Journal of Agroforestry and Environment

Volume 18, Issue 2, 2025

Journal DOI: https://doi.org/10.55706/jae
Journal homepage: www.jagroforenviron.com

Floral Diversity in a Coffee-based Agroforestry System in Abra, Philippines

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Received: 07/06/2025
Accepted: 17/08/2025
Available online: 25/08/2025

Abstract: Agroforestry systems play a vital role in conserving biodiversity while sustaining livelihoods in upland agricultural landscapes, yet their contribution to floral diversity remains underexplored in many parts of the Philippines. This study, conducted in Licuan-Baay, Abra, examined a coffee-based agroforestry system, focusing on plant species composition, importance values, richness, diversity, and evenness. Plant species were categorized by diameter and assessed for conservation status. Stratified sampling utilized 20m x 20m plots with nested 10m x 10m subplots. Larger plots analyzed trees with diameters ≥10cm, while saplings (1-9 cm DBH) were studied in smaller subplots. A total of 93 trees representing 21 native species were recorded, with small trees (10-30 cm DBH) being the most prevalent. Among trees, *Shorea contorta* showed the highest relative density, dominance, and importance value, while *Coffea canephora* led in these metrics among saplings. The Shannon Diversity Index reflected moderate diversity (2.35) for tree plots and low diversity (2.04) for sapling plots, alongside high evenness values of 1.58 for trees and 1.84 for saplings. The presence of several threatened species, including critically endangered *Agathis philippinensis*, endangered *Anisoptera thurifera*, vulnerable species like *Shorea negrosensis* and *Nephelium lappaceum*, and the near-threatened *Canarium luzonicum*, emphasizes the urgency of conservation in the area. Findings highlight that coffee cultivation supports biodiversity and coexists with native species, underscoring the importance of preserving the site and its threatened flora.

Keywords: Agroforestry; Biodiversity; Conservation; Livelihood; Natural Resources Management

INTRODUCTION

In tropical areas, coffee-based agroforestry systems are a crucial part of sustainable farming methods. These systems create multilayered landscapes that mimic natural forests by integrating coffee cultivation with trees and other flora. This arrangement greatly aids in biodiversity protection in addition to offering a steady environment for coffee growing. These systems provide vital ecological services, including carbon sequestration, soil preservation, and enhanced water retention; thus, their advantages go beyond their direct agricultural value (Rice, 2011; Tscharntke *et al.* 2011).

Agroforestry systems, particularly those integrating coffee cultivation, have emerged as pivotal strategies for sustainable land management in tropical regions. These systems emulate natural forest structures by combining coffee plants with diverse tree species and understory vegetation, fostering multilayered landscapes that fosters sustainability and income generations for communities (Salinas *et al.* 2016; Notaro *et al.* 2022). Such configurations not only stabilize microclimates and enhance soil fertility but also contribute significantly to environmental sustainability and enhance land productivity (Bagny Beilhe *et al.* 2020; Le *et al.* 2021).

Forests significantly face significant threats due to agricultural land conversion (FAO, 2020). This land-use change results in the decline of biodiversity and diminishes capability of forests in providing various benefits (Yguel *et al.* 2019; Rodrigues de Mello *et al.* 2020). In addition, it also affects the below-ground organisms, which have some essential implications for hydrological regulation (Bruijnzeel, 2004). This conversion can cause irreversible changes in soil functions and structures.

In the year 2020, the remaining forest cover in the Philippines was 7.23 x 10^4 hm^2. It is considered equivalent to 24.09% of the total land area in the Philippines (FMB, 2021). The decline in forest areas is caused by many anthropogenic threats (Posa & Sodhi, 2006; Mallari *et al.* 2016). That is why conservation of biodiversity has become a growing concern of central significance to all sectors of society.

Moreover, with the increasing demand for food, forests are converted to other land uses, most of which are for agricultural production. The establishment of fast-wood plantations poses a threat to biodiversity, or worse, leading to the loss of biodiversity. FAO reported that within the tropics, natural forests are continuously converted for other land uses, which is becoming alarming. The forestry plantations being converted account for 6% to 7% losses. The remaining 93% to 94% is lost to agriculture and industrial development (Cossalter & Pye-Smith, 2003).

A coffee-integrated agroforestry system is recognized as an environmental land approach that integrates woody plants with coffee production, addressing current and future environmental challenges that provide income to the community. This land-use system aims to enhance ecological health while promoting agricultural productivity.

In addition, the decline of biodiversity and land conversion results in promoting agroforestry as a solution. It involves trees and other woody vegetation into farms offering various advantages such as increased production diversity and improved social, economic, and environmental outcomes (Scroth *et al.* 2013). The Intergovernmental Panel on Climate Change (IPCC) recognized the potential of agroforestry to provide various benefits such as economic, ecological and social benefits for the communities (McCarthy *et al.* 2001). Agroforestry is continuously recognized for its importance in promoting sustainable land management and in achieving sustainable intensification. It serves as a response to various land and water issues linked to traditional agricultural practices (Kumar *et al.* 2023).

Similar studies have underscored the importance of floristic inventories in identifying priority species and assessing biodiversity levels in institutional or managed landscapes. For instance, Lozano *et al*. (2024) assessed fruit-bearing tree diversity in the DMMMSU Forest Reserve and reported *Coffea* spp. as having the highest importance value, reinforcing its ecological and economic role in mixed-species agroforests. Their findings also showed that fruit trees, including exotic species like coffee, can contribute significantly to biodiversity metrics when grown under shade. This supports the idea that well-managed agroforestry systems can sustain species richness and ecosystem services while supporting livelihoods. While Lozano *et al*. (2024) focused on a university-managed forest reserve, the current study examines a farmer-led agroforestry site, thereby expanding insights into community-based conservation and agroecological practices.

Hence, conducting a comprehensive inventory for plant species serves as the foundation for conserving, safeguarding, managing biological resources and mitigating biodiversity loss (Lumbres *et al*. 2012). With these issues, this study aims to analyze the floral diversity of a coffee-based agroforestry system. Specifically, its objectives are to: a) identify the different floral species according to their taxa, species, genus, and family; b) evaluate the endemicity of the species present in the site; c) classify the species found as to diameter sizes; d) assess the ecological importance of each species by analyzing the relative density, relative frequency and relative dominance; e) assess the abundance of species in terms of species diversity, species richness, and species evenness; and f) determine the conservation status of the documented species within the study site.

MATERIALS AND METHODS

Location of the Study Area

The study was carried out in a coffee-based agroforestry system established in 2013 in Licuan-Baay, Abra (17°32'34.61"N, 120°56'55.46"E), situated at an elevation of 370.6 meters above sea level. Covering an area of 65 hectares, the site is characterized by gently undulating terrain and soil with a loamy texture (refer to Fig. 1)

DOI: https://doi.org/10.55706/jae1819

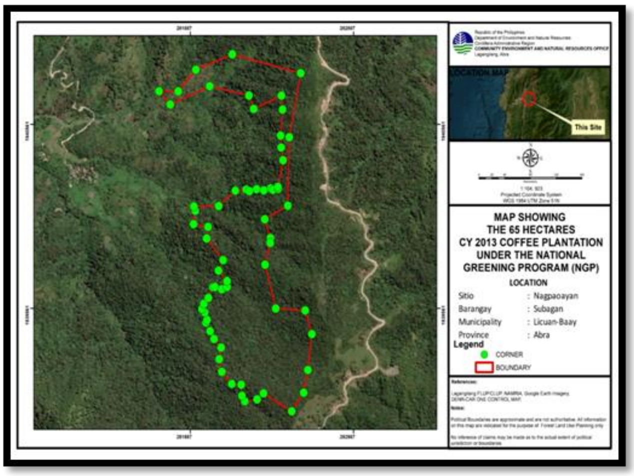

Figure 1. Geographic map illustrating the study area's location.

Design of Sampling Methodology

Stratified sampling was employed to set up 20 m x 20 m quadrats along transects positioned 50 m apart. Within these quadrats, 10 m x 10 m subplots were nested for evaluating saplings.

Data Collection

Trees with a diameter at breast height (DBH) of at least 10 cm were documented within the quadrats, while subplots were used to record saplings with a DBH ranging from 1 to 9 cm. Species identification utilized Co's Digital Flora of the Philippines (CDFP) at https://www.philippineplants.org/, and unidentified samples were collected for later verification. Conservation status was assessed following DAO 2017-11 and IUCN guidelines. Parameters such as relative density, dominance, species richness, and the Shannon diversity index were computed, with trees categorized by diameter size. Geographic coordinates were obtained to map the spatial distribution of species.

Establishment of Sample Plots

Secondary information on the location of the coffee-based agroforestry system, including existing maps, was obtained from the Department of Environment and Natural Resources – Community Environment and Natural Resources Office Lagangilang (DENR-CENRO), Abra. These were used to generate a map as the basis for coming up with the field sampling design and plan. A representative sample site was selected from each distinct location.

Sample plots were arranged following the quadrat method described in DENR Technical Bulletin No. 16 (Department of Environment and Natural Resources-Forest Management Bureau [DENR-FMB], n.d.). Baseline transects were aligned with firebreaks, with lines spaced 50 meters apart. Within these transects, 20 m x 20 m quadrats were placed, and nested within these quadrats were 10 m x 10 m subplots (refer to Fig. 2).

The larger plots were used to inventory all trees with a DBH ≥10 cm, while the subplots assessed saplings (1–9 cm DBH) and non-tree vegetation. Geographic coordinates for each plot and sampled trees were recorded using GPS for spatial analysis.

Within the 20 m x 20 m quadrats, all trees with a DBH of 10 cm or more were measured and identified. Conversely, the 10 m x 10 m quadrats were designated for assessing smaller trees (saplings) with a DBH below 10 cm and other vegetation such as shrubs, vines, and herbs, which were documented and counted

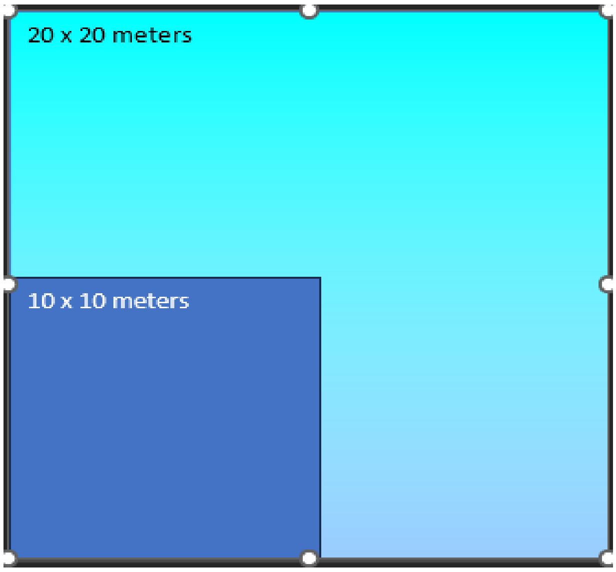

Figure 2. Diagram of the nested quadrat arrangement used in the study, set at 25-meter intervals.

Measurement of Macrofloral Attributes/Characteristics

In each plot, the following parameters were determined or measured:

Plot and tree coordinates: The geographic center of each plot and all sampled trees were mapped using a hand-held GPS receiver or, alternatively, a mobile device with geo-tagging capabilities.

Species identification and individual count: Macroflora within the plots were cataloged to the species level, with individual counts systematically recorded. Species identification was verified using the Co's Digital Flora of the Philippines (CDFP) database, accessible at https://www.philippineplants.org.

Diameter measurement: A diameter tape or tree caliper was used to determine the trees' DBH, taken 1.3 m above the ground. These were recorded on a prepared data sheet.

Data Analysis

The parameters used to evaluate floral diversity in the study area comprised relative density, relative frequency, relative dominance, species importance value, diversity index (H'), and species richness. The computation of these parameters was guided by methodologies detailed in the works of Curtis and McIntosh (1951) and Terbio *et al*. (2022)

Density

The total number of individuals for each species was recorded, and the density was computed using the formula:

$$Density = \frac{Number\ of\ individuals}{are\ sampled}$$

$$Relative\ density = \frac{Density\ of\ species}{Total\ density\ of\ species} * 100$$

Frequency (F)

The frequency of species occurrence in the plots was noted, and frequency values were determined using the formula:

$$Frequency = \frac{Number\ of\ plots\ in\ which\ species\ occur}{number\ of\ plots\ sampled}$$

$$Relative\ frequency = \frac{Frequency\ of\ species}{Total\ frequency\ of\ species} * 100$$

Dominance (cover)

Species dominance was computed using the formula:

$$Dominance = \frac{Basal\ area\ of\ species}{sampled}$$

Where: $Basal\ area\ = \frac{\pi}{4} d^2$

d= diameter at breast height

$$Relative\ dominance = \frac{Dominance\ of\ species}{Total\ dominance\ for\ all\ species} * 100$$

Importance Value (IV)

The species importance value (IV) serves as a measure of a plant species' relative significance or role within a community. This value was calculated using the formula:

Importance Value = RD + RF + Rdom

Where
RD = Relative Density
RF = Relative Frequency
Rdom = Relative Dominance

Overall Diversity Index (H')

We used the Shannon Index (H') to quantify overall plant diversity within the study area, integrating both species abundance and evenness. Higher values of H' signify a community with greater diversity and more uniform distribution, while lower values indicate less diversity. As noted by Gotelli and Chao (2013), a community composed of only one species would result in an H' value of 0. Typically, the index ranges from 1.5 to 3.5, with values exceeding 4.5 being uncommon. The formula used for calculating this index was adapted from the work of Nolan and Callahan (2006):

$$H' = \sum(pi)(lnpi)$$

Where:
H' = Diversity of the species
ln = natural logarithm
pi= the proportion of individuals of a species in relation to the total number of species present.

Table 1. Classification of Shannon Diversity Index values as per Fernando *et al*. (1998).

Shannon Diversity Index (H')	Classification
0–1.0	Very Low
1.1–2.0	Low
2.1–3.0	Moderate
3.1–3.5	High
3.6–4.0	Very High
4.1–4.5	Exceptionally High

Species Richness

The count of species present is used to calculate species richness, a measure of biodiversity. This approach assigns equal importance to species with both small and large population sizes. The species richness was determined using the following formula:

$$Species\ richness = \frac{(S-1)}{Log\ N}$$

Where:
S = Total species count
N = Total individuals across all species

Species Evenness

Pielou's evenness index (J') was utilized to evaluate the distribution uniformity of species in the community. The values of J' are categorized into three levels: low species evenness (J'≤03), moderate species evenness (0.3<J'≤0.6), and high species evenness (J'>0.6) (Magurran, 2004; Edwin *et al*., 2021). The index calculation followed the formula

DOI: https://doi.org/10.55706/jae1819

specified by Baleta & Casalamitao (2016) and Baliton et al. (2020):

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

Where:
H' =Shannon Diversity Index
lnS = Natural logarithm of species richness

Table 2. Range of Pielou's evenness index (J') values and their categories (Magurran, 2004; Edwin *et al.,* 2021).

Pielou's Species Evenness Index (J')	Category
0.81-1.00	Very High
0.61-0.80	High
0.41-0.60	Moderate
0.21-0.40	Low Evenness
0-0.20	Very Low

The Conservation Status of each Species

The conservation status for each species identified in the study site was assessed using the 2025 IUCN Red List of Threatened Species and the DENR Administrative Order (DAO) 11-2017. Species were categorized and documented based on their respective conservation classifications.

GIS Mapping of the Trees in the Agroforest

The geographic coordinates of each tree were recorded to create a GIS map showing their spatial distribution within the study site. Tagging of individual trees was performed using a GPS-enabled mobile application. Figure 3 presents the spatial distribution of tree species and saplings documented in the study area.

Findings and Analysis

In the 20 m x 20 m plots, a total of 93 individual trees with DBH greater than 10 cm were recorded. These represented 13 families, 16 genera, and 21 species, all of which were identified as native species (Table 3). According to Paredes (2022), dipterocarp species are commonly found and abundant in both the interior and exterior areas of mining sites in Licuan-Baay, Abra. This aligns with findings that dipterocarp species thrive in this municipality, consistent with literature on their distribution in the Philippines (Lagerberger, 2006). Most of the dipterocarp species are naturally grown and able to penetrate areas with soil fertility and thrive at higher elevations. They regenerate naturally and become populated because communities protect their environment and minimize illegal activities. In terms of plant families, the Dipterocarpaceae is considered the most common family of trees, especially in the tropics (Encylopedia Britannica, 2025). They are diverse and contribute to biodiversity because of their diverse ecosystem and ability to grow all year. Whether the sites have warm temperatures or there is a large amount of rainfall (Krishnapillay, 2004).

The natural regeneration of Dipterocarp species within the study area is primarily due to conservation initiatives led by the local community. These efforts include minimizing illegal activities and adopting agroforestry practices combined with traditional methods of preservation. Similar results were observed in Ethiopia's Yayo Coffee Forest Biosphere Reserve, where community-driven agroforestry practices effectively conserved native tree species (Tadesse *et al.*, 2014). Likewise, Gomez et al. (2008) noted that shade-grown coffee plantations in Veracruz, Mexico, enhance tree biodiversity, underlining the critical role of agroforestry in conserving native species.

A total of 52 saplings (DBH <10 cm) were identified within the 10 m x 10 m subplots (Table 4). These saplings represented 12 families, 13 genera, and 13 species. Among them, only Robusta coffee (*Coffea canephora*) and kakawate (*Gliricidia sepium*) were recognized as naturalized species, with the others classified as native species according to Pelser *et al*. (2011).

Robusta coffee thrives in the study area due to its adaptability to temperatures between 22°C and 30°C (Kath *et al*., 2020). Kakawate is particularly beneficial in agroforestry systems, providing a rich mineral composition for soil enrichment and chemical compounds that deter soil-borne pathogens and insects (Villegas-Pangga, 2010).

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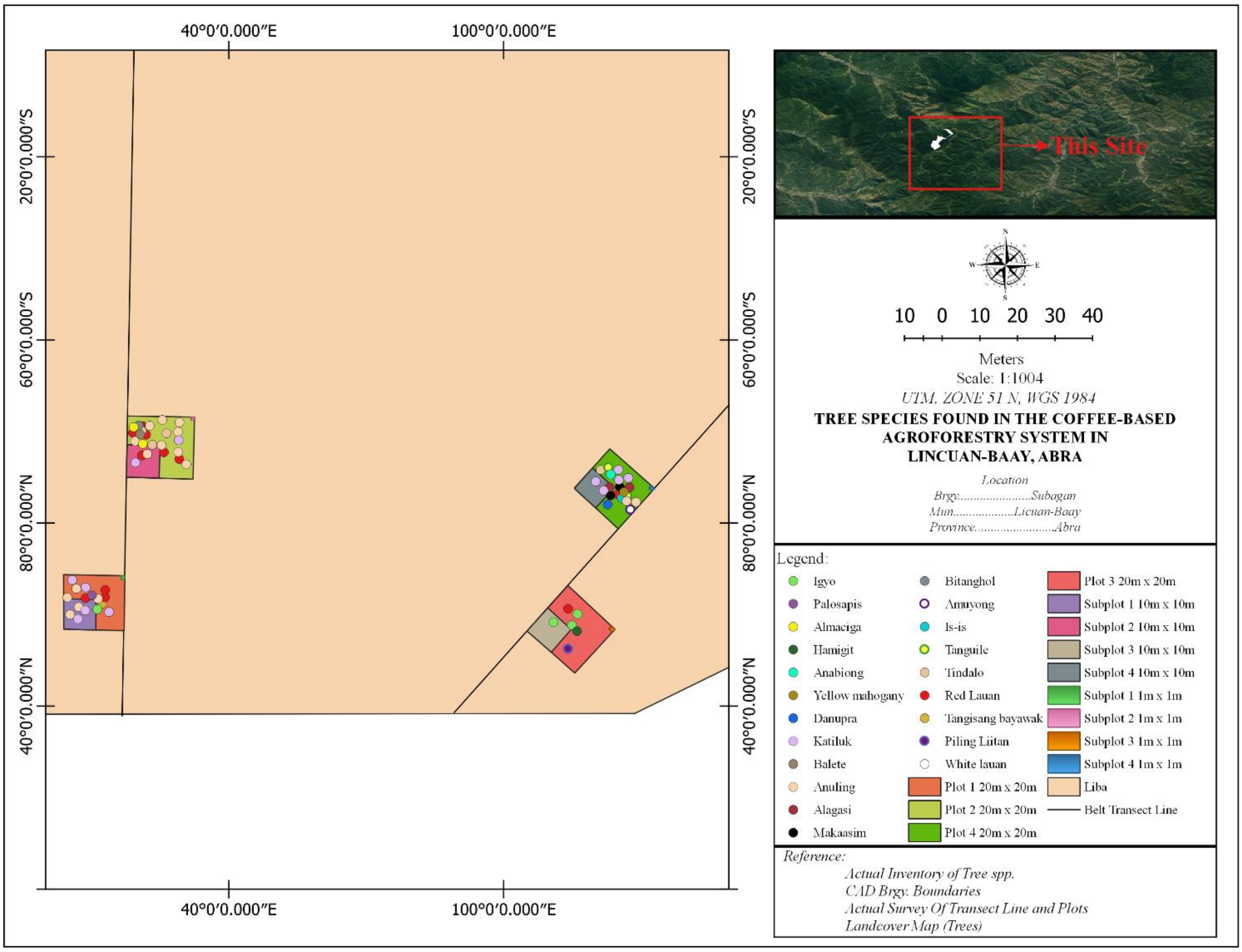

Figure 3. Distribution map of tree species in the study site.

Table 3. Tree species identified in 20 m x 20 m quadrats of a coffee-based agroforestry area in Abra, Philippines.

Species (Common/Scientific Name)	Family Name	Number of Individuals	Endemicity	Conservation Status
White Lauan (*Shorea contorta*)	Dipterocarpaceae	24	Native	Vulnerable (DAO 2017-11)
Anuling (*Ceodes umbellifera*)	Nyctaginaceae	18	Native	Least Concern (IUCN, 2024 & DAO 2017-11)
Katiluk (*Lithoscarpus jordanae*)	Fagaceae	12	Native	Vulnerable (IUCN, 2016 & DAO 2017-11)
Red Lauan (*Shorea negrosensis*)	Dipterocarpaceae	10	Native	Vulnerable (DAO 2017-11)
Igyo (*Dysoxylum gaudichaudianum*)	Meliaceae	5	Native	Least Concern (IUCN, 2019 & DAO 2017-11)
Tindalo (*Afzelia rhomboidea*)	Fabaceae	5	Native	Vulnerable (IUCN, 1998 & DAO 2017-11)
Alagasi (*Leucosyke capitellata*)	Urticaceae	2	Native	Least Concern (IUCN, 2022)

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Almaciga (*Agathis philippinensis*)	Araucariaceae	2	Native	Vulnerable (IUCN, 2011 & DAO 2017-11)
Makaasim (*Syzygium nitidum*)	Myrtaceae	2	Native	Critically Endangered (IUCN, 2016) & Vulnerable (DAO 2017-11)
Tanguile (*Shorea polysperma*)	Dipterocarpaceae	2	Native	Least Concern (IUCN, 2020) & Vulnerable (DAO 2017-11)
Anabiong (*Trema orientalis*)	Ulmaceae	1	Native	Least Concern (IUCN, 2018)
Balete (*Ficus benjamina*)	Moraceae	1	Native	Least Concern (IUCN, 2017)
Bitanghol (*Callophyllum blancoi*)	Clusiaceae	1	Native	Not yet evaluated
Danupra (*Toona ciliata*)	Meliaceae	1	Native	Not yet evaluated
Hagimit (*Ficus minahassae*)	Moraceae	1	Native	Least Concern (IUCN, 2019)
Is-is (*Ficus sinuosa*)	Moraceae	1	Native	Least Concern (IUCN, 2024)
Amuyong (*Goniothalamus amuyon*)	Annonaceae	1	Native	Vulnerable (IUCN, 2023)
Palosapis (*Anisoptera thurifera*)	Dipterocarpaceae	1	Native	Vulnerable (IUCN, 1998); Endangered (DAO 2017-11)
Piling-liitan (*Canarium luzonicum*)	Burseraceae	1	Native	Near Threatened (IUCN, 2020)
Tangisang-bayawak (*Ficus variegata*)	Moraceae	1	Native	Least Concern (IUCN, 2018); Other Threatened Species (DAO 2017-11)
Yellow Mahogany (*Epicharis parasitica*)	Meliaceae	1	Native	Least Concern (IUCN, 2016); Other Threatened Species (DAO 2017-11)

Table 4. List of saplings found in the 10 m × 10 m plots under a coffee-based agroforestry system in Abra, Philippines

Species (Common/Scientific Name)	Family Name	Number of Individuals	Category	Conservation Status
Robusta coffee (*Coffea canephora*)	Rubiaceae	20	Naturalized	Least Concern (IUCN, 2017)
Anuling (*Ceodes umbellifera*)	Nyctaginaceae	7	Native	Least Concern (IUCN, 2018& DAO 2017-11)
Makaasim (*Syzygium nitidum*)	Myrtaceae	5	Native	Critically Endangered (IUCN, 2016) & Vulnerable (DAO 2017-11)
Pandakaki (*Tabernaemontana pandacaqui*)	Apocynaceae	5	Native	Least Concern (IUCN, 2018) & Vulnerable (DAO 2017-11)
Katiluk (*Lithocarpus jordanae*)	Fagaceae	4	Native	Vulnerable (IUCN, 2016 & DAO 2017-11)

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Species (Common/Scientific Name)	Family Name	Number of Individuals	Category	Conservation Status
Almaciga (*Agathis philippinensis*)	Araucariaceae	2	Native	Vulnerable (IUCN, 2011 & DAO 2017-11)
Rambutan (*Nephelium lappaceum*)	Sapindaceae	2	Native	Vulnerable (DAO 2017-11)
Tibig (*Ficus nota*)	Moraceae	2	Native	Least Concern (IUCN, 2018)
Amuyong (*Goniothalamus amuyon*)	Annonaceae	1	Indigenous	Vulnerable (IUCN, 2023)
Mangkono (*Xanthostemon verduganianos*)	Myrtaceae	1	Indigenous	Endangered (DAO 2017-11)
Kakawate (*Gliricidia sepium*)	Fabaceae	1	Naturalized	Least Concern (IUCN, 2019)
Kamiring (*Semecarpus philippinensis*)	Anacardiaceae	1	Native	Not yet evaluated
Malasantol (*Dysoxylum cyrtobotryum*)	Meliaceae	1	Native	Least Concern (IUCN, 2019)

Diameter Size Classification

In the coffee-based agroforestry plantation, the result shows that 72.04 % are small-sized trees (> 10 cm - 30 cm DBH), while only a few were categorized as medium-sized (30 cm - 60 cm DBH) (26.88%) and large-sized individuals (1.08%) (Table 3). The abundance of small-sized trees could be associated with the growth characteristics of the species found in the area. As can be observed in Tables 3 and 4, there are various tree species recorded. The incorporation of different species of trees in a coffee-based agroforestry has an environmental benefit. Sayer *et al*. (2013) and Tscharntke *et al*. (2011) highlight the value of integrating trees into diverse, multifunctional landscapes and agricultural systems. Such approaches provide numerous benefits, including enhancing local biodiversity and supporting vital ecosystem functions. Key advantages include better soil fertility, improved carbon sequestration, water retention, and the creation of habitats for wildlife.

Trees can also function as windbreaks and shelterbelts, offering protection during storms (Waha *et al*., 2013; Rahman *et al*., 2011; Kalame *et al*., 2011). Furthermore, findings from a study in Western Kenya demonstrated that trees provide a consistent and accessible source of fuelwood for energy and income, particularly benefitting women (Thorlakson & Neufeldt, 2012)

Table 5. Classification of individual plant species based on diameter size in a coffee-based agroforestry system in Abra, Philippines

Size Category	Diameter Range (cm)	Count	Percentage (%)
Small Trees (S)	10 – 30 cm	67	72.04
Medium Size (M)	30 – 60 cm	25	26.88
Large Trees (L)	> 60 cm	1	1.08
Total		93	100.00

Importance Value Determination

Relative Density (RD)

Figure 4 illustrates the tree species with the highest relative densities within the 20 m x 20 m plots. Analysis revealed that White Lauan demonstrated the greatest relative density (25.81%), followed by Anuling (19.35%). This dominance of White Lauan correlates with its prevalence in the area. Its availability as a seed source significantly contributes to successful dispersal, germination, and establishment, reinforcing its population over time. Noteworthy attributes such as a straight trunk and classification as a dominant species enhance its role as a seed source for natural regeneration and reforestation.

Gregorio *et al*. (2020) emphasized that ideal seed trees typically exhibit straight, singular stems with minimal branches and belong to dominant or co-dominant categories within their habitat.

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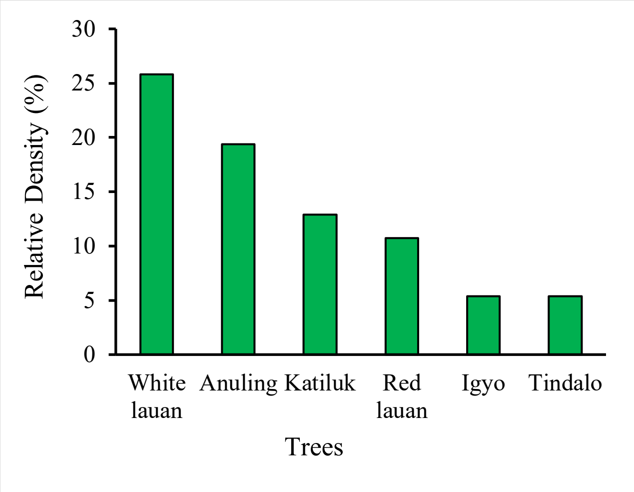

Figure 4. Tree species exhibiting the highest relative density values.

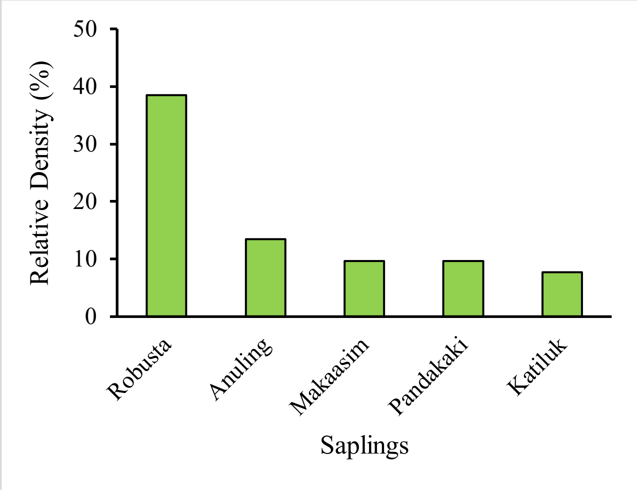

Figure 5. Saplings with the highest relative density value.

Figure 5 depicts the sapling species with the highest RD values recorded in the study area. Robusta coffee had the highest RD value at 38.42%, while Katiluk had the lowest at 7.69%. Other significant species included Anuling (13.46%), Makaasim, and Pandakaki, both at 9.62%. The dominance of Robusta coffee in RD reflects its adaptability and competitive edge in this environment (Tscharntke *et al*., 2011).

Robusta coffee (*Coffea canephora*) is extensively cultivated in the Philippines, particularly in regions like Mindanao, where favorable climate conditions prevail (Philippine Coffee Industry Roadmap, 2017). Its adaptability to various altitudes, soil types, and resistance to certain pests and diseases contribute to its prevalence (Gregorio *et al.,* 2020).

Although limited studies exist on the RD of Robusta saplings in natural forests, widespread cultivation and natural regeneration observed in several regions support this study's findings. The dominance of Robusta coffee in both sapling and mature stages highlights its potential for long-term prominence in the Philippine coffee industry (Gregorio *et al*., 2020).

As presented in Fig. 6, Red Lauan had the tree species with the greatest RF value (12.50%) among the species identified and assessed inside the 20m x 20m plots. This was followed by Anuling, Katiluk, and White Lauan, each recording a 9.38% RF. The other species are Igyo and Tindalo, with an RF Value of 6.25%. The dominance of red lauan in the surveyed plots, as indicated by the highest RF value, is supported by its ecological adaptability, regenerative capacity, and role as a key structural species in Philippine forests. According to the Energy Development Corporation (2020), Red Lauan is classified as critically endangered and is native to the Philippines. This species is integral to forest ecosystems, acting as a crucial marker of ecological stability and regeneration. Nonetheless, its high commercial demand and fragile status underscore the pressing necessity for robust conservation efforts.

Similarly, the saplings Anuling, Pandakaki, and Robusta coffee emerged as the most prominent species within the 10 m x 10 m subplots, each contributing 14.29% to the total. They were closely succeeded by Makaasim and Katiluk, both accounting for 9.52% (Fig. 7).

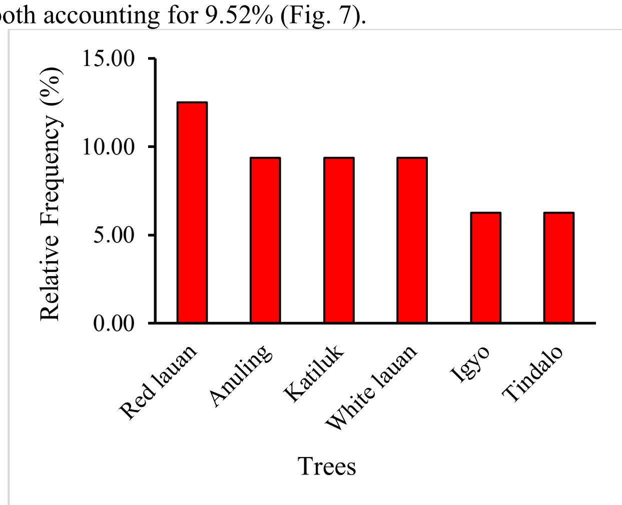

Figure 6. Tree species with the highest relative frequency value.

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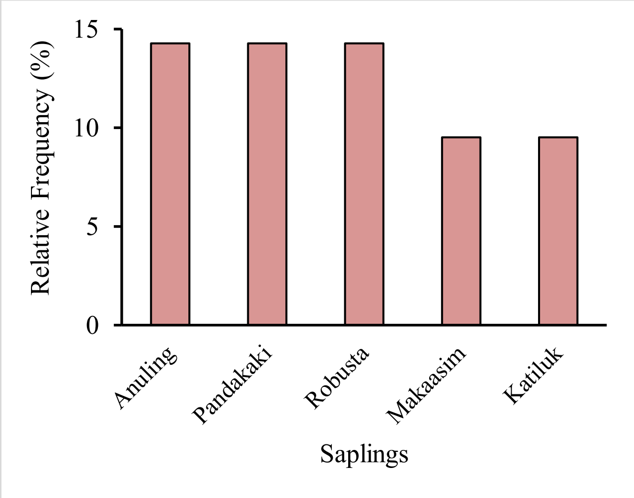

Figure 7. Species of saplings with the highest relative frequency value.

Relative Dominance (RDom)

The overall basal area, as outlined by the U.S. Forest Service (2021), is calculated by summing the basal areas of all tree species present within a forested region.

This metric is crucial for evaluating the relative dominance of tree species, as it captures both the size and density of trees within a given area. Trees with larger diameters and greater densities contribute significantly to the overall basal area, highlighting their dominance within the forest ecosystem. Such dominance is often linked to advanced successional stages, where certain species surpass others in resource competition, resulting in a more stable and mature forest composition (Fig. 8).

The assessment of RDom values within the 20 m × 20 m plots revealed that White Lauan exhibited the highest RDom value at 90.78%, indicating its strong dominance among the tree species present. This was followed, albeit distantly, by Anuling and Katiluk, which registered much lower RDom values of 3.51% and 3.06%, respectively. Other species showing notable, yet comparatively smaller, contributions to RDom included Red Lauan (1.08%) and Igyo (0.39%). Similarly, the analysis of saplings, as illustrated in Fig. 9, showed that Robusta coffee had the highest RDom value at 66.75%, emphasizing its dominance in the regeneration layer. Among the saplings, Anuling recorded the lowest RDom value among the top five dominant species, at 5.56%. The other species with considerable contributions to the overall sapling dominance included Katiluk (9.26%), Pandakaki (7.29%), and Makaasim (6.65%).

These findings suggest that while mature stands are overwhelmingly dominated by native species like White Lauan, the sapling layer is increasingly influenced by cultivated species such as Robusta coffee, reflecting land-use patterns and management practices observed in similar agroforestry systems (Tadesse *et al.*, 2014; Thorlakson & Neufeldt, 2012).

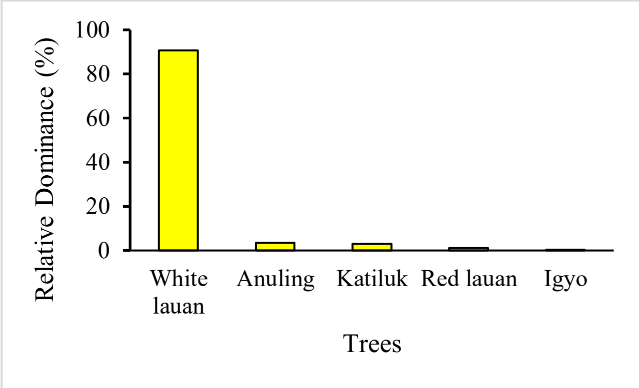

Figure 8. Tree species with their corresponding relative dominance

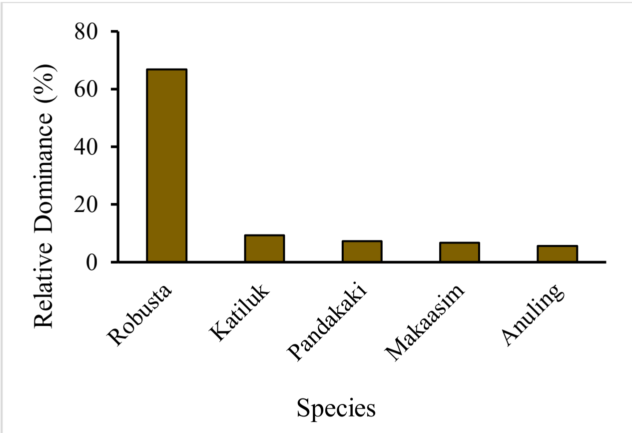

Figure 9. Species of saplings with the highest relative dominance value.

Importance Value (IV)

The Importance Value (IV) offers a more comprehensive measure than density alone in determining the role or significance of a species within its ecosystem (Alibuyog *et al.*, 2015).

Figure 10 illustrates the tree species evaluated in the study area with the highest IV. White Lauan consistently ranked highest, followed by Anuling with respective values of 125.96% and 32.24%. Other notable species include Katiluk (25.34%), Red Lauan (24.34%), Igyo (12.02%), and Tindalo (11.90%).

Additionally, the IVs of sapling species identified in the 10 m x 10 m subplots are shown in Figure 11. Among these, Robusta coffee, being the primary agricultural species intercropped in the area, recorded the highest IV at 119.50%.

DOI: https://doi.org/10.55706/jae17XX

This was followed by Anuling (33.31%), Pandakaki (31.20%), Katiluk (26.47%), and Makaasim (25.89%).

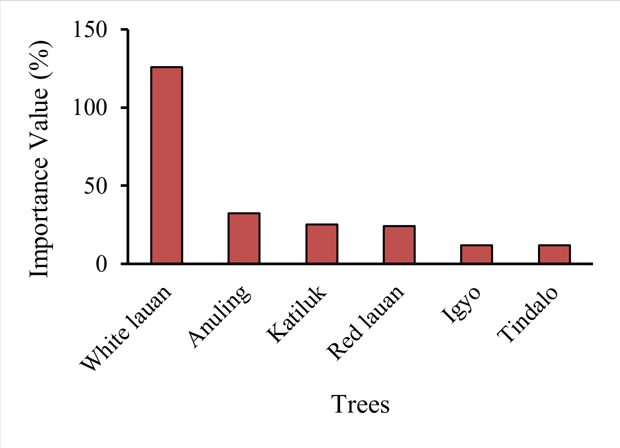

Figure 10. Tree species exhibiting the greatest importance values.

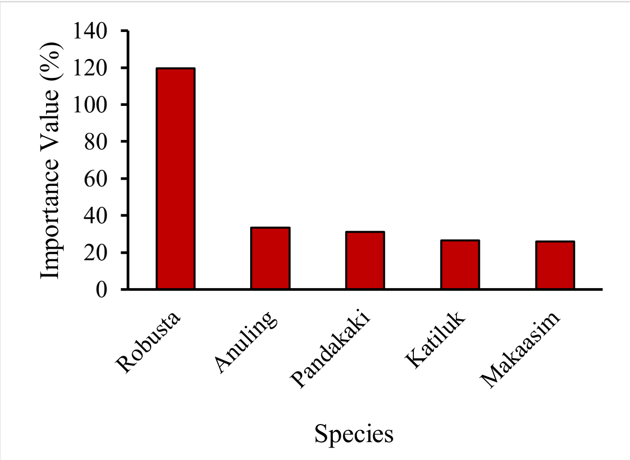

Figure 11. Sapling species with the greatest importance value.

Species Richness

Species richness represents diversity through the number of species present in a community (Magurran, 2004). It assigns equal importance to species with only a few individuals and those with many. As a common metric for biodiversity, species richness simply tallies the number of distinct taxonomic species within an area (de Quiroz, 2007; Corcoran & Boeing, 2012). At the study site, 154 individuals were documented, comprising 93 trees and 52 saplings. The species richness indices calculated were 39.37 for trees and 20.59 for saplings, indicating a greater variety of species within the tree layer compared to the sapling layer. Typically, ecosystems with high species richness exhibit better health and resilience, as they support a wide range of ecological functions (Hooper *et al*., 2005).

The species richness observed at the site points to a moderately diverse ecosystem, which is vital for maintaining stability, enriching soil nutrients, and enhancing resistance to disturbances. High species richness often correlates with improved ecological processes, such as pollination, nutrient cycling, and pest regulation, thereby increasing ecosystem resilience (Tilman *et al*., 1997). Species richness is influenced by various factors, including habitat diversity, geographic location, and resource availability. For example, because of their stable climates and plentiful resources, tropical locations usually support a greater number of species (Myers, 1988). More species diversity in agroforestry systems has been associated with improved land productivity and ecosystem services in contrast to monoculture systems (Landis *et al.* 2000).

However, as Cortado and De Jesus (2025) note, the ecological sustainability of tree-based systems, such as coffee agroforests, hinges on both aboveground diversity and belowground soil quality. These systems, when managed appropriately, can enhance soil retention, carbon sequestration, and nutrient cycling. However, poorly planned land-use modifications or conversions may compromise soil function. Therefore, the presence of native and threatened tree species in the study site, coupled with sustainable coffee cultivation, reinforces the importance of integrated agroforestry management that balances biodiversity conservation with soil stewardship.

Species Diversity

Assessing biodiversity often emphasizes species-level diversity, which is a crucial factor in ecological evaluation (Ardakani, 2004). Ecosystems with a greater variety of species typically exhibit higher values on the Shannon Diversity Index (H'), whereas those with fewer species show lower H values, indicating reduced diversity (Sobuj & Rahman, 2011). The recorded Shannon Diversity Index in the area is moderate plant diversity, with a value of 2.35 in the 20m × 20m plots. In contrast, a lower H' value of 2.04 was observed in the smaller 10m × 10m subplots, indicating a low level of diversity (Fig. 12). These results highlight that plant diversity varies across spatial scales, and finer-scale assessments may show less richness and evenness than broader ones.

Multistorey agroforestry systems, including those centered on coffee cultivation, play a significant role in conserving biodiversity. These systems enhance environmental complexity and increase habitat or landscape heterogeneity (Torralba *et al*., 2016; Boinot *et al*., 2019; Haggar *et al*., 2019). The rich biodiversity supported by agroforestry contributes to essential ecological functions such as improving soil fertility, controlling erosion, and producing a variety of crops, while simultaneously bolstering food security and fostering sustainable agriculture (Jarvis *et al*., 2007). Exploring the effects of agroforestry on biodiversity patterns is vital for designing and implementing sustainable agri-environment initiatives (Ansell *et al*., 2016;

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Pavlis *et al*., 2016). By encouraging species diversity, agroforestry enhances both agricultural and forested landscapes, promoting biodiversity conservation while ensuring continued land productivity.

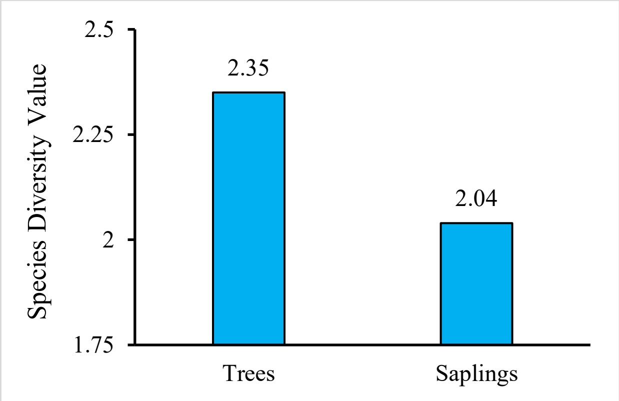

Figure 12. Diversity of plant species identified within a Coffee-based Agroforestry System in Abra, Philippines.

Species Evenness

In the study area, 93 individual trees from 21 species had a species evenness value of 1.585, compared to 52 seedlings from 13 species with a greater evenness value of 1.837 (Fig. 13). As noted by Wilsey & Potvin (2000). Species evenness measures the numerical balance among species within an environment, with higher values reflecting a more equitable distribution where no single species predominates. The saplings' evenness rating is 26% greater than that of the trees, indicating that sapling species are more uniformly dispersed throughout the research area than mature trees. In contrast, the decreased evenness among trees implies that certain tree species are significantly more prevalent than others, resulting in an uneven species structure.

This pattern can be explained by the land management practices in the coffee-based plantation, where the primary focus is on cultivating Robusta coffee rather than maintaining diverse timber species. The economic value of Robusta coffee has influenced farmers to prioritize its growth, resulting in a few dominant tree species. Meanwhile, the sapling layer, which is subject to less intensive management, shows a more natural and diverse regeneration. As noted by Toledo & Moguel (2012), farmers in such systems often balance between commercial production and subsistence needs, leading to mixed planting and a richer diversity at the younger plant stage. Therefore, species evenness not only reflects the current plant distribution but also highlights the socio-economic factors influencing the area's vegetation dynamics.

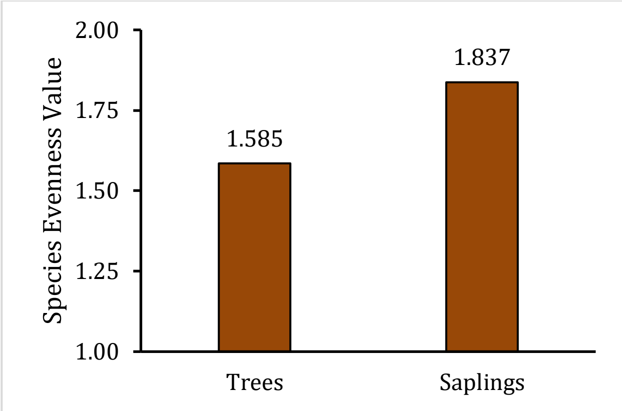

Figure 13. Evenness of plant species observed in the study area.

Conservation Status

This research evaluated multiple species to create a foundation for their preservation, conservation, monitoring, and assessment. The conservation status of each species was determined following the guidelines of the DENR Administrative Order (DAO) 2017-11 and the criteria set by the International Union for Conservation of Nature (IUCN) (Table 1).

The study area hosts numerous economically significant and threatened species, as highlighted by their conservation classifications. For instance, *Syzygium nitidum* is recognized as Critically Endangered on the IUCN Red List and Vulnerable under the DENR criteria. Similarly, *Anisoptera thurifera* is categorized as Critically Endangered by the DENR and Vulnerable by the IUCN.

Other species at risk include *Agathis philippinensis*, *Lithocarpus jordanae*, and *Afzelia rhomboidea*, all of which are labeled as Vulnerable by both the IUCN Red List and DAO 2017-11. Additional species such as *Shorea contorta*, *Shorea polysperma*, *Shorea negrosensis*, *Tabernaemontana pandacaqui*, and *Nephelium lappaceum* hold a Vulnerable status under DAO 2017-11. In contrast, *Goniothalamus amazon* is listed as Vulnerable by the IUCN. Moreover, *Canarium luzonicum* is categorized as Near Threatened, while *Ficus variegata* and *Epicharis parasitica* are designated as Other Threatened Species by the DENR.

Assessing a species' conservation status is vital for guiding sustainable management and preservation, especially in regions experiencing agricultural development. Research highlights agroforestry as an effective approach to mitigating species loss in farming landscapes and supporting the conservation of endangered species (Mosquera-Losada et al., 2020; Torralba *et al*., 2016; Udawatta *et al*., 2019). The Cordillera Green Network, Inc. (2020) further emphasizes that coffee-based agroforestry systems play a vital role in environmental protection and conservation.

DOI: https://doi.org/10.55706/jae17XX

CONCLUSION

This study demonstrates that combining coffee cultivation with diverse tree species significantly contributes to improving biodiversity in agricultural settings. The results emphasize the system's capacity to preserve native plant species, including those at risk, while simultaneously maintaining agricultural yields. This dual advantage positions agroforestry as an effective strategy to combat biodiversity loss and mitigate land degradation issues. The moderate diversity and presence of vulnerable species call for targeted conservation strategies and enhanced agroforestry management. This approach will ensure the resilience of the ecosystem while maintaining economic benefits for local communities. Expanding such systems across similar regions could contribute significantly to global biodiversity and climate goals, aligning with sustainable development frameworks.

Recommendations

Related to the study's findings, the following recommendations are proposed:

To ensure sustainable biodiversity monitoring in coffee-based agroforestry plantations, it is recommended to develop conservation management strategies based on the ecological characteristics of the area.

A similar study could be replicated in other coffee-based agroforestry areas in the Philippines to determine the effects of the coffee-based agroforestry practice on biodiversity.

Enrichment planting should be undertaken in the study site to improve local livelihood opportunities of the community, to increase their productivity, and to raise awareness of sustainable land use.

The coffee-based agroforestry system can be integrated into the Philippines government's expanded Expanded National Greening Program. It will involve the planting of timber and fruit trees, and it will help to alleviate poverty, promote biodiversity conservation, and environmental awareness.

Acknowledgment

The authors thank the local farmers of Abra for the invaluable support and cooperation especially during the data gathering in the study area. Appreciation is also dedicated to all the assistants during the field visits to the sites and data gathering. Researchers are forever grateful to all the people behind the success of the pursuit of this endeavor.

Conflict of Interest

The authors confirm that there are no conflicts of interest associated with this research.

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