Camino FA, Delima AGD, Mantiquilla JA, Puentespina Jr. RP, Salvana FRP. 2019. Species richness of trees in disturbed habitats within a protected area and its implications for conservation: The case of Mt. Apo Natural Park, Mindanao Island, Philippines. Biodiversitas 20 (7): 2081-2091. DOI: 10.13057/biodiv/d200740.