

Plant community and diversity in a privately-owned multi-story agroforest in Mindanao, Philippines

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Abstract. Achondo MJMM, Raganas AFM, Espaldon MVO. 2026. Plant community and diversity in a privately-owned multi-story agroforest in Mindanao, Philippines. *Biodiversitas* 27 (4): d270406. <https://doi.org/10.13057/biodiv/d270406>. The lower slopes of Mt. Kitanglad Natural Park in Bukidnon, Mindanao, are increasingly dominated by monoculture plantations that threaten native biodiversity. The Binahon Agroforestry Farm (BAFF), a privately managed multi-strata agroforest, represents an alternative land-use model that integrates production and ecological stewardship. This study assessed the plant community composition, diversity, and structure of BAFF using 34 quadrats with size 20 m × 20 m each (total sampling area = 13,600 m²) and 800 m of transect sampling. A total of 165 plant species belonging to 65 families were recorded, with Fabaceae, Moraceae, Asteraceae, Euphorbiaceae, and Myrtaceae as the most represented families. Trees (67 species) were the dominant growth form, followed by herbs (35) and shrubs (33). Nine endemic (5.5%) and nine threatened species (5.5%) were documented, highlighting the ecological value of the site. The Shannon-Wiener index ($H' = 4.08$) and Pielou's evenness index ($J = 0.80$) indicated a diverse and almost balanced plant community, falling within the range reported for secondary forest ecosystems in previous studies in Mindanao. Species with the highest importance values were *Pinus kesiya*, *Acacia mangium*, *Eucalyptus* sp., *Rubroshorea negrosensis*, and *Vitex parviflora*. The coexistence of native, endemic, and cultivated species suggests a structurally heterogeneous vegetation that promotes ecological functions within a managed landscape. Overall, the findings indicate that well-managed agroforests such as BAFF may serve as valuable components of landscape-level conservation, supporting biodiversity within productive land-use systems and potentially informing agroforestry-based planning and policy in Mindanao.

Keywords: Agroforestry, Bukidnon, Importance value, Mt. Kitanglad, Shannon diversity

INTRODUCTION

Agroforestry is a land-use system where trees or other woody perennial plants are deliberately cultivated alongside agricultural crops and, in some cases, livestock and their fodder (Roy et al. 2025). By combining forestry and farming, it provides both production and ecological benefits such as soil protection, microclimate regulation, and habitat provision (ICRAF 2000). Across tropical regions, agroforestry commonly includes cocoa, coffee, or rubber grown with shade trees, fruit-bearing species, and other useful plants, sometimes with grazing animals. The multi-layered structure of agroforests, from ground herbs to emergent trees, allows them to support greater species richness than monoculture systems, although generally below that of intact forests (Udawatta et al. 2019). In addition to supporting biodiversity, agroforestry systems can contribute to climate change mitigation by enhancing biomass production and storing carbon in both vegetation and soils (Jose and Bardhan 2012). Globally, such systems are increasingly recognized for their role in maintaining biodiversity within modified landscapes (Nair et al. 2022).

The Philippines has experienced extensive forest conversion over the past century, placing considerable pressure on native biodiversity (Catacutan 2000; DENR-B+WISER 2015). In Mindanao, agricultural intensification

and the expansion of monoculture plantations, particularly banana and pineapple, have altered large portions of montane and lower montane ecosystems around key biodiversity areas such as Mt. Kitanglad Natural Park (MKNP). These land-use changes contribute to forest fragmentation and habitat loss, especially below 1,200 meters above sea level (masl), where clearing, charcoal production, and shifting cultivation persist despite established conservation policies (Peterson et al. 2008; Ortiz and Torres 2020; de Luna et al. 2022). Within these disturbed zones, managed vegetation patches and agroforestry farms may serve as ecological links between forest remnants and cultivated lands, supporting connectivity and reducing edge effects. Integrating biodiversity-friendly land-use systems such as agroforestry is therefore critical not only for agricultural production but also for sustaining the ecological functions of protected areas.

Agroforestry in the Philippines has historical roots in indigenous farming practices involving selective tree retention and mixed cropping (Conklin 1957). Modern agroforests can also act as buffer zones and biological corridors (McGinty et al. 2008), with low-intensity multi-strata systems shown to harbor considerable plant diversity (Beyene et al. 2018; Esquivel et al. 2023; Kassa et al. 2023). However, floral assessments in Philippine agroforestry systems remain scarce. Barrientos et al. (2025) recorded

substantial vascular plant diversity in a coffee-based agroforest in La Union and highlighted the value of biodiversity monitoring. Yet, few studies have quantified vegetation structure or ecological composition in Philippine agroforestry systems, particularly those adjacent to protected areas.

The Binahon Agroforestry Farm (BAFF) in Lantapan, Bukidnon, situated on the lower slopes of Mt. Kitanglad Natural Park, presents an ideal setting to address this gap. Managed under ecologically guided practices, BAFF integrates fruit trees, timber species, ornamentals, and crops within a long-established multi-strata system (Espaldon 2008). Its location adjacent to a protected area and its structurally complex vegetation make it a suitable site for examining floristic composition and vegetation structure within upland agroforestry systems in Mindanao.

This study was guided by the expectation that long-term, low-intensity agroforestry management would result in distinct vegetation patterns. Specifically, cultivated tree species were expected to dominate the canopy and exhibit high structural importance due to deliberate planting and selective maintenance. The understory layer was expected to support relatively high species richness, including pioneer and ruderal taxa associated with minimal agrochemical input and continuous disturbance. We further expected the coexistence of native and introduced species arising from both management-driven species selection and natural recruitment processes. Finally, the occurrence of endemic and threatened taxa was anticipated, particularly within shaded and semi-forested microhabitats where moderated light and microclimatic conditions may favor their persistence.

Accordingly, this study aimed to characterize the plant species composition of BAFF, quantify plant diversity across vegetation strata, and describe vegetation structure based on species importance values of dominant woody taxa. By

addressing these objectives, the study evaluates the ecological role of a privately managed agroforestry system as a complementary habitat that may contribute to biodiversity conservation in landscapes adjacent to Mt. Kitanglad Natural Park.

MATERIALS AND METHODS

Study area

Mt. Kitanglad Range Natural Park (MKNP) in Bukidnon, southern Philippines, is a Key Biodiversity Area (KBA), an Important Bird Area (IBA), and an ASEAN Heritage Park (Catacutan 2000; DENR-B+WISER 2015). It encompasses diverse ecosystems from lowland dipterocarp to mossy montane forests, including Mt. Dulang-dulang, the country's second-highest peak. Despite long-standing protection efforts, forest degradation persists due to slash-and-burn farming, charcoal production, and illegal tree cutting (Peterson et al. 2008; Ortiz and Torres 2020; de Luna et al. 2022).

Within this landscape lies the Binahon Agroforestry Farm (BAFF) in Sitio Bol-ogan, Barangay Songco, Lantapan ($8^{\circ}03'25''\text{N}$, $124^{\circ}55'44''\text{E}$; 1,332 m asl; Figure 1). Although geographically part of the Mt. Kitanglad range, BAFF is located outside the official boundary and designated buffer zone of MKNP. It represents a privately managed agroforestry site on the mountain's lower slopes, covering approximately eight hectares (80,000 m²). The farm was established in 1992 by Henry and Perla Binahon and has gradually expanded through additional land acquisitions in subsequent years. Prior to its establishment, the area was largely a degraded upland site previously used for vegetable production.

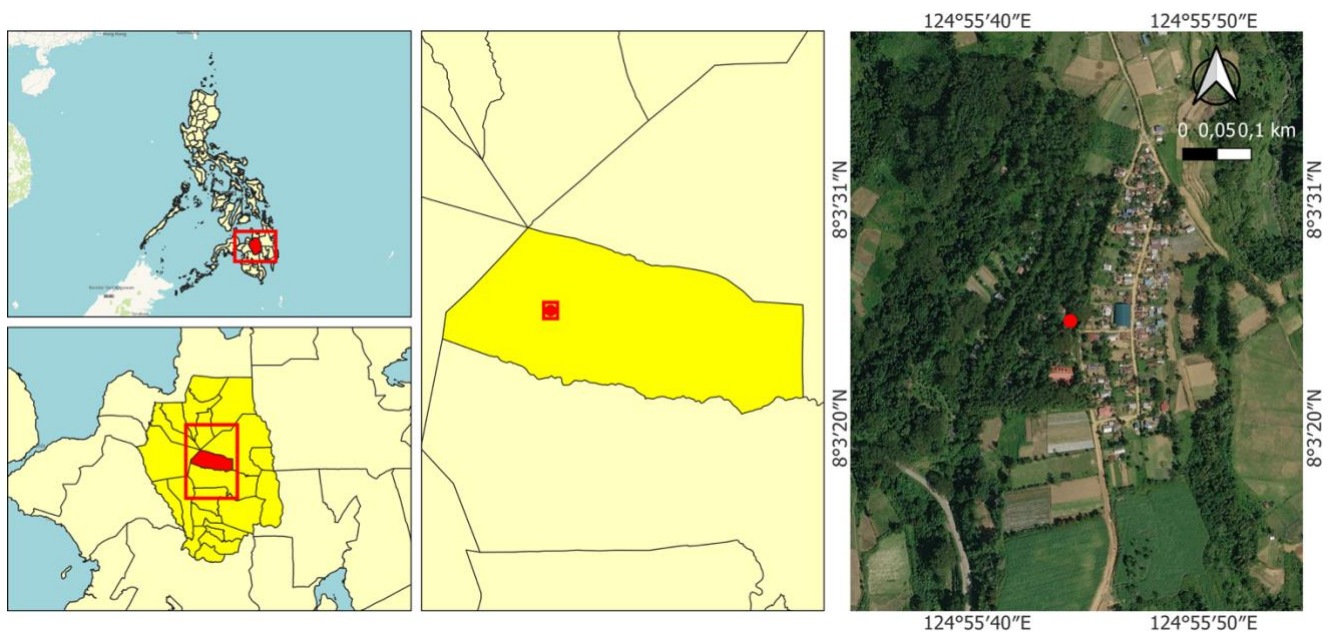


Figure 1. Location of the Binahon Agroforestry Farm ($8^{\circ}03'25''\text{N}$, $124^{\circ}55'44''\text{E}$) in Lantapan, Bukidnon, Philippines



Figure 2. Multi-layered vegetation structure at the Binahon Agroforestry Farm (BAFF), Lantapan, Bukidnon, illustrating canopy and understory composition within managed agroforestry system

At present, the farm serves as a model for sustainable multi-storey farming (Espaldon 2008). The farm operates several integrated components including seedling production, farm tourism, food processing, organic agriculture, high-value vegetable crop production, herbs and spices, orchard gardens, industrial and ornamental crops, poultry and livestock, and transportation services. It also serves as an accredited learning site of the Agricultural Training Institute for training activities related to sustainable agriculture and agroforestry practices. Unlike many agroforestry systems in the region that are primarily practiced for subsistence or smallholder production, BAFF was intentionally developed to demonstrate ecologically sustainable upland farming and diversified agroforestry practices.

Its system integrates timber and fruit trees, vegetables, ornamentals, and nitrogen-fixing species using low-intensity practices such as organic composting, minimal tillage, and biological pest control. The structure follows a multi-strata design with an upper canopy of tall timber and fruit trees (Figure 2), a middle layer of shrubs and smaller trees, and a ground layer of herbs, vines, and crops.

The area experiences a Type IV climate under the Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA) classification, characterized by evenly distributed rainfall throughout the year and indistinct dry and wet seasons. Average monthly rainfall is 224.54 mm, with an annual maximum of 2,552.4 mm. The period from November to April is relatively dry, while May and October usually record the highest rainfall (Evangelista et al. 2015). Mean annual temperature ranges from 19–31°C, with an average relative humidity of 87% (1980–2016). The soils of Lantapan, primarily Adtuyon and Kidapawan clay, are highly suitable for agriculture and contribute to the municipality's reputation as the “vegetable basket” of southern Mindanao (Catacutan and Duque 2006).

Data collection

Plant surveys were conducted in November 2022 and March 2023 using two complementary sampling approaches

designed to capture both vegetation structure and overall species diversity within the Binahon Agroforestry Farm (BAFF). The use of fixed-area quadrats and a linear transect was intended to address different components of the vegetation and to account for the structural heterogeneity typical of multi-strata agroforestry systems.

For woody vegetation, the quadrat method was applied following the Biodiversity Assessment and Monitoring System (BAMS) Manual of the Biodiversity Management Bureau (BMB 2017), with minor modifications. Thirty-four (34) 20 m × 20 m plots (total sampling area = 13,600 m²), equivalent to approximately 17% of the total farm area, were established across distinct vegetation patches within BAFF. Plots were systematically spaced at least 25 m apart to minimize spatial overlap and avoid double-counting of individuals. Within each plot, all woody and non-woody plants ≥1 m in height were recorded. For tree-sized individuals, circumference at breast height (1.3 m) was measured using a diameter tape, and crown diameter was estimated following Blozan (2006). Data from the quadrats were used exclusively for quantitative vegetation structure analyses, including density, basal area, frequency, dominance, and species importance values.

To document plant species occurring in the ground and understory layers that are often underrepresented in fixed-area plots, a single 800 m line transect was established across representative portions of the farm. The use of a transect to capture variation across vegetation patches is consistent with the spatial logic of the Biodiversity Assessment and Monitoring System (BAMS) protocol, where transects are established across heterogeneous habitats and quadrats are used to assess vegetation layers along the transect (BMB 2017). In this study, the transect component was implemented independently from the quadrats to accommodate the patch-based structure and management zones within the agroforestry farm.

The transect traversed multiple management zones and vegetation conditions, including shaded canopy areas, semi-open patches, and actively cultivated sections, thereby capturing spatial heterogeneity across the site. Transect length was selected to maximize species detection across the approximately 8-ha farm while remaining consistent with rapid floristic assessment approaches commonly applied in heterogeneous tropical agroecosystems. All plant species touching or occurring within one meter of the transect line were recorded. The transect was deliberately positioned to avoid intersecting any quadrat plots to ensure independence between the two datasets.

Vegetation was stratified into overstorey and understory components for analytical clarity. The overstorey comprised canopy and sub-canopy species with ≥5 cm DBH or ≥3 m height, while the understory included herbs, grasses, sedges, vines, epiphytes, and juvenile woody plants with <5 cm DBH or <3 m height. These thresholds were applied only in vegetation structure analysis and not in species richness or diversity calculations (Chianucci et al. 2016; Noulèkoun et al. 2023).

Species diversity, expressed using the Shannon-Wiener index (H'), was calculated based on the combined species list derived from both quadrat and transect surveys to

capture total plant diversity across all vegetation strata. In contrast, vegetation structure metrics, including relative density, relative dominance, relative frequency, and species importance values, were derived solely from quadrat data. This analytical separation ensured that diversity estimates reflected whole-site floristic richness, while structural analyses remained based on standardized area-based sampling of woody vegetation.

Permission and ethical compliance

Fieldwork was conducted with the consent of the landowner of the BAFF, who granted access for ecological assessment and specimen documentation. No destructive sampling was performed, and all procedures followed non-invasive vegetation survey protocols.

Species identification

Plant species were identified primarily through field-based morphological observation without specimen collection to minimize disturbance and to comply with the conservation-oriented management of the privately owned site. Identification was conducted using a combination of regional floras, published field guides, and online taxonomic databases. Scientific names, species distributions, and endemism were verified using Plants of the World Online (POWO 2025), while conservation status followed the DENR Administrative Order 2017-11 on the national list of threatened Philippine plants. Additional confirmation was supported by available Philippine floristic literature and comparative image references from herbarium-based online resources where applicable.

For species that could not be confidently identified in the field, individuals were documented using high-resolution photographs and detailed morphological notes focusing on diagnostic characters such as leaf arrangement, venation, bark texture, reproductive structures, and growth form. These records were subsequently reviewed against published descriptions and database entries to achieve the highest possible taxonomic resolution. Species-level identification was retained only when diagnostic characters were sufficient and unambiguous.

In cases where reliable species-level identification was not possible due to the absence of reproductive material or overlapping morphological traits, taxa were conservatively identified only to genus or family level. These taxa were included in vegetation structure analyses to reflect their structural contribution but were excluded from species-level ecological interpretation and conservation assessments. The absence of physical voucher specimens is recognized as a limitation, particularly for threatened and endemic taxa; however, the combination of field expertise, photographic documentation, and authoritative database verification provided reasonable confidence for most identifications reported in this study.

Vegetation analysis

All plants ≥ 1 m in height recorded within the quadrats were included in the vegetation structure analysis. Structural metrics were calculated following Mueller-Dombois and Ellenberg (1974) and BMB (2017). For each individual,

circumference was measured at breast height (1.3 m), from which diameter at breast height (DBH) and basal area were derived. The parameters and formulas used are presented below:

Diameter at breast height (DBH):

$$DBH = \frac{Circumference}{\pi} \text{ (cm)}$$

Basal Area (BA):

$$BA = \frac{C^2}{4\pi}$$

Where, C: circumference, π : constant pi.

Density (D):

$$D = \frac{n_i}{A} \text{ (ind. m}^{-2}\text{)}$$

Where, n_i : number of individuals of species i , A : quadrat area.

Frequency (F):

$$F = \frac{P_i}{P}$$

Where, P_i : number of plots in which species i occurs, P : total number of plots.

Dominance (DOM):

$$DOM = \sum BA_{species} \text{ (m}^2\text{)}$$

Relative Density (RD):

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

Where, n_i : number of individuals of species i , N : total number of individuals of all species.

Relative Dominance (RDOM):

$$RDOM = \frac{DOM_i}{DOM_{total}} \times 100$$

Relative Frequency (RF):

$$RF = \frac{F_i}{F_{total}} \times 100$$

Where, F_i : frequency of species i , F_{total} : total frequency of all species.

The Species Importance Value (SIV) was calculated as:

$$SIV = RD + RF + RDOM$$

For species-level structural metrics, DBH and crown diameter values were averaged across all recorded individuals of each species to derive representative sizes per taxon. This approach is consistent with vegetation structure assessments that use mean DBH and crown dimensions to compare structural attributes across layers or taxa (Chianucci et al. 2016; Li et al. 2019).

Species diversity was assessed using the Shannon-Wiener Index (H'):

$$H' = -\sum \left(\frac{n_i}{N} \ln \frac{n_i}{N} \right)$$

Where, n_i : number of individuals of species i and N : total number of individuals. Interpretation followed the classification of Fernando et al. (1998).

The index was calculated from the combined species list derived from both quadrat and transect surveys to represent total plant diversity across all vegetation strata within the farm. The two sampling methods were designed to capture different structural components of the vegetation, with quadrats used for quantitative assessment of woody plants and structural metrics, and the transect used to document herbaceous and ground-layer species that are often underrepresented in fixed-area plots (Mueller-Dombois and Ellenberg 1974; BMB 2017).

Pooling the datasets allowed the diversity index to reflect whole-site floristic richness rather than structure-based diversity within a single sampling method. However, because the quadrat and transect surveys represent different sampling units (area-based versus line-based), the resulting diversity value should be interpreted as a descriptive index of overall species heterogeneity rather than a strictly standardized structural diversity estimate.

Species evenness was calculated using Pielou's evenness index (J):

$$J = \frac{H'}{\ln(S)}$$

Where, H' is the Shannon-Wiener diversity index and S is the total number of species recorded. This metric was used to assess the distribution of individuals among species within the plant community. Interpretation followed Napaldet (2023).

RESULTS AND DISCUSSION

Floristic composition

A total of 165 vascular plant species belonging to 65 families were documented across the Binahon Agroforestry Farm (BAFF) (Table 1). The flora was dominated by angiosperms, while gymnosperms and pteridophytes were represented by four species (2.4%) and 7 species (4.2%), respectively. In terms of plant habit, trees accounted for 67 species (40.6%), followed by herbs (21.2%), shrubs (20.0%), vines (8.5%), ferns (4.2%), grasses/sedges (3.6%), and palms (1.8%). The most species-rich families were Fabaceae (13 species) and Moraceae (11 species), followed by Asteraceae, Euphorbiaceae, and Myrtaceae, which together constituted a substantial proportion of the site's floristic diversity (Figure 3).

The coexistence of cultivated and naturally occurring species reflects BAFF's long history of mixed land use management. High-value crops such as *Citrus maxima*, *Theobroma cacao*, *Coffea* spp., *Durio zibethinus*, and *Syzygium cumini* were present alongside native forest trees belonging to Dipterocarpaceae, Fabaceae, and Lauraceae.

Native wild taxa such as *Ficus* spp., *Angiopteris evecta*, *Cyathea* sp., various palms, orchids, and vines occurred in shaded microhabitats and semi-forested margins, whereas introduced ornamentals and short-cycle vegetables dominated open areas and cultivated plots.

Native, introduced and threatened species

Of the 165 species recorded, 66 (40.0%) were native, including 9 Philippine endemics, while 61 species (37.0%) were introduced, comprising both cultivated and naturalized taxa. The remaining 38 species (23.0%) could not be assigned an origin due to identification limitations at the genus or family level. The degree of naturalization among introduced species could not be fully determined due to limited historical evidence of establishment.

Trees contained the highest number of native species (30), including seven endemics, while herbs had the most introduced species (22) and only six native species, indicating active regeneration and a strong presence of ruderal components in the lower strata. Many introduced species serve functional and economic roles, including food crops (*Sicyos edulis*, *Mangifera indica*, *Annona muricata*, *Selenicereus undatus*), ornamentals (*Euphorbia pulcherrima*, *Calliandra calothyrsus*, *Hibiscus rosa-sinensis*), and income-generating agroforestry species (*Falcataria falcata*, *C. maxima*, *Coffea* sp.).

A total of nine species (5.5%) were listed as threatened under DAO 2017-11, with seven classified as Vulnerable and two as Other Threatened Species. The presence of *Ficus ulmifolia*, *Macaranga grandifolia*, and other native taxa in shaded portions of the farm highlights the capacity of BAFF to retain conservation-relevant flora despite ongoing management. As pioneer and fruit-bearing species, these taxa may contribute to forest regeneration and wildlife foraging activity (Rohman et al. 2019; Yuni et al. 2022).

Species diversity index

The Shannon-Wiener index ($H' = 4.08$) was calculated from the combined species list derived from both quadrat and transect surveys and included all recorded plant individuals regardless of height or stem size. This approach allowed the assessment of total vegetation richness across strata. The corresponding evenness value (J) was 0.80, indicating an almost balanced plant community. Following the interpretation of Fernando et al. (1998), the computed diversity value indicates high species diversity within the agroforestry system. Published H' values from secondary forest systems at comparable elevations in Mindanao fall within a similar range (Amoroso et al. 2012; Coritico et al. 2020). Although direct comparisons are limited by differences in sampling design, spatial extent, and habitat type, these patterns suggest that agroforests such as BAFF can contribute meaningfully to landscape-level biodiversity in montane agricultural mosaics.

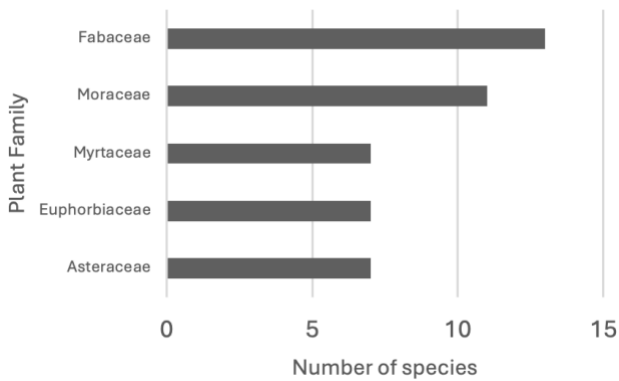


Figure 3. Most represented plant families recorded in the Binahon Agroforestry Farm (BAFF), based on total species richness (N = 165 species) obtained from both quadrat and transect sampling

Table 1. Summary of vascular plant species recorded in the Binahon Agroforestry Farm (BAFF), categorized by plant habit, with corresponding family counts and percentage contribution of each habit to total species richness

Plant habit	Family	Species	Total species (%)
Trees	26	67	40.6
Shrubs	19	33	20
Herbs	19	35	21.2
Vines	9	14	8.5
Palms	1	3	1.8
Grasses and sedges	1	6	3.6
Ferns	7	7	4.2
Total		165	100

The observed diversity reflects the coexistence of native, cultivated, and weedy components, with the understorey dominated by pioneer and ruderal species such as *Ageratum conyzoides*, *Amaranthus spinosus*, *Bidens pilosa*, *Crassocephalum crepidioides*, and *Eleusine indica*. These taxa are commonly associated with disturbance and low-input farming systems, suggesting ongoing regeneration and minimal agrochemical use across the site. Under low-management pressure, such species may contribute to soil cover, nutrient cycling, and microhabitat formation, further facilitating seedling establishment. Diversity comparisons among vegetation layers were descriptive only, as sampling was restricted to a single site without replicated strata, limiting statistical inference. Nevertheless, the vegetation profile indicates a vertically structured agroforestry system capable of supporting varied ecological functions across multiple strata.

Vegetation structure

Vegetation structure analysis was based solely on quadrat data and included only individuals ≥ 1 m in height. From the total species inventory, 34 taxa met these structural criteria and were included in the analysis presented in Table 2. These were dominated by trees (94%), along with a single palm (*Adonidia merrillii*) and one tree fern (*Cyathea* sp.), while most herbs, vines, and smaller shrubs

recorded in the transect or as juvenile individuals were excluded from structural calculations. Some taxa were only identified up to genus or family level, such as *Eucalyptus* sp., *Cyathea* sp., and Dipterocarpaceae sp., and were therefore retained in structural calculations but excluded from ecological interpretation due to unresolved taxonomic identity. Per species structural metrics were calculated using averaged DBH and crown diameter values, while basal area was summed across individuals to quantify prominence within the vegetation layer (Chianucci et al. 2016; Li et al. 2019).

The five species with the largest diameter at breast height (DBH) were *Pinus kesiya* (range 0.07-1.43 m; mean = 0.28 m), *Acacia mangium* (range 0.24-0.45 m; mean = 0.37 m), *Eucalyptus* sp. (range 0.06-0.38 m; mean = 0.21 m), *Rubroshorea negrosensis* (range 0.04-0.30 m; mean = 0.11 m), and *Vitex parviflora* (range 0.07-0.26 m; mean = 0.14 m). In terms of crown spread, *P. kesiya* exhibited the widest canopy extent (2-25 m; mean = 4.65), followed by *Eucalyptus* sp. (2-5.5 m; mean = 4 m), *V. parviflora* (2-7 m; mean = 3.71 m), *A. mangium* (3-7.5 m; mean = 4.28 m), and *R. negrosensis* (1.25-3 m; mean = 2.0 m).

Quantitative analysis identified *P. kesiya* as the most structurally prominent species, with the highest relative density (17.42%), relative frequency (9.09%), relative dominance (57.40%), and Species Importance Value (SIV = 83.9). *A. mangium*, *Eucalyptus* sp., *R. negrosensis*, and *V. parviflora* followed with importance values of 29.6, 25.2, 22.2, and 20.0, respectively (Table 2). Taxa identified only up to genus or family level were retained for structural metrics, but were not given functional interpretation due to insufficient taxonomic resolution.

Discussion

Composition and diversity in a managed agroforest

The high floristic richness recorded in the Binahon Agroforestry Farm (BAFF) demonstrates that managed agroforests can sustain complex and diverse plant communities consistent with those observed in secondary forests. With 165 species representing 65 families, a high Shannon-Wiener diversity index ($H' = 4.08$), and an almost balanced Pielou's evenness index ($J = 0.80$), BAFF exhibits a diverse plant community comparable to patterns reported in other tropical agroforests (Salazar-Díaz and Tixier 2019; Prastiyo et al. 2020; Legesse and Negash 2021; Esquivel et al. 2023; Barrientos et al. 2025). This high diversity reflects long-term management and structural complexity, where multiple vegetation layers, from tall canopy trees to herbaceous ground cover, create heterogeneous microhabitats and light conditions conducive to species coexistence (Beyene et al. 2018; Tzuk et al. 2020; Esquivel et al. 2023).

The coexistence of native and cultivated species in BAFF illustrates dynamic ecological processes such as colonization, regeneration, and disturbance adaptation. Reduced agrochemical use, organic soil enrichment, and selective maintenance of shade trees may have allowed natural recruitment of wild and weedy species. This management-driven heterogeneity enhances resource availability and microhabitat diversity, both of which sustain species richness in managed systems (Nair et al. 2022; Mathieu et

al. 2025). The combination of fruit-bearing trees, timber species, and ground crops may resemble certain structural patterns observed in successional gradients in secondary forests, where varied age and size classes promote structural and compositional diversity (Legesse and Negash 2021; Esquivel et al. 2023).

The role of BAFF in conserving threatened and endemic flora

Although only 5.5% of the recorded flora were endemic to the Philippines, their persistence within a privately owned and actively managed property demonstrates that well-managed private lands can contribute meaningfully to biodiversity conservation. The presence of species such as *Artocarpus blancoi*, *F. ulmifolia*, and *R. negrosensis* indicates that low-intensity agroforestry practices can support native and even threatened trees. Many of these species, originally planted for demonstration and reforestation, have matured

into canopy components that now function as seed sources and microhabitat providers.

Introduced species accounted for a substantial portion of the recorded flora, and several of these taxa, including *P. kesiya*, *A. mangium*, and *Eucalyptus* sp., also dominated the structural layer. This pattern indicates that planted exotics strongly influence canopy structure and microenvironmental conditions within BAFF. These dominant introduced trees may have both facilitative and inhibitory effects on native regeneration, depending on canopy density, disturbance regime, and litter accumulation. In *P. kesiya* systems, plantations have been shown to facilitate secondary forest recovery by providing canopy cover that supports the establishment of broadleaf woody species over time, leading to more structurally complex stands (Oberhauser 1997). However, pine-dominated systems can also exhibit reduced understorey diversity under frequent disturbance or fire, suggesting that regeneration outcomes are strongly management-dependent (Ho et al. 2020).

Table 2. Relative Density (RD), Relative Frequency (RF), Relative Dominance (RDOM), and Species Importance Value (SIV) of plant species ≥ 1 m in height recorded across 34 sampling plots in the Binahon Agroforestry Farm (BAFF), Bukidnon, Philippines

Species	n (Individuals)	RD %	RF %	RDOM %	SIV %
<i>Acacia mangium</i> Willd.	9	6.82	7.27	15.50	29.6
<i>Adonia merrillii</i> (Becc.) Becc.	6	4.55	1.82	0.37	6.7
<i>Araucaria heterophylla</i> (Salisb.) Franco	4	3.03	1.82	0.28	5.1
<i>Artocarpus heterophyllus</i> Lam.	2	1.52	3.64	0.78	5.9
<i>Artocarpus odoratissimus</i> Blanco	4	3.03	3.64	1.37	8.0
<i>Calliandra calothyrsus</i> Meisn.	3	2.27	3.64	0.19	6.1
<i>Cassia fistula</i> L.	2	1.52	1.82	0.02	3.3
<i>Cedrus</i> sp.	2	1.52	1.82	0.08	3.4
<i>Cinnamomum mercadoi</i> S.Vidal	2	1.52	1.82	0.13	3.5
<i>Cyathea</i> sp.	1	0.76	1.82	0.03	2.6
<i>Delonix regia</i> (Bojer ex Hook.) Raf.	1	0.76	1.82	0.06	2.6
Dipterocarpaceae sp. 1	1	0.76	1.82	0.03	2.6
<i>Eucalyptus</i> sp.	12	9.09	7.27	8.82	25.2
<i>Falcataria falcata</i> (L.) Greuter & R.Rankin	2	1.52	3.64	0.51	5.7
<i>Ficus benjamina</i> L.	2	1.52	1.82	0.13	3.5
<i>Ficus nota</i> (Blanco) Merr.	2	1.52	3.64	0.67	5.8
<i>Garcinia mangostana</i> L.	1	0.76	1.82	0.01	2.6
<i>Homalanthus populneus</i> (Geiseler) Pax	1	0.76	1.82	0.04	2.6
<i>Hopea</i> sp.	1	0.76	1.82	0.01	2.6
<i>Lansium domesticum</i> Corrêa	1	0.76	1.82	0.03	2.6
<i>Leucaena pulverulenta</i> (Schltdl.) Benth.	1	0.76	1.82	2.44	5.0
<i>Melia azedarach</i> L.	1	0.76	1.82	0.31	2.9
<i>Nephelium lappaceum</i> L.	2	1.52	1.82	0.04	3.4
<i>Pinus kesiya</i> Royle ex Gordon	23	17.42	9.09	57.40	83.9
<i>Pterocarpus indicus</i> Willd.	3	2.27	3.64	0.09	6.0
<i>Rubroshorea almon</i> (Foxw.) P.S.Ashton & J.Heck.	1	0.76	1.82	0.05	2.6
<i>Pentacme contorta</i> (S.Vidal) Merr. & Rolfe	3	2.27	3.64	0.68	6.6
<i>Rubroshorea negrosensis</i> (Foxw.) P.S. Ashton & J.Heck.	18	13.64	3.64	4.90	22.2
<i>Solanum nigrum</i> L.	1	0.76	1.82	0.01	2.6
<i>Spathodea campanulata</i> Beauverd	2	1.52	1.82	0.02	3.4
<i>Swietenia macrophylla</i> King	3	2.27	1.82	1.10	5.2
<i>Syzygium cumini</i> (L.) Skeels	2	1.52	1.82	0.29	3.6
<i>Syzygium myrtifolium</i> Walp.	1	0.76	1.82	0.01	2.6
<i>Vitex parviflora</i> A.Juss.	12	9.09	7.27	3.60	20.0

Note: RD: Relative Density, RF: Relative Frequency, RDOM: Relative Dominance, SIV: Species Importance Value

For *A. mangium*, rapid growth and nitrogen fixation can improve nutrient availability and microclimatic conditions, potentially supporting plant recruitment beneath its canopy where propagule supply is adequate. The species can also influence nutrient cycling through litter inputs, including elevated nitrogen fluxes, and may modify soil chemical properties, with studies reporting measurable changes in soil chemistry associated with *A. mangium* litter in tropical systems (Inagaki and Ishizuka 2011; Ibrahim et al. 2025). However, *A. mangium* is also widely recognized for its potential invasiveness in tropical ecosystems (Osunkoya et al. 2005; Global Invasive Species Database 2026), where it may spread beyond planted areas and compete with native vegetation. This ecological risk requires careful management in biodiversity-oriented landscapes.

These findings suggest that in BAFF, dominant introduced canopies may provide functional ecosystem services, such as shade and soil protection, while also creating competitive filters through canopy closure and litter effects that could disadvantage some native recruits. More broadly, introduced species in agroforestry systems can alter ecological interactions, nutrient cycles, and regeneration dynamics when left unmanaged, underscoring the importance of monitoring their spread and ecological influence (Beyene et al. 2018; Dyderski and Jagodziński 2020; Rai and Singh 2020; Gonçalves et al. 2021; Esquivel et al. 2023). Consequently, monitoring should focus not only on the presence of introduced species, but also on regeneration indicators, particularly the density and identity of native seedlings and saplings beneath *Pinus* and *Acacia* canopies across management zones, to evaluate whether introduced dominance facilitates or inhibits the long-term persistence of native and conservation-relevant flora.

By integrating native and introduced species, BAFF demonstrates how species selection in agroforestry can align with biodiversity conservation goals, provided that canopy dominance and regeneration patterns are carefully managed. Native trees enhance soil stability, nutrient cycling, and habitat connectivity, while economically valuable crops sustain local livelihoods (Sistla et al. 2016; Tzuk et al. 2020; Santos et al. 2022). This dual-purpose system supports calls for biodiversity-friendly farming in production landscapes, particularly in Mindanao where agricultural expansion continues to erode lowland forests. The persistence of endemic and threatened taxa within BAFF highlights the role of agroforests as complementary refuges that strengthen conservation efforts beyond protected area boundaries.

Vegetation structure and ecological implications

The dominance of cultivated trees such as *P. kesiya*, *A. mangium*, and *Eucalyptus* sp. strongly influences BAFF's vegetation profile, reflecting the role of management in shaping canopy structure. Although *Eucalyptus* was identified only to genus level, its structural prominence suggests potential influence on canopy cover and resource distribution; however, ecological interpretations remain tentative until species-level identification is confirmed. Many of these species were intentionally planted within the past 30 years (Espaldon 2008) and now contribute to soil

stabilization, microclimate regulation, and shade provision. However, taxa only identified up to the genus or family level (e.g., *Cedrus* sp., Dipterocarpaceae sp. 1) were retained solely for structural analysis and excluded from functional interpretation due to insufficient taxonomic resolution.

Although cultivated canopy species provide ecological functions, their dominance may also limit the regeneration of shade-intolerant native taxa through canopy closure and litter accumulation (Elliot et al. 2022). Despite these potential trade-offs, the persistence of native herbs, vines, ferns, and pioneer tree species may indicate resilience and active regeneration processes within the farm. This outcome aligns with expectations that management-driven canopy structuring could coexist with spontaneous recruitment under low agrochemical input.

The multi-layered vegetation profile observed in BAFF resembles the vertical stratification commonly reported in secondary forest systems (Li et al. 2019; Wu et al. 2023; Matsuo et al. 2024). This suggests that even under anthropogenic management, agroforests may sustain a combination of productive and ecologically functional components. The co-occurrence of cultivated and naturally occurring species highlights agroforestry's potential to deliver ecosystem services such as pollination, seed dispersal, soil protection, and microclimate buffering, while maintaining agricultural productivity within a managed tropical landscape.

Comparison and implications of BAFF in the regional context

The vegetation profile observed in BAFF highlights the potential role of agroforestry systems as complementary habitats within agricultural landscapes surrounding protected areas. The presence of endemic and threatened species, together with a structurally diverse, multi-layered canopy, indicates that well-managed agroforests can retain conservation-relevant flora even outside formally protected boundaries. Regional studies in the Mt. Kitanglad range have similarly emphasized the importance of structurally complex vegetation in supporting plant diversity across elevational gradients (Amoroso et al. 2012; Coritico et al. 2020), although direct comparisons are limited by differences in spatial scale and sampling design.

Unlike monoculture plantations that dominate much of the region's lowlands, BAFF maintains a heterogeneous vegetation structure composed of native, endemic, and cultivated species. Such structural complexity can reduce edge effects, improve habitat continuity, and provide resources for a range of organisms, potentially enhancing connectivity between forest remnants and agricultural matrices. These characteristics are consistent with the ecological functions often attributed to agroforestry systems acting as buffer zones and movement corridors in human-modified tropical landscapes.

The ecological attributes observed in BAFF reinforce the potential of agroforestry as a strategy for sustainable land management and biodiversity conservation in Mindanao. When implemented across broader landscapes, structurally complex agroforests may help mitigate habitat fragmentation and support ecological processes beyond protected areas.

These findings align with national biodiversity and climate adaptation frameworks that promote ecosystem-based approaches within production systems (DENR-BMB 2024). Encouraging the use of native species and maintaining continuous canopy cover in agroforestry design can therefore improve both productivity and ecological resilience in degraded landscapes.

Methodological limitations and future research

This study establishes a quantitative baseline for understanding plant community composition within a long-established agroforestry system. However, its focus on a single site and a short sampling period limits broader generalization. The absence of temporal data restricts insights into successional dynamics and long-term species turnover, highlighting the need for longitudinal studies that capture seasonal and management-related variations in vegetation structure and composition.

Future research should integrate long-term ecological monitoring with faunal assessments, particularly of pollinators and seed dispersers, to clarify the biotic interactions that sustain biodiversity in managed agroforests. Comparative studies across farms with varying management intensity and crop composition are also recommended to assess trade-offs between agricultural productivity and ecological integrity. In addition, evaluating the ecological roles of introduced and naturalized species will help clarify their influence on regeneration processes, competitive interactions, and the long-term conservation value of agroforestry systems.

Voucher specimens were not deposited due to the privately managed nature of the site. While many taxa were documented through field observations and photographic records and verified using taxonomic literature and online databases, the absence of herbarium vouchers limits independent verification, particularly for endemic, threatened, or genus-level identifications. Future studies in privately managed or conservation-sensitive sites should consider non-destructive vouchering approaches, such as systematic photographic documentation of diagnostic features and the use of georeferenced image repositories, to improve taxonomic transparency while minimizing ecological disturbance.

In addition, the Shannon-Wiener diversity index and Pielou's evenness index were calculated from pooled quadrat and transect data representing different sampling units. While this approach improved detection of species across vegetation strata, it differs from strictly standardized sampling designs, and the resulting diversity value should be interpreted as a descriptive indicator of site-level floristic heterogeneity rather than a directly comparable structural diversity metric.

In conclusion, the Binahon Agroforestry Farm (BAFF) on the lower slopes of Mt. Kitanglad demonstrates that a long-established, privately managed multi-strata agroforest can retain high plant diversity and conservation-relevant flora within a production landscape increasingly dominated by monocultures. Using 34 quadrats (20 m × 20 m; 13,600 m²) complemented by an 800 m transect, the study recorded 165 vascular plant species from 65 families, with

trees as the dominant growth form, and diversity metrics indicating a highly diverse and nearly balanced community ($H' = 4.08$; $J = 0.80$). Importantly, the site harbored both endemic and threatened taxa (each 5.5% of the flora), underscoring its value as complementary habitat outside protected area boundaries. Vegetation structure was strongly shaped by planted canopy species, with *Pinus kesiya* showing the highest structural prominence (SIV = 83.9) and other key taxa including *Acacia mangium*, *Eucalyptus* sp., *Rubroshorea negrosensis*, and *Vitex parviflora*, reflecting the decisive role of management in shaping canopy dominance and microhabitat conditions. Overall, the coexistence of native, endemic, cultivated, and ruderal species indicates that well-managed agroforests can function as biodiversity-supporting mosaics that contribute to landscape connectivity and ecological functions adjacent to Mt. Kitanglad Natural Park. Future work should strengthen taxonomic verification where identifications remained unresolved and expand monitoring across multiple farms and seasons to evaluate long-term regeneration dynamics and the net conservation outcomes of introduced canopy dominance.

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