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Comprehensive assessment of floral composition in restoration sites at mount Kitanglad, Brgy. Lirongan, Bukidnon: Analysis of diverse restoration initiatives

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Abstract

This study examines the floristic composition, biodiversity indices, and conservation status of the seven restoration sites in Mt. Kitanglad, Talakag Bukidnon. A total of 532 individual plants from 79 species and 37 families were recorded, with angiosperms comprising the majority of the flora. The Fabaceae, Asteraceae, and Poaceae families exhibited the highest species richness, with *Calliandra calothyrsus* and *Acacia auriculiformis* being particularly abundant due to their ecological roles in nitrogen fixation and weed suppression. Gymnosperms, notably *Pinus merkusii,* played as significant role in reforestation, while pteridophytes such as *Nephrolepis bisserata* served as indicators of environmental conditions. Biodiversity indices revealed distinct ecological patterns across sites, the Shannon-Wiener index ranged from 2.01 to 3.33, with riparian sites (RA1 and RA2) demonstrating the highest diversity and evenness, while areas dominated by Indigenous Forest Trees (IFT) exhibited lower diversity and greater species dominance. Simpson index values (0.73-0.94) further supported these findings, highlighting the balanced species distribution in riparian sites compared to IFT-dominated areas. Evenness values ranged from 0.40 to 0.68, indicating varying species uniformity across sites, while dominance values (0.06-0.41) suggested a greater influence of select species in IFT areas. The conservation status assessment identifies 74 species as Least Concern, while *Diplazium costulisorum* and *Sphaeropteris glauca* were classified as Endangered. These findings emphasize the ecological significance of vegetated riparian zones in biodiversity conservation and ecosystem resilience. Restoration strategies should prioritize species diversity and structural complexity to enhance ecological stability and functionality in degraded landscapes.

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Introduction

The current state of biodiversity is a matter of urgency. According to Redford and Mace (2018), biodiversity refers to the range of genes, species, and ecosystems within a particular system. Tropical forests play a crucial role in mitigating climate change by sequestering substantial amounts of atmospheric carbon dioxide (Lumbres *et al.*, 2023). These mountains in the Philippines, including the Mt. Kitanglad Range National Park (MKRNP), stand out due to their rich flora composition, comprising native and endemic species. Numerous studies have confirmed that plant biodiversity significantly impacts supporting and regulating ecosystem services (Chen *et al.*, 2018; Peri *et al.*, 2019a; Ma *et al.*, 2020). However, deforestation-induced tropical forest fragmentation causes increased tree mortality (Reis *et al.*, 2018), which facilitates more accessible access to interior forests and increases resource exploitation (Broadben *et al.*, 2019).

The Mt. Kitanglad Range National Park (MKRNP) spans seven (7) municipalities and one (1) city in the province of Bukidnon. It is one of the protected areas and the last remaining frontiers of the Philippines (Saway and Mirasol, 2004). On November 9, 2000, Mt. Kitanglad Range Natural Park was designated as a protected area, and on October 29, 2009, it was designated as an ASEAN Heritage Park (NORDECO, 1998). Four indigenous tribes in the province of Bukidnon—the Manobo, Talaandig, Maranao, and Maguindanao—all have ancestral domains that include the MKRNP (Saway and Mirasol, 2004). MKRNP has 19 species of ferns and one species of fern allies, a new record in the Philippines, and supports a rich biodiversity of 661 plant species, including endangered, endemic, rare, or economically significant ones (Amoroso *et al.*, 2011). However, despite its significance, it has been severely threatened by man-made activities such as slash-and-burn farming, illegal logging, eco-tourism, and agricultural intensification (Canoy and Suminguit, 2001).

To address this issue, various initiatives are being implemented to support climate change, including the National Greening Program (NGP), to restore 1.5 million hectares of degraded land with 1.5 billion trees, and has successfully planted approximately 1.83 billion seedlings across 2.18 million hectares of barren forestlands from 2011 to August 2022 (FMB, 2022). Another strategy to mitigate forest loss, forest and landscape restoration was developed to address this issue. Restoration is "any intentional activity that starts or hastens an ecosystem's recovery from a degraded state" (IPBES, 2014). The tropics worldwide require a focus on restoration (Brancalion *et al.*, 2019). In addition to addressing various issues like soil stability and condition, water quality, habitat and biodiversity, human culture and recreation, and climate stability, restoration aims to re-establish a self-sustaining ecosystem (SERI, 2004; Crossman and Bryan, 2009; Barral *et al.*, 2015; Alexander *et al.*, 2016). This study aimed to assess and inventory the threatened, endemic, and economically important plants in Mt. Kitanglad Range Natural Park, Bukidnon. Specifically, this study (i) determined the diversity of the flora present in the different restoration sites, (ii) compared the diversity of flora across various restoration models, and (iii) assessed their conservation status.

Materials and methods

Study area and sampling sites

The study area consists of three approaches: restoration in the riparian area with IFT and Caribbean pine trees, restoration in the riparian area with IFT only, and restoration in the riparian area with vegetation (Table 1). This treatment includes various restoration strategies, which are categorized into sub-models based on the year of establishment, namely, as follows.

A. Riparian area with IFT and Caribbean pine trees

The riparian area with IFT and Caribbean pine trees has four (4) replicates labelled IFTC1, IFTC2, IFTC3, and IFTC4. The IFTC1 (8°3'31.8"N and 8°3'31.8"N) has matured Caribbean pines and bamboo, young *Saurauia elegans* (Choisy) fern.-Vill, and *Shorea negrosensis* Foxw. with high litter cover (branches and leaves) from matured Caribbean pine trees.

Table 1. Description of the study sites at Mt. Kitanglad, Lirongan, Talakag, Bukidnon

Site code	Description	IFT planted/ vegetation	Year established	Land use
RA1	Riparian Areas with vegetation	Matured Caribbean Pine and dense grass vegetation	2020	Dense vegetation of Flemingia, cogon grass, *Lantana camara* L. 'Miss Huff', Matured Caribbean pine trees, and few *Callandra calothyrsus* nearby.
RA2	Riparian Area with vegetation	Matured *N.nicobarica*	2020	Dense shrub (wils sunflower, ferns, cogon grass, *Flemingia macrophylla*). There are also few IFT and *C. calothyrsus* observed in the area.
IFTC1	Riparian with young IFT and Caribbean Pines	Matured Caribbean Pines and Bamboo, Young *S. elegans* and *S. negrosensis*	2018	High litter cover (branch and leaves) from matured Caribbean Pine Trees
IFTC2	Riparian with young IFT and Caribbean Pines	Matured Caribbean Pines and Bamboo, Young *S. elegans* and *S. negrosensis*	2018	Vegetation are mostly ferns, Bamboo grass, and Caribbean Pine are also around. The area has litter cover
IFTC3	Riparian with young IFT and Caribbean Pines	Matured Caribbean Pines and young *Saurauia elegans*	2019	Dense litter cover, taller UFTs, and Bamboo grass and shrubs are present in the area.
IFTC4	Riparian with young IFT and Caribbean Pines	Young *S. elegans* and *C. evansii*, Matured bamboo	2019	Dense shrubs and ferns in the area, there are also few IFTs. Located adjacent to the bamboo grass, Pine trees are too far from the baseline point.
IFT	Riparian with IFT only	Bamboo grass and dense grass vegetation		Dense grass complex. Adjacent land has been cleared for agricultural purposes (Broccoli), Bamboo grass nearby, *C. calothyrsus* everywhere and other secondary trees, IFT nearby mature pine trees.

The IFTC2 (8°3.30.425"N and 124°48.40.047"E) has matured Caribbean pines and bamboo, young *S. elegans* and *S. negrosensis* with vegetation of mostly ferns, bamboo grass, and C. pine also present. The area has litter cover.

The IFTC3 (8°3'24.993"N and 124°48'33.987"E) has matured Caribbean pines and young *S. elegans* with dense litter cover, taller IFTs, bamboo grass, and shrubs are present in the area.

The IFTC4 (8°3.24.024"N and 124°48'34.097"E) has young *S. elegans* and *Castanopsis evansii* Elmer and matured bamboo with dense shrubs and ferns in the area, there are also few IFTs, located adjacent to bamboo grass. Pine trees are too far from the baseline point.

B. Riparian area with IFT only

The riparian area with IFT only has one (1) site which is labelled as IFT1 (8°3'15.936"N and 124°48'26.243"E). This area has bamboo grass and dense vegetation with dense complex. Adjacent land has been cleared for agricultural purposes (broccoli) with bamboo grass in the near vicinity, C. pine trees everywhere and other secondary trees, and IFTs.

C. Riparian area with vegetation

The Riparian without vegetation has two replicates, designated as RA1 and RA2. The RA1 (8°3'10.231"N and 124°48'39.582"E) has an elevation of 1,430 m and gently sloping. This has matured Caribbean Pine Tree and dense grass vegetation of *Flemingia macrophylla* (Willd.) Kuntze ex Merr., ferns, cogon grass, *Lantana camara* L., and a few *C. calothyrsus*.

The RA2 (8°2'44.115"N and 124°48'4.416"E) is gently sloping and has an elevation of 1,373 m. It has *Neoscortechinia nicobarica* and dense shrubs (wild sunflower, ferns cogon grass, *F. macrophylla*). Few IFT and *C. calothyrsus* have been observed in the area (Fig. 1).

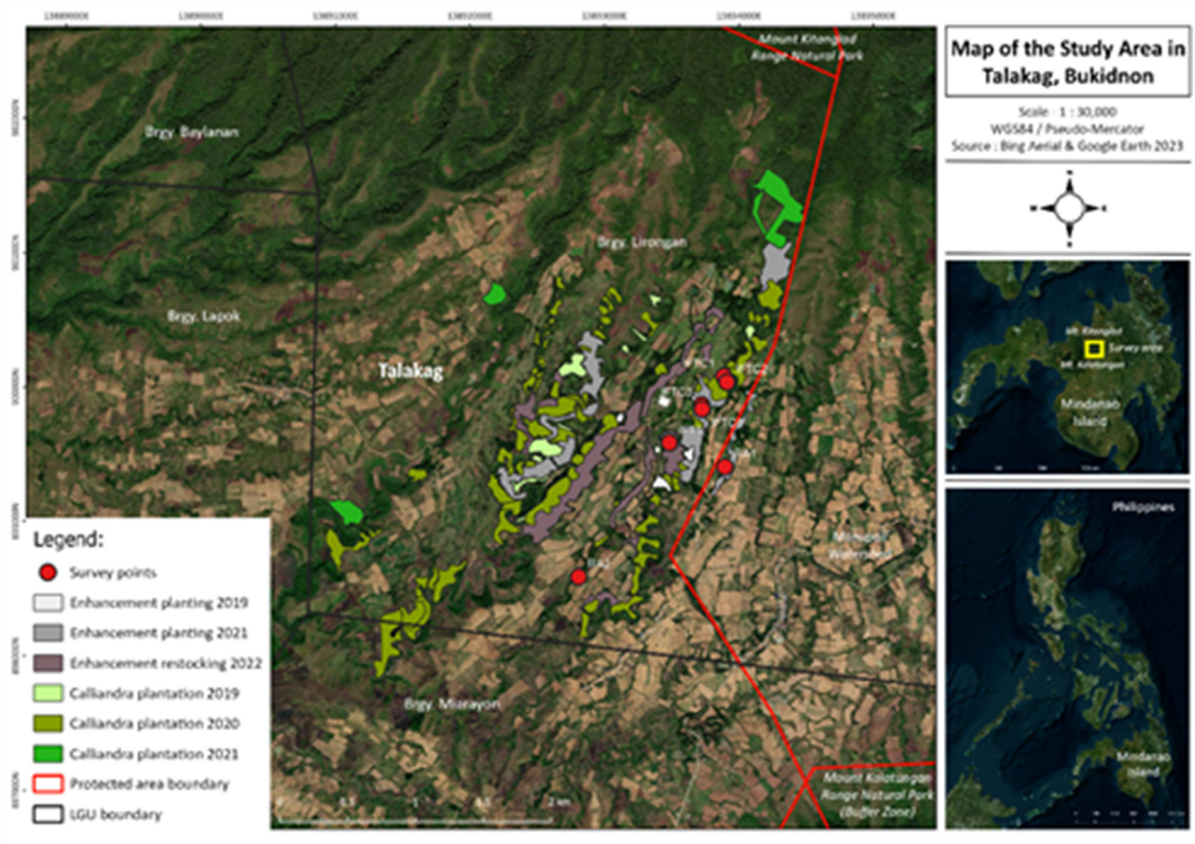

Fig. 1. Location of the different restoration sites at Mt. Kitanglad, Lirongan, Talakag, Bukidnon, Philippines

Data collection

Field data collection

The Biodiversity Assessment and Monitoring System (BAMS) methodology prescribed by the Biodiversity Management Bureau (BMB) for all protected areas in the country was used for the survey/sampling (BMB, 2015). A modified belt transect method was employed wherein nine quadrats with 20 m × 20 m was laid out along a 2-km transect at every 250 m interval. Trees at least 10 cm in diameter at breast height (DBH) inside the quadrats were identified, measured, and recorded. A 5 m x 5 m quadrat was constructed inside the 20 m × 20 m quadrat. Within this quadrat, the number of individuals of intermediate species (shrubs, poles, and saplings) was counted. Moreover, the percentage cover of understory species (grasses and other plant species of less than 1 m) was also assessed inside a 1m x 1m quadrat built inside the 5m × 5m quadrat.

Collection and identification of plant specimens

Data that were recorded in the field were as follows: (i) plant names from family down to species level; (ii) diameter at breast height (cm) and total height (m) of species in the canopy; (iii) plant groups of observed plants; and (iv) GPS coordination of all corners of each segment and nested plots.

Identification and nomenclature were aided using the following: Images of each plant for identification were taken using a camera, and the photographic method was based on the manual of Co's Digital Flora in the Philippines, an online database. Other online databases were used for identifying species' nomenclature, such as the International Plant Names Index (www.ipni.org) and Plants of the World Online (www.plantsoftheworldonline.org). The assessment of the status of each species, whether threatened, endemic, rare, or economically important, were based on the IUCN listings/categories and Department Administrative Order 11 series of 2017, a national list of threatened Philippine plants (Fernando *et al.*, 2008), and from some published floristic works and monographs.

Data analysis

The Shannon-Weiner Index (H') and Simpson's Index of Diversity (Wen *et al.*, 2010) were computed to calculate the species' diversity. The Shannon-Weiner index (H') was applied as a measure of both species' abundance, richness, and proportion of each species within the local community.

$H' = -\sum(n_1/N) \ln (n_1/N)$

Where n_1 represents the number of individuals of species *i*, *N* is the number of individuals, and ln demotes the natural logarithm. This index measures species richness and evenness, providing insights into the ecosystem's overall diversity.

Additionally, Simpson's diversity index was complementary to evenness. It gives the probability that any two individuals are drawn randomly from an infinitely large community belonging to the same species. It is the common measure of dominance, with values ranging from 0 to 1- 1 representing infinite diversity and 0, no diversity (Barcelona Field Studies Center, 2018).

$D = 1 - \sum(n_1/N)^2$

Where D = Simpson's Index, n_1 = number of individuals, N = total number of species

Pielous Evenness Index (J') was calculated in R studio using the standard formula $J' = \frac{H'}{\ln(S)'}$, where *H'* represents the Shannon-Wiener Diversity and *S* denotes species richness (Pielou, 1966).

Table 2. Classification of the diversity indices interpreted using the description proposed by Fernando (1998)

Relative value rating	Species diversity (H')	Evenness (E')
Very high	3.50 – above	0.75 – 1.00
High	3.00 – 3.49	0.50 – 0.74
Moderate	2.50 – 2.99	0.25 – 0.49
Low	2.00 – 2.49	0.15 – 0.24
Very low	0.00 – 1.99	0.05 – 0.14

Results and discussion

Floristic composition

The table below (Table 3) presents a comprehensive survey of the seven restoration sites in Mt. Kitanglad, revealing a remarkable diversity of plant species, comprising 532 individual plants from 79 species and 37 families. This diversity is particularly notable among the angiosperms that dominate the region's flora. The representation of angiosperms, comprising 336 species, underscores their ecological significance and adaptive strategies, enabling them to thrive across diverse environments within the surveyed area. Within the angiosperm group, families such as Fabaceae, Asteraceae, and Poaceae emerged as particularly rich in species, with 151, 38, and 24 individual plants, respectively. Among the Fabaceae family, *Calliandra calothyrsus*, *Acacia auriculiformis*, and *Flemingia macrophylla* have the greatest number of individual plants, comprising 70, 33, and 14, respectively. The *A. auriculiformis* and *C. calothyrsus* were recorded in multiple restoration sites. The *A. auriculiformis* is recognized by Boland *et al.* (1990) and Reza *et al.* (2019) as a preferred species for rehabilitation, while *C. calothyrsus* is widely utilized for weed suppression as a nurse species in plantations, intercropping systems, and alley cropping and also contributes to nitrogen cycling, nutrient retention, and soil conservation (Angima *et al.*, 2002; Heuzé *et al.*, 2017; Wambugu, 2002). As the most diverse plant family in the world (Beech *et al.*, 2017), the high species richness within the Fabaceae family is consistent with its global prominence in various ecosystems due to its nitrogen-fixing capabilities, which enhance soil fertility and contribute to the overall productivity of the ecosystems.

Elephantopus mollis, a member of the Asteraceae family, is recorded with 17 individuals, illustrating the family's adaptability across various habitats. The leaves and roots are traditionally utilized for their tonic, fever-reducing, expectorant, anti-inflammatory, soothing, wound-healing, anti-rheumatic, astringent, and diuretic properties (Setyawati *et al.*, 2015).

Table 3. Family, scientific, and English names and the number of species in different restoration sites at Mt. Kitanglad, Talakag, Bukidnon

Family	Scientific name	English name	Number of individual flora species per plot							TNPS
			RA1	RA2	IFTC1	IFTC2	IFTC3	IFTC4	IFT1	
Araliaceae	*Aralia spinosa* L.	Devil's walking stick	0	0	1	1	1	0	0	3
	Heptapleurum sp.		0	0	1	0	1	0	0	2
Asteraceae	*Acmella uliginosa* Sw.	Mars Para Cress	0	0	0	1	0	0	0	1
	Ageratum conyzoides L.	Billy goat weed	1	1	0	0	0	0	0	2
	Bidens pilosa L.	Hairy beggars tick	1	2	0	0	0	0	0	3
	Crassocephalum crepidioides Benth.	Redflower ragleaf	0	2	0	0	0	0	0	2
	Elephantopus mollis Kunth	Soft elephant's foot	6	3	1	2	2	0	3	17
	Galinsoga parviflora L.	Potato weed	0	2	0	0	0	0	0	2
	Mikania micrantha Kunth	Mile-a-minute	1	1	0	0	2	1	0	5
	Tithonia diversifolia (Hemsley) A. Gray	Mexican sunflower	3	3	0	0	0	0	0	6
Athyriaceae	*Diplazium costulisorum*		2	2	0	0	0	0	0	4
Balsaminaceae	*Impatiens platypetala* DC.	Broad petaled Balsma	0	3	2	2	0	1	3	11
Bignoniaceae	*Spathodea campanulata* P. Beauv.	African tulip	1	1	0	0	1	1	0	4
Blechnaceae	Blechnopsis sp.		1	0	1	0	0	0	0	2
	Telmatoblechnum serrulatum (Rich.) Perrie, D.J. Ohlsen & Brownsey	Swamp fern	0	0	0	1	0	0	0	1
Caryophyllaceae	*Drymaria cordata* (L.) Willd ex Roem. & Schult.	Tropical chickweed	0	0	0	0	1	0	0	1
Cyatheaceae	*Sphaeropteris* sp.	Anutong	12	5	0	4	1	3	4	29
Cyperaceae	*Carex* sp.		0	0	0	0	1	0	0	1
	Cyperus brevifolius Rottb.		3	1	0	0	0	0	0	4
	Scirpus sp.		1	0	0	0	0	0	0	1
	Scleria terrestris L.	Nutrushes	1	1	0	0	0	0	2	4
Davalliaceae	*Davallia trichomanoides* Sw.		0	0	0	0	1	0	0	1
Dennstaedtiaceae	*Pteridium aquilinum* (L.) Khun	Common bracken Fern	0	2	3	3	4	1	2	16
Dryopteridaceae	*Dryopteris pseudocaenopteris* (Kunze) Li Bing Zhang		0	0	0	1	0	0	0	1
Euphorbiaceae	*Macaranga tanarius* (L) Müll. Arg.	Elephant's ear	0	1	0	0	0	0	1	2
Fabaceae	*Acacia auriculiformis* A. Cunn. Ex Benth	Earleaf acacia	0	23	2	0	5	3	0	33
	Aeschynomene americana L.	Joint vetch	0	1	0	0	0	0	0	1
	Arachis pintoi Krapov. & W.C. Greg	Pintoi peanut	0	1	0	1	1	0	0	3
	Calliandra calothyrsus Meisn.		14	6	9	25	0	7	9	70
	Desmodium canescens (L.) DC.		0	4	1	0	1	1	0	7
	Flemingia macrophylla (Willd.) Merr.	Enoki-mame	5	1	0	0	0	0	8	14

	Gliricidia sepium (Jacq.) Walp.	Madre de cacao	2	0	0	0	0	0	0	2
	Indigofera spicata Forssk.	Red nerinjy	0	1	0	0	0	0	0	1
	Mimosa diplotrica C. Wright ex Sauvelle	Giant sensitive plant	0	1	0	0	0	0	0	1
	Ptericarpus indicus Willd.	Narra	0	0	0	0	0	2	0	2
Gentianaceae	*Gentiana asclepiadea* L.	Willow gentian	0	1	0	0	0	0	0	1
Hypoxidaceae	*Curculigo capitulata* (Lour.) Kuntze	Ground orchids	0	2	0	1	0	0	0	3
Iridaceae	*Crocosmia x crocosmiiflora* (Lemoine) N.E.Br.	Montbretia	0	0	2	1	0	0	0	3
Lamiaceae	*Hyptis capitata* Jacq.	False ironwort	0	2	0	0	0	0	0	2
Lythraceae	*Cuphea carthagenensis* (Jacq.) J.F. Macbr.	Columbian waxweed	0	1	0	0	0	0	0	1
Malvaceae	*Sida rhombifolia* L.	Cuban jute	3	2	0	0	0	1	0	6
	Urena lobata L.	Caesarweed	3	2	0	1	0	2	0	8
Melastomataceae	*Melastoma sanguineum* Sims		1	1	0	1	0	0	2	5
Moraceae	*Ficus heteropleura* Blume		4	1	1	0	2	2	3	13
Musaceae	Musa sp.		0	0	0	0	1	2	3	6
Myrtaceae	*Syzygium crassipes* Gaertn., nom. cons.		0	0	0	1	2	0	0	3
Nephrolepidaceae	*Nephrolepis biserrata* (Sw.) Schott	Giant sword fern	2	3	1	3	1	2	3	15
	Nephrolepis brownii (Desv.) Hovenkamp & Miyam	Asian sword fern	3	2	0	2	0	0	0	7
Orchidaceae	*Spathoglottis plicata* Blume		2	0	2	0	0	0	2	6
Pinaceae	*Pinus merkusii* Jungh & de Vriese	Pine tree	2	0	19	2	31	0	52	106
Piperaceae	*Piper aduncum* L.	Spiked pepper	2	1	0	0	0	0	2	5
Poaceae	*Bambusa vulgaris* Schrad. ex Wendl.	Common bamboo	1	0	0	2	0	0	0	3
	Brachiaria mutica (Forssk.) Stapf	Paragrass	1	1	0	0	0	0	0	2
	Cymbopogon citratus (DC.) Stapf	Lemon grass	0	0	1	0	0	0	0	1
	Cynodon dactylon (L.) Pers.	Bermuda grass	0	3	0	0	0	0	0	3
	Imperata cylindrica (L.)	Cogon grass	0	2	0	0	0	0	0	2

	P.Beauv.									
	Miscanthus x giganteus J.M.Greef & Deuter ex Hodk. & Renvoize		1	0	0	0	0	0	0	1
	Oplismenus hirtellus (L.) P.Beauv.	Basket grass	0	0	0	1	2	0	3	6
	Paspalum conjugatum P.J. Bergius	Buffalo grass	2	0	2	0	0	2	0	6
Polygalaceae	*Polygala paniculata* L.	Bubble gum plant	1	1	2	2	1	0	0	7
Polypodiaceae	*Phymatosorus scolopendria* (Burm.fil.) Pic.Serm.		0	1	0	0	0	0	0	1
Rosaceae	*Potentilla indica* (Andrews) Th. Wolf	Mock strawberry	0	0	0	1	0	0	0	1
	Rubus fraxinifolius Poir.	Atherton raspberry	1	1	1	0	0	1	0	4
Rubiaceae	*Spermacose laevis* Lam.		0	3	0	0	0	0	0	3
Selaginellaceae	*Selaginella tamariscina* (P.Beauv.) Spring	Spikemosses	0	0	0	1	1	0	0	2
Solanaceae	*Cestrum nocturnum* L.	Night-blooming jasmine	1	0	0	0	0	1	0	2
Thelypteridaceae	*Macrothelypteris* sp.		0	0	0	0	0	0	1	1
Verbenaceae	*Lantana camara* L.	Common lantana	2	2	2	1	1	1	1	10
	Stachytarpheta jamaicensis (L.) Vahl	Blue porter weed	2	2	0	0	0	1	0	5

Asteraceae species are widespread due to their adaptive traits, including clusters of tiny, pollinator-attracting florets (capitula), self-pollination, and lightweight achenes that are dispersed by wind, supported by a pappus (Bhattacharyya, 2016; Purnomo *et al.*, 2016).

According to Fonseca and Venticinque (2018), the widespread distribution of Asteraceae across diverse environments underscores its exceptional resilience and adaptability, as this family thrives globally in nearly all ecological niches, tolerating variations in temperature, salinity, drought, solar radiation, and wind conditions (Bremer, 1994; Minaeifer *et al.*, 2015; Azizi *et al.*, 2018; Zhang *et al.*, 2021; Asif *et al.*, 2020; Abd E-Fatah *et al.*, 2022).

The study's findings on gymnosperms, particularly *Pinus merkusii* from the Pinaceae family, with the highest individual count of 106 species, highlight the ecological importance of gymnosperms in these ecosystems. *P. merkusii*, typically found in high plains, also thrives in lowland and harsh soil conditions, which makes it a common choice for reforestation and rehabilitation (Imanuddin *et al.*, 2020). Despite gymnosperms generally exhibiting lower species diversity than angiosperms, *P. merkusii* stands out as a dominant species within the surveyed area.

Pteridophytes, comprising ferns and related plants, displayed moderate family and species diversity in the study area. Notable families among the pteridophytes include Thelypteridaceae, Cyatheaceae, and Nephrolepidaceae, which comprise 30, 29, and 22 individual plant species, respectively. The presence of *Nephrolepis bisserata* with 15 individuals underscores the ecological suitability of the habitat for pteridophytes. Zuquim (2015) and Dai *et al.* (2020) suggest that ferns are suitable indicators of environmental conditions due to their diverse adaptive strategies in response to changes in climate and soil factors. The diversity and distribution of ferns across the study sites highlight the complex ecological dynamics in these areas, making them valuable candidates for addressing critical issues in biodiversity assessment, monitoring, and restoration (Alcala *et al.*, 2019; De Los Angeles and Buot, 2012, 2018). In summary, the diverse plant species composition across the surveyed restoration sites in Mt. Kitanglad underscores the complex ecological dynamics of the region, highlighting the critical roles of angiosperms, gymnosperms, and pteridophytes in maintaining ecosystem productivity, resilience, and biodiversity.

Flora diversity analysis

The figure below (Fig. 2) illustrates biodiversity across seven (7) different sites (RA1, RA2, IFTC1, IFTC2, IFTC3, IFTC4, and IFT) using four biodiversity indices: Shannon-Wiener index, Simpson index, Evenness, and Dominance. The Shannon-Wiener index results indicate a transparent gradient of species diversity among the sites, with riparian sites with vegetation (e.g., RA1 and RA2) demonstrating the highest values (3.14 to 3.33), indicating rich biodiversity. According to Fernando (1998), these values fall within the "high" category, indicating that these riparian sites support a diverse range of species, which is consistent with the high species numbers observed in the area. In many ecological studies conducted in the Philippines, H′ values typically range from 1.5 to 3.5, with higher values indicating greater species diversity (Batani *et al.*, 2023). Riparian forest plants possess various morphological and physiological adaptations that make them well-suited to thrive in high-energy, wet environments (Barker *et al.*, 2002; Merritt *et al.*, 2010) and are crucial pathways for the movement of organisms between various landscapes, functioning as dispersal routes for both terrestrial and aquatic species (Ament *et al.*, 2014; Bennett *et al.*, 2014; Tonkin *et al.*, 2018).

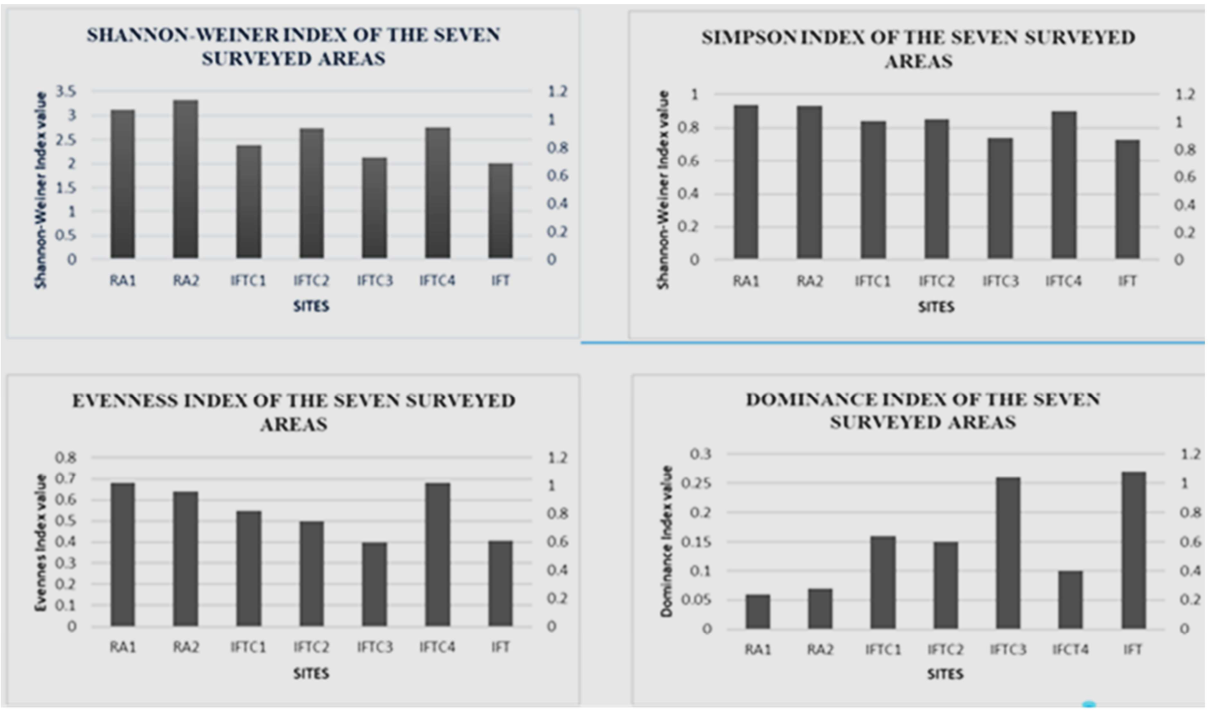

Fig. 2. The four (4) diversity indices of the even restoration sites at Mt. Kitanglad, Lirongan, Talakag, Bukidnon, Philippines

The riparian areas with vegetation (RA1 and RA2) recorded the highest number of species (33 and 34), further supporting the notion of a balanced and healthy ecosystem. The *C. calothyrsus* is one of the most prominent species in the area. The HFI's restoration approach employs the Associated Climax-Pioneer Species (ACPS) Scheme to promote the re-establishment of Indigenous Forest Trees (IFTs), utilizing *C. calothyrsus* as a nurse species to develop dense canopy that inhibits cogon grass growth (Binayao III *et al.*, 2021). According to Barral *et al.* (2017), *C. calothyrsus* supports the recovery of diverse plant communities and provides habitats for multiple species of flora and fauna. On the other hand, the *A. auriculiformis* species is also notable in these areas. It is described as a fast-growing tree species used in plantations in Asia and West Africa (Fonton *et al.*, 2002; Tonouéwa *et al.*, 2019). Fast-growing exotic species like *A. auriculiformis* and other Acacia varieties are widely applied in reforestation programs across degraded tropical and subtropical zones, such as in Southern Benin (Aoudji *et al.*, 2017), Indonesia (Sutomo *et al.*, 2016; Koutika and Richardson, 2019), South China and the Philippines (Lee and Woo, 2012).

This is followed by riparian areas with young IFT and Caribbean pines at four sites (e.g., IFTC1, IFTC2, IFTC3, IFTC4), and riparian areas with IFT only (IFT), ranging from 2.01 to 2.75. These values fall into the category of "low" index values, suggesting the lowest species diversity among the surveyed sites. This means these sites have fewer species or a more uneven distribution, with some species dominating while others are scarce.

The Simpson index estimates the probability that two individuals randomly selected from a sample belong to the same species; thus, a high Simpson index value indicates higher diversity. The graph shows that riparian areas with vegetation have the highest index values of 0.94 and 0.93, indicating that these sites have a relatively balanced species distribution, with no single species dominating the community. This also aligns closely with the findings of the Shannon-Weiner index, which means that the species in the area are relatively diverse and have a considerably even distribution of individuals among species. In contrast, the index values of riparian areas with young IFT and Caribbean Pines (IFTC1, IFTC2, IFTC3, and IFTC4) range from 0.73 to 0.90, while the riparian area with IFT only has the lowest index value of 0.73. This indicates that individuals from the same species are more frequently encountered, suggesting an uneven distribution where certain species predominate. The Simpson diversity index clearly demonstrates variation in species evenness across the sites, with riparian areas (RA1 and RA2) exhibiting the most diverse and balanced ecosystems. In contrast, the IFT area has the lowest species evenness.

The evenness (E') values across the surveyed sites indicate varying levels of species distribution uniformity. The evenness values of the seven sites range from 0.40 to 0.68, indicating notable differences in the uniformity of the species. High evenness values were observed in riparian areas with vegetation and in riparian areas with IFT and Caribbean Pines (IFTC1, IFTC2, and IFTC4), with corresponding evenness figures of 0.68, 0.64, 0.55, and 0.50, respectively. These evenness values are "high," indicating that these sites possess a relatively balanced species composition, of which the likelihood of any single species dominating the area is low. This also suggests a healthy and diverse ecosystem with a well-distributed presence of multiple species (Ulfah *et al.*, 2019). In contrast, IFTC3 (E' = 0.40) and the IFT area (E' = 0.41) fall into the category "moderate" evenness category. These lower E' values suggest that these sites have a more uneven species distribution, where certain species are more prevalent or dominant. This unevenness could indicate competitive advantages for specific species within these areas, potentially due to environmental factors, resource availability, or other ecological pressures that allow certain species to outcompete others.

The data also depicts the Dominance values of the surveyed area. This measures the degree to which a few species dominate the ecosystem, with higher values indicating greater dominance by one or a few species. The provided data below show dominance values ranging from 0.06 to 0.41, indicating varying levels of dominance across the seven sites. The maximum dominance values were observed at 0.40-0.41, respectively, at IFTC3 and IFT, which implies that a small number of species are disproportionately abundant compared to others. *P. merkusii,* a gymnosperm species, predominantly thrives in riparian areas with young IFT and Caribbean Pines (IFTC3) as well as in riparian areas with IFT only (IFT), further confirming its status as the dominant species in these habitats. This species thrives across diverse natural habitats, ranging from lowlands to highlands, and exhibits strong growth performance at varying elevations. Due to its wide ecological adaptability, this species is commonly utilized as a pioneer plant in reforestation and rehabilitation programs (Imanuddin *et al.*, 2020) as well as for production purposes (Bharali *et al.*, 2012; Susilowati *et al.*, 2016). This dominance of *P. merkusii* observed suggests a less balanced ecosystem that favors certain species over others. This was followed by the dominance indices at IFTC1, IFTC2, and IFTC4, ranging from 0.15 to 0.27, indicating intermediate levels of species dominance. The lowest dominance values were observed at sites RA1 and RA2, with values of 0.06 and 0.07, respectively. Thus, this low dominance aligns with the high evenness values observed at these sites, signifying a well-balanced ecosystem where no single species has an overwhelming presence.

Integrating these findings, the biodiversity indices across the seven surveyed sites reveal distinct patterns of species diversity, evenness, and dominance. Riparian areas with vegetation exhibit the most balanced and diverse ecosystems. In contrast, areas dominated by IFT exhibit reduced diversity and uneven species distribution, highlighting the ecological variability and dynamics of these restoration sites. According to Stieger and McKenzie (2024), riparian zones are among the most ecologically significant areas for biodiversity. These zones serve as essential interfaces between terrestrial and aquatic ecosystems, providing key ecological services (ES), including pollutant filtration from runoff, flood mitigation, enhancement of fish biodiversity and abundance, and the supply of plant and animal resources that contribute to recreation and well-being (Stieger and McKenzie, 2024). Similarly, Hanna *et al.* (2018) emphasize that riparian zones rank among the most biologically diverse and productive ecosystems worldwide, facilitating the movement of energy, nutrients, and organisms. The vegetation of these zones is vital for maintaining environmental stability and ecosystem health (Monteiro *et al.*, 2016). Therefore, the findings underscore the critical role of vegetative riparian zones in supporting biodiversity, maintaining ecosystem balance, and enhancing ecological resilience. The higher species diversity and evenness in these areas highlight their ability to provide stable habitats and essential ecological functions. Conversely, the lower diversity and uneven species distribution in IFT-dominated areas suggest habitat limitations that restrict species interactions and overall ecosystem recovery. These findings underscore the importance of restoration strategies that foster vegetation diversity and structural complexity, thereby enhancing ecosystem resilience and functionality.

Conservation status and endemicity

A region's biodiversity is critical to its ecological health and stability. A survey assessed the conservation status of 352 individual plants within the seven areas. This report categorized these species according to the International Union for Conservation of Nature (IUCN) Red List criteria: Least Concern, Nearly Threatened, Threatened, Vulnerable, and Endangered. The findings provided valuable insights into the state of biodiversity of the restoration areas.

The Table 4 presents the number of species by conservation status for each sampling site. Among the 79 species surveyed, 74 were categorized as Least Concern. This group represents most of the species assessed, indicating that they currently face no immediate threat to their populations. The survey identified two species classified as Endangered:

Diplazium costulisorum and *Sphaeropteris glauca*. The *D. costulisorum* was predominantly observed in riparian areas with vegetation (RA1 and RA2), whereas *S. glauca* was distributed across multiple sites, including riparian areas with vegetation, areas with Caribbean pines and IFT, and sites with IFT only. Both species are classified as pteridophytes and belong to the fern group. The presence of ferns reflects a forest ecosystem's ability to sustain diverse organisms while playing a crucial role in maintaining soil moisture, facilitating ecological succession as pioneer species, supporting food chain dynamics as primary producers, and contributing to soil nutrient enrichment (Fauziah *et al.*, 2022; Majid *et al.*, 2022; Pradipta *et al.*, 2020). Additionally, they hold potential for use in medicine, food production, and ornamental horticulture (Mowata *et al.*, 2020). Moreover, ferns are adaptable plants that can grow in diverse habitats, including terrestrial environments, aquatic ecosystems, and as epiphytes clinging to trees or rocks (Wardiah *et al.*, 2019). The survey also identified one species, *Syzygium crassipes*, categorized as Near Threatened. This species was found exclusively in the IFT2 area, indicating a limited distribution range.

The classification of this species highlights the importance of preserving its habitat to prevent further decline and potential reclassification into a higher threat category. *P. merkusii* was classified as Vulnerable, which is found in several areas: RA1, IFTC1, IFTC2, IFTC3, and IFT. The primary reasons for the decline in population size and distribution likely include logging, habitat conversion to agricultural land, timber extraction, clear-cutting, and frequent forest fires (FAO, 2010; Periera *et al.*, 2015). Considering the ongoing threats and declining population, this species has been classified as Vulnerable on the IUCN Red List (Farjon, 2013). The broad distribution of this species indicates a need for comprehensive conservation measures to safeguard its population, including habitat protection and restoration initiatives.

Table 4. Conservation status and endemicity of each plant species in Mt. Kitanglad, Lirongan, Talakag, Bukidnon

Family	Scientific name	Conservation status			Endemicity		
		DAO 2017-11	IUCN	Others	N	I	NA
Araliaceae	*Aralia spinosa* L.	-	LC	-	-	-	✓
	Heptapleurum sp.	-	-	-	✓	-	-
Asteraceae	*Acmella uliginosa* Sw.	-	LC	-	-	-	✓
	Ageratum conyzoides L	-	-	Secure/NT (Nature serve/AERP)	-	-	✓
	Bidens pilosa L.	-	-	NT(AERP)	-	-	✓
	Crassocephalum crepidioides Benth.	-	-	NT(AERP)	-	✓	-
	Elephantopus mollis Kunth	-	-	NT(AERP)	-	-	✓
	Galinsoga parviflora L.	-	-	NT(AERP)	-	-	✓
	Mikania micrantha Kunth	-	LC	NT (AERP)	-	-	✓
	Tithonia diversifolia (Hemsley) A. Gray	-	-	NT (AERP)	-	-	✓
Athyriaceae	*Diplazium costulisorum* (Copel) C. Chr.	EN	-	-	✓	-	-
Balsaminaceae	*Impatiens platypetala* DC.	-	-	NT (AERP)	✓	-	-
Bignoniaceae	*Spathodea campanulata* P. Beauv.	-	LC	-	-	-	✓
Blechnaceae	*Blechnopsis* sp.	-	-	-	-	-	-
	Telmatoblechnum serrulatum (Rich.) Perrie, D.J. Ohlsen & Brownsey	-	-	-	✓	-	-
Caryophyllaceae	*Drymaria cordata* (L.) Willd ex Roem. & Schult.		-	NT (AERP)	-	-	✓

Cyatheaceae	*Sphaeropteris glauca* (Wall.) Copel.	EN (as *Cyathea contaminans*)	LC		✓	-	-
Cyperaceae	Carex sp.	-	-	-	✓	-	-
	Cyperus brevifolius Rottb.	-	LC (synonym *Kallinga brevifolia*)	-	✓	-	-
	Scirpus sp.	-	-	-	✓	-	-
	Scleria terrestris L.	-	-	NT (AERP)	✓	-	-
Davalliaceae	*Davallia trichomanoides* Sw.	-	-	-	✓	-	-
Dennstaedtiaceae	*Pteridium aquilinum* (L.) Khun	-	LC	-	✓	-	-
Dryopteridaceae	*Dryopteris pseudocaenopteris* (Kunze) Li Bing Zhang	-	-	-	✓	-	-
Euphorbiaceae	*Macaranga tanarius* (L) Müll. Arg.	-	LC	NT (AERP)	✓	-	-
Fabaceae	*Acacia auriculiformis* A. Cunn. Ex Benth	-	LC	-	-	-	✓
	Aeschynomene americana L.	-	-	NT (AERP)	-	-	✓
	Arachis pintoi Krapov. & W.C. Greg	-	-	NT (AERP)	-	✓	-
	Calliandra calothyrsus Meisn.	-	-	LC (inaturalist)	-	-	✓
	Desmodium canescens (L.) DC.	-	-	-	-	-	✓
	Flemingia macrophylla (Willd.) Merr.	-	-	NT (AERP)	✓	-	-
	Gliricidia sepium (Jacq.) Walp.	-	LC	-	-	-	✓
	Indigofera spicata Forssk.	-	-	NT (AERP)	-	-	✓
	Mimosa diplotrica C. Wright ex Sauvelle	-	-	NT (AERP)	-	-	✓
	Ptericarpus indicus Willd.	CE	EN	-	✓	-	-
Gentianaceae	*Gentiana asclepiadea* L.	-	-	NT (AERP)	✓	-	-
Hypoxidaceae	*Curculigo capitulata* (Lour.) Kuntze	-	-	NT (AERP)	✓	-	-
Iridaceae	*Crocosmia x crocosmiiflora* (Lemoine) N.E.Br.		-	NT (AERP)	-	-	✓
Lamiaceae	*Hyptis capitata* Jacq.	-	-	NT (AERP)	-	-	✓
Lythraceae	*Cuphea carthagenensis* (Jacq.) J.F.Macbr.	-	-	NT (AERP)	-	✓	-
Malvaceae	*Sida rhombifolia* L.	-	-	NT (AERP)	✓	-	-
	Urena lobata L.	-	LC	-	-	-	✓
Melastomataceae	*Melastoma sanguineum* Sims	-	LC	-	✓	-	-
Moraceae	*Ficus heteropleura* Blume	-	-	NT (AERP)	✓	-	-
Musaceae	*Musa* sp.	-	-	-	✓	-	-
Myrtaceae	*Syzygium crassipes* Gaertn., nom. cons.		NT	-	✓	-	-
Nephrolepidaceae	*Nephrolepis biserrata* (Sw.) Schott	-	-	Secure (Nature serve)	✓	-	-
	Nephrolepis brownii (Desv.) Hovenkamp & Miyam	-	-	-	✓	-	-
Orchidaceae	*Spathoglottis plicata* Blume	-	-	NT (AERP)	✓	-	-
Pinaceae	*Pinus merkusii* Jungh & de Vriese	VU	VU	-	✓	-	-
Piperaceae	*Piper aduncum* L.	-	LC	-	-	-	✓
Poaceae	*Bambusa vulgaris* Schrad. ex Wendl.	-	-	Secure/NT (NatureServe/AERP)	-	-	✓
	Brachiaria mutica (Forssk.) Stapf		LC	-	-	-	✓
	Cymbopogon citratus (DC.) Stapf	-	-	NT (AERP)	-	✓	-

	Cynodon dactylon (L.) Pers.	-	-	NT (AERP)	✓	-	-
	Imperata cylindrica (L.) P.Beauv.	-	-	NT (AERP)	✓	-	-
	Miscanthus x giganteus J.M.Greef & Deuter ex Hodk. & Renvoize	-	-	NE (PFAF)	✓	-	-
	Oplismenus hirtellus (L.) P.Beauv.	-	-	NT (AERP)	✓	-	-
	Paspalum conjugatum P.J. Bergius	-	LC	-	-	-	✓
Polygalaceae	*Polygala paniculata* L.	-	LC	-	-	-	✓
Polypodiaceae	*Phymatosorus scolopendria* (Burm.fil.) Pic.Serm.	-	-	-	✓	-	-
Rosaceae	*Potentilla indica* (Andrews) Th. Wolf	-	LC	-	✓	-	-
	Rubus fraxinifolius Poir.	-	LC	-	✓	-	-
Rubiaceae	*Spermacose laevis* Lam.	-	LC	-	-	-	✓
Selaginellaceae	*Selaginella tamariscina* (P.Beauv.) Spring	EN	-	-	✓	-	-
Solanaceae	*Cestrum nocturnum* L.	-	LC	-	-	✓	-
Thelypteridaceae	*Macrothelypteris* sp.	-	-	-	✓	-	-
Verbenaceae	*Lantana camara* L.	-	-	NT (AERP)	-	-	✓
	Stachytarpheta jamaicensis (L.) Vahl	-	LC	-	-	-	✓

Notes: Scientific names are arranged by families and are classified based on status occurrence (Native= N, Introduced= I, Naturalized= NA), conservation status (LC– Least Concern; En– Endangered; Vu – Vulnerable; NE– Not Evaluated) based on the IUCN (2023) and the DENR-DAO 2017-11 (DENR 2019). Others denote the conservation status of each species based on other online classifications (AERP- Angiosperm Extinction Risk Prediction v1, iNaturalist, NatureServe).

Lastly, *Ptericarpus indicus* and *Selaginella tamariscina,* are two species identified as Endangered and found in areas IFCTC4, IFTC2, and IFTC3 (Fig. 3). The classification of these species reflects their critical status, which has a significant risk of extinction in the wild. *P. indicus,* commonly known as Narra, is classified as "Endangered" by the International Union for Conservation of Nature (IUCN, 2023) due to excessive harvesting and illegal logging and is designated as "Critically Endangered" in the Philippines according to the Philippine National Red List for Plants (DENR, 2017), prompting the implementation of various government and non-government programs aimed at addressing forest degradation, protecting key biodiversity species, and promoting sustainable livelihoods within communities (Posa *et al.*, 2008; Von Kleist *et al.*, 2021). These species' limited distribution and specialized habitat needs require urgent conservation measures, including habitat protection, regulatory enforcement, and potentially ex-situ conservation.

The survey across the seven sites showcased a diverse range of plant life in the Table 4. Of the 79 species, 42 were identified as native, eight were introduced, and 29 were naturalized. The presence of these species underscores the region's rich biodiversity. They play critical roles in maintaining ecological balance, providing food and habitat for other organisms, and supporting the ecosystem's overall health; thus, their presence underscores the importance of protecting these areas to preserve the natural heritage and ensure the sustainability of the local biodiversity. Introduced and naturalized species may pose a danger to native species. There is a need to monitor and manage these species to mitigate any adverse impacts they may have on native species.

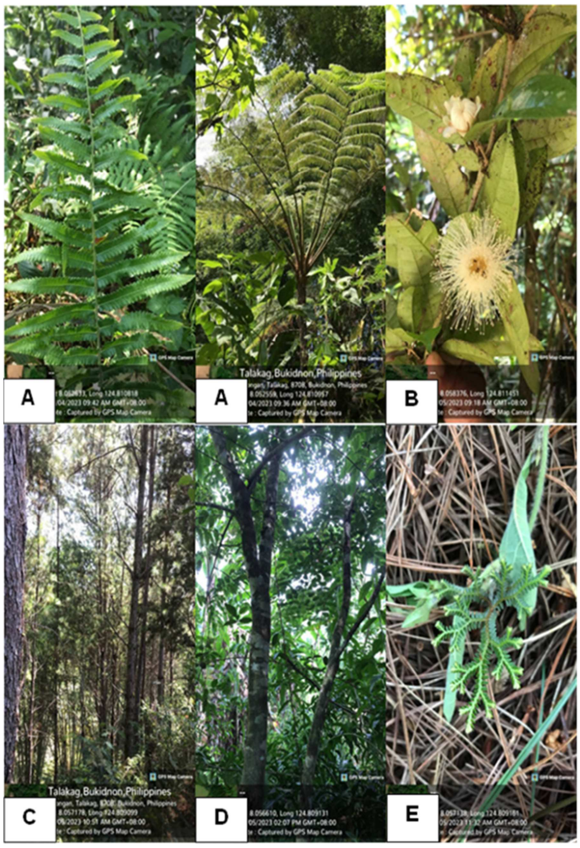

Fig. 3. Identified (a) Endangered, (b) Nearly Threatened, (c) Vulnerable, (d) Critically endangered, and (e) Endangered species in the seven restorations: a *Diplazium costulisirum* & *Sphaeropteris glauca*, b- *Syzygium crassipes*, c- *Pinus merkusii,* d- *Ptericarpus indicus,* e- *Selaginella tamariscina*sites

However, alien species are being recorded in the area, such as *Mikania micrantha, Ageratum conyzoides, and Elephantopus mollis*, of which these species under the family Asteraces have also been documented to be invasive in the Northern and Southern American forest (UNEP, 2013). Asteraceae has been identified as an invasive alien plant family in China, posing significant threats to the diversity of native species and the stability of the ecosystem (Yang *et al.*, 2023). Similarly, in North Sumatra, this family is prominently represented among Invasive Alien Plant Species (IAP), with *Ageratum conyzoides* and *Chromolaena odorata* being particularly aggressive invaders (Huda *et al.*, 2022).

Assessing the conservation status of species and identifying native, introduced, and naturalized plants across the surveyed sites highlights the urgency of implementing targeted conservation measures.

Conclusion

The survey of seven restoration sites in Mt. Kitanglad revealed substantial plant diversity, with 532 individual plant species, dominated by angiosperms in the Fabaceae, Asteraceae, and Poaceae families, underscoring their ecological importance and roles. The highest species diversity and even distribution were observed in riparian zones RA1 and RA2, indicated by high Shannon-Weiner and Simpson indices, suggesting resilient and balanced ecosystems. In contrast, IFTC and IFT sites exhibited lower diversity and greater species dominance, likely due to environmental pressures that favored specific species. The conservation assessment identified several threatened species, such as *Syszygium crassipes* and vulnerable *P. merkusii,* underscoring the need for targeted conservation efforts. Additionally, introduced species like *M. micrantha, A. conyzoides,* and *E. mollis* pose a risk to native flora, highlighting the importance of ongoing monitoring.

Recommendations

Further ecological studies and long-term biodiversity monitoring

Long-term biodiversity monitoring should be conducted to assess species regeneration and ecosystem changes over time. Research on soil composition, water availability, and climate factors will help improve restoration strategies. Additionally, studies on the ecological impact of invasive species can guide management efforts to prevent biodiversity loss.

Conservation of endangered species

Endangered species such as *Pterocarpus indicus* and *Selaginella tamariscina* require immediate conservation efforts. To prevent further population decline, habitat restoration, seed banking, and strict enforcement of policies against deforestation and land conversion should be implemented.

Community engagement and participation

Local communities' involvement in conservation initiatives is crucial. The community should participate in reforestation programs, biodiversity monitoring, and sustainable livelihood projects such as ecotourism and agroforestry. Establishing native tree nurseries can also provide a sustainable source of planting materials for restoration efforts. Encouraging participation through citizen science initiatives can empower residents to monitor plant species, report sightings of endangered flora, and track invasive species.

Reforestation and habitat restoration

Restoration programs should focus on planting native species, especially nitrogen-fixing plants like those in Fabaceae family, to enhance soil fertility to enhance soil fertility. Strengthening fire prevention measures and rehabilitating degraded riparian areas will further support ecosystem stability and species diversity.

Policy strengthening and institutional support

Government agencies, non-government organizations (NGOs), and research institutions should collaborate in developing stronger conservation policies. Securing financial support and establishing stricter legal protections for critical habitats will ensure sustainable forest restoration and biodiversity conservation efforts.

Environmental education and ecotourism

Promoting environmental education and ecotourism will increase awareness and encourage local participation in conservation. Organizing guided nature walks, workshops, and community-led biodiversity monitoring can foster a sense of responsibility toward protecting natural resources.

Invasive species management

Regular monitoring and removal programs should control the spread of invasive species such as *Mikania micrantha, Ageratum conyzoides,* and *Elephantupos mollis.* Replanting native species in affected areas can help restore ecological balance and protect native biodiversity from further threats.

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