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Ecological insights on communal forests in the tropics: The case of Alapang Communal Forest of La Trinidad, Benguet, Philippines

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ABSTRACT: Communal forests are recognized to be of critical importance for the attainment of sustainable development goals (SDGs) but these are often understudied. Such is the case in Cordillera Central Range with its unique biodiversity and urban biodiversity sites requiring protection like the Alapang Communal Forest in Benguet, Northern Philippines. This study documented the floral diversity, carbon stock and the community perspectives as baseline for conservation. A total of 187 plant species belonging to 145 genera and 70 families were recorded with *Pinus kesiya* as the most dominant species. The forest exhibited high species richness, evenness, and diversity including indigenous, endemic species and some conservation important species. The total forest carbon was estimated at 6,931.44 t with an average of 192.54 t/ha. An interesting trade off was documented in the study with the pine dominated ridge stations having lower diversity but higher carbon stock while broad-leaf dominated depressed stations have higher diversity but lower carbon stock. Community surveys revealed the willingness to protect the forest due to its crucial role as a water source, highlighting its value and the importance of preservation. These findings offer empirical evidences on the role of communal forest on biodiversity conservation, carbon stock as well as forest goods and services. Locally, these findings offer insights for conservation and sustainable management of the Alapang Communal Forest and other local urban forests.

KEY WORDS: carbon stock, community perspective, depressed station, *Pinus kesiya*, urban communal forest.

INTRODUCTION

Communal forests, defined by interaction with human societies, are now becoming particularly relevant with the climate and biodiversity crises. These forests are recognized by Food and Agriculture Organization to be of critical importance due to their huge size, the large amounts of carbon they capture and store, their great biodiversity, cultural diversity, and their potential for culturally appropriate forms of rural development (Garnett *et al*., 2018). Moreover, Katila *et al*. (2017) and Seymour and Busch (2016) affirm that forests interaction with human societies have been associated with specific Sustainable Development Goals (SDGs). For example, forest exploitation and its wider contribution to livelihood contribute to SDG 1, Reducing Poverty; food from forests links them to SDG 2, Reducing Hunger; health contribution of medicinal plants found in forests as well as other therapeutic qualities contribute to SDG 3, Improving Health; fuel from forest for cooking and boiling water for a large segment of the global population contribute to SDG 7, Energy for All; capture and store carbon by forest links them to SDG 13, Climate Change Mitigation; water regulating attributes makes them relevant for SDG 6, Clean Water; forest biodiversity is crucial for SDG 15, Life on Land; aid in regulating microclimate, absorb pollutants and provide aesthetic sceneries – linking them to SDG 11, Sustainable Cities and Communities; and, reduce landslides which is relevant for infrastructure (SDG 9), and improve the condition of coastal waters, thereby benefiting aquatic ecosystems under SDG 14 (de Jong *et al*., 2018; Sarre and Davey, 2021).

Small-scale communal forests in tropical countries, however, are often understudied despite their ecological importance. The critical functions and services of these small-scale communal forests are greatly underappreciated. For example, in the meta-analysis conducted by Hajjar *et al*. (2020) on communal forests, the Philippines and other tropical countries were represented by only few studies. Also, Sarre and Davey (2021) showed that SDG studies on forestry are often limited to macro-scale forests while small-scale communal forests are often left out due to the notion that their contribution is limited due to their small size. However, small-scale communal forests occur in large numbers in the tropics particularly among indigenous people domains and combining these could span large areas. For example, approximately 29 million ha in Papua New Guinea are small-scale communal forest (Scudder *et al*., 2019) while International Tropical Timber Organization (2012) reported 332 million ha of communal forest in developing countries. Locally in Benguet, Philippines, a total of 76 communal forests exist but to date, only Alno and Alapang Communal Forest have initial studies. This highlight the need for more thorough study on small-scale communal forests in the tropics particularly their contribution to biodiversity and climate change.

Nansikombi *et al*. (2020) highlighted the importance of conducting scientific studies on communal forest as means of lobbying for support from government and international agencies. Coupled this with the complexity of the community interaction and its overall unpredictability, the importance of customary cultural practices, and the lack of models and information linking community decisions to large-scale sustainable patterns make it difficult for community forest managers to convince policymakers to support practices and institutions that may seem distantly related to conservation, but which may be critical to community cultures and livelihoods. A better scientific understanding of how community practices relate to large-scale ecological dynamics will also help national and global climate change initiatives to more effectively support the local community in sustaining their contributions to combating climate change. Further, systematic investigation of the mechanics and dynamics of indigenous land use and local ecological processes can support Indigenous peoples' efforts by helping them present the strongest possible argument in dialog with policymakers and managers (Downey *et al*., 2023).

Ecological aspects have been identified by experts as major research gaps in forest sustainability (Guldin, 2019). The research gap on the underlying ecological patterns and processes within tropical communal forest is particularly glaring amidst their supposed importance to SDGs. Only few recent studies had been conducted on this field such as the study of Downey *et al*. (2023) that found intermediate level of disturbance with customary agricultural practices increasing the species diversity in Maya community forests. On the other hand, Balangen *et al*. (2023) found the degree of human disturbance dictating the type of floral diversity in secondary forest of Benguet, Philippines. Obviously, more studies are needed to better understand these underlying ecological patterns and processes. The ecological aspect of communal forest will also include socioeconomic particularly in Southeast Asian nations since significant portion of their population are still dependent on these forests (Poffenberger 2006; Chechina *et al*., 2018). The ecological, social and climate change aspects of tropical communal forests have been studied by some authors (eg. Lumbres *et al*., 2014; Chechina *et al*., 2018; Hugé *et al*., 2022) but often, these were tackled singly and not collectively. Rader *et al*. (2024) stressed the data gap on the interplay of ecology and biodiversity conservation, considering social and economic aspects, and recommended more studies on these for sustainable future.

Our study aims to contribute to these data gaps by presenting the floral diversity, carbon stock and community perspective on Alapang Communal Forest in Benguet, Philippines. The study was able to highlight some interesting ecological patterns and processes within this tropical communal forest. It also presented a holistic view on the ecological, social and climate change aspect of the communal forests which is uncommon in available literatures and we hope to start building these up as important baseline for tropical communal forest.

MATERIAL AND METHODS

Study Site

The Alapang Communal Forest (Figure 1) is one of the four communal forests in La Trinidad, Benguet. These were established during the American colonization (September 1922) and were maintained by the local government units to this date, even assigning forest rangers to guard these. It is located in Barangay Alapang, from which it derive its name. Originally, the communal forest covers a total of 73.92 ha (Alapang Demographic Profile, 2015) but was reduced to 36 ha due to encroachment and ancestral domain claims.

Floral Diversity Assessment

The study employed nested plot sampling method to ensure maximum sampling in measuring the floral richness of the area. During the reconnaissance, two major types of forest occur in the area namely pine forest in the ridge slopes while broad-leaf forest along depressions. Each forest type has three layers namely tree canopy, understory and forest floor. Thus, the selection and distribution of sampling stations follow the forest type, forest layers and elevation. A total of six (6) stations were established with three stations each for ridge (Pine Peak, Pine Mid, Pine Lower) and depressed areas (Depressed Peak, Depressed Mid, Depressed Lower). Each station consisted of three (3) nested plots. Each nested plot consists of a 20m × 20m ($400m^2$) main plot for trees, two 5m × 5m ($25m^2$) subplots for understory (shrubs/tree sapling/ liana), and three 1m x 1m ($1m^2$) subplots for forest floor. Woody plants with DBH ≥ 5 cm are counted as trees while those lower were included in the understory sampling.

Importance Value and Biodiversity Indices. The floral inventory of Alapang Communal Forest was analyzed using several ecological measures such as importance value (IV) and biodiversity indices. IV assesses species dominance in a specific forest area. In the study, density, frequency, and basal area for trees were the parameters used in determining the IV of the species. These were analyzed using the standard formulae adopted from Guron *et al*. (2019) in Microsoft Excel.

For biodiversity indices, Shannon Diversity Index, Simpson's Diversity Index, Pielou's Index of Evenness, Margalef index of Species richness and Jaccard index of similarity were computed using standard formulae from Aureo *et al*. (2020) and Ulfah *et al*. (2019). Additionally, Co's Digital Flora was used for the identification of the species distribution category while IUCN (2023) and DAO 2017-11 (DENR, 2017) for the conservation status.

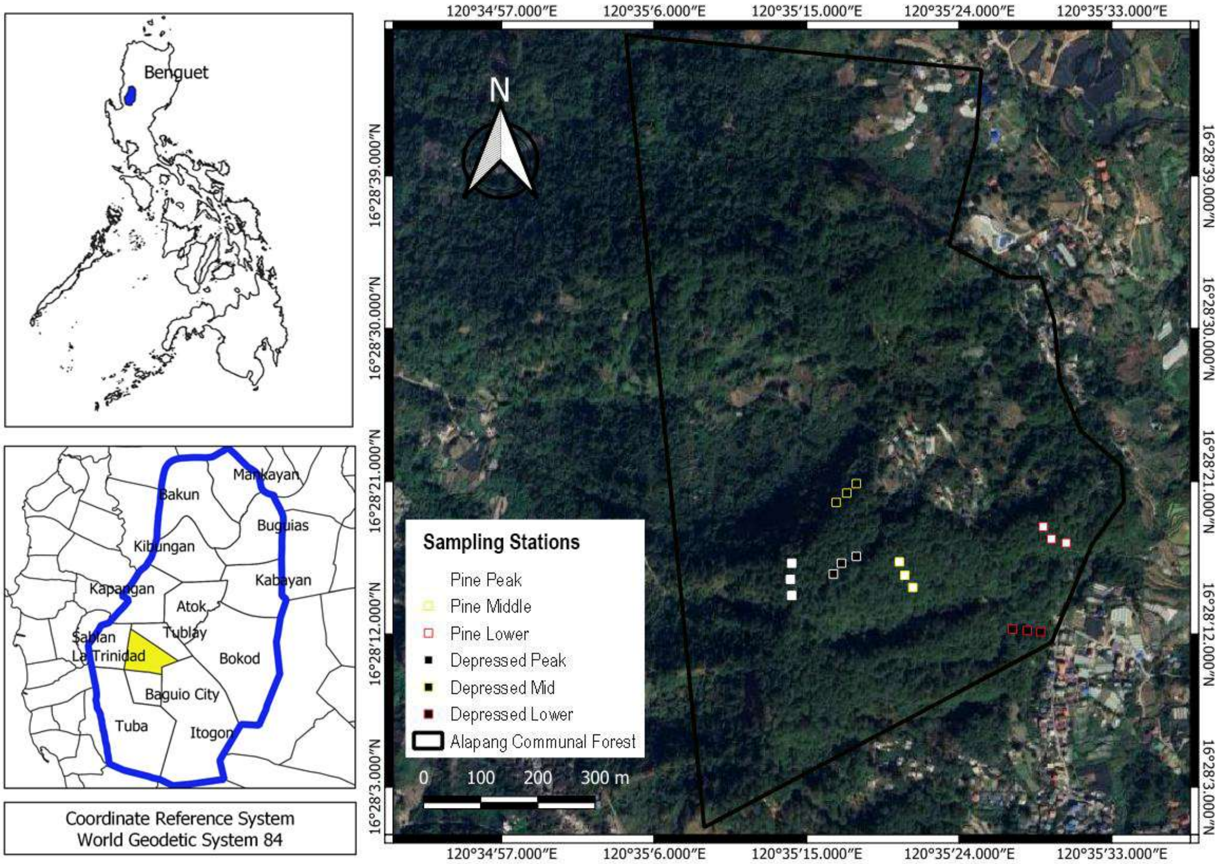

Fig. 1. Sampling stations in the study site, Alapang Communal Forest in Benguet, Northern Philippines.

Carbon Stock Assessment

The carbon stock of the communal forest was estimated by measuring the tree carbon, understory carbon and soil carbon. These three major carbon pools of the forest were estimated individually before summing to get the total forest carbon.

Tree Biomass. For the aboveground tree carbon**,** the circumference at breast height (CBH) were first measured before being converted into diameter at breast height (DBH) on all trees within the 20x20 m plots in all six stations. The allometric equations used for the computation of aboveground biomass (AGB), were adopted from Napaldet and Gomez (2018) and Racelis *et al*. (2019), as follows:

Benguet Pine (*Pinus kesiya*) AGB = $0.067DBH^{2.474}$

For broad-leaved trees AGB = $\exp[-2.134 + 2.530 \times \ln(DBH)]$

The belowground biomass was estimated as 20% of the aboveground biomass (Santantonio *et al*., 1997; Ravindranath and Ostwald, 2008). The aboveground tree biomass was added with the belowground biomass to get the tree biomass.

Understory and Litter Biomass. The understory and litter biomass were sampled through harvest method. The same 1m × 1m subplots used for floral inventory analysis were used to collect understory and litter samples. These forest litters were weighed to get the total fresh weight. After getting the total fresh weight, a composite sample of 500g was gathered per plot. The collected sample of understory and litter from the communal forest were brought to the BSU-CNS laboratory for drying for 1 week and then oven drying at 95-105°C for at 24 hours. The computed constant ODW were recorded as biomass (Parao *et al*., 2015). The moisture content (Dulnuan and Napaldet, 2023) and biomass of the understory and litter (Racelis *et al*., 2017) in the communal forest were determined using the following formulae:

$$Moisture\ Content\ \% = \frac{W_1 - W_2}{W_1} \times 100$$

Where: W_1= fresh weight of air – dried understory and litter (g); W_2= oven dry weight of understory and litter (g)

$$Understory\ and\ litter\ biomass = \frac{ODW(g)}{Area\ of\ plot\ (m^2)} \times \frac{10{,}000\ m^2}{1\ ha.} \times \frac{1\ ton}{10^6 g}$$

Where: ODW= oven-dry weight of sample

Area of plot = 1m^2

After determining tree and the understory and litter biomass, these were multiplied by 45 % as the carbon content (Labata *et al*., 2012; Racelis *et al*., 2017).

Soil Organic Carbon. Composite soil samples were also collect from the subplots in each station. The soil sample were air dried for 1 week, oven dried for 24 hours to obtain the moisture content and then into a furnace for about 3 hours at 550°C (Hoogsteen *et al*., 2015) for the soil organic carbon. The determination of soil organic carbon followed the Loss-on-ignition (LOI) method (Dulnuan and Napaldet, 2023; Bhatti and Bauer, 2002) that determines the soil organic matter (SOM) from sample to convert into soil organic carbon (SOC). After which, percent Loss on Ignition (LOI) were divided by the Van Bemmelen factor which is 1.724 (Ahn and Jones, 2013) and then converted to tons per hectare unit.

The total carbon stock were determined by adding the forest carbon pools namely total tree biomass plus understory and litter biomass plus soil biomass. These were then compared between stations using ANOVA and Tukey's test as post hoc in PASTv3.

Ecological Patterns in Alapang Communal Forest

To further elucidate the ecological patterns in the communal forest, Bray-Curtis Similarity Index, Endemicity and Conservation Importance Index were employed. Bray-Curtis index were used to build dendrograms that could reveal patterns indicative of community processes within the assembly of complex landscapes (Gravel *et al*., 2014). On the other hand, Endemicity and Conservation Importance Indices were recently developed by Bullong *et al*., (2024) to identify specific plots or areas within tropical forest ecosystems priority for conservation due to high number of native and conservation important species (those with conservation status). Data analyses were done using PAST v3 and Microsoft Excel.

Community Assessment

The study employed a semi-structured questionnaire, which consists of both closed and open-ended questions, to gather data from the residents. The questionnaire was adapted from Baur *et al*., (2016). Convenience sampling was utilized to select the respondents for the study. According to Morse (2000), semi-structured interviews yield a small amount of data per question, and in order to obtain sufficient data richness for qualitative analysis, a large number of participants is necessary, typically ranging from 30 to 60. Thus, this study followed Morse's recommendation and set the sample size at 55 participants.

The selection criteria for the respondents in the study needed the participants to be residents of Alapang for a period exceeding ten years. Additionally, the study included key informants interviews with the local government unit (LGU) including the Punong Barangay of Alapang, three (3) foresters, and one representatives each from the Municipal Environment and Natural Resources Office (MENRO) and Barangay Environment and Natural Resources Office (BENRO). The study interviewed 55 individuals for the semi-structured questionnaires and 5 individuals for the key informant interview. Of these, 29 were males and 26 were females with majority aged 20-30 yrs old. All of the respondents have been living in the area for >10 years with three respondents reaching 70 years.

A four (4) point Likert scales adopted from Chyung *et al*., (2017) were utilized in determining the level of familiarity (4-very familiar, 3-familiar, 2-slightly not familiar, and 1-not familiar), provide (4-provided extremely well, 3- provided well, 2-provided very poorly, and 1-not provided at all), threat (4-severe threat, 3-threat, 2-slightly not threat, and 1-not a threat), importance (4-most important, 3-important, 2-slightly not important, and 1-not important), and agreement (4-strongly agree, 3-agree, 2-disagree, and 1-strongly disagree) to a specific situation/challenge or recommendation. Data analyses were conducted in Microsoft Excel.

RESULTS

Floral Diversity of Alapang Communal Forest

A total of 187 plant species belonging to 145 genera and 70 families were recorded in Alapang Communal Forest (Figure 2A). Of these, 22 were pteridophytes, 1 gymnosperm, 28 monocots and majority were dicots (136). Majority of the plants were indigenous (105) with several endemics (55), some naturalized (26) and few (2) exotic species (Figure 2B). Some conservation important species were also documented including 9 species under the national category (DAO 2017-11) and 16 under international category (IUCN) (Figure 2C). Refer to Annex Table 1 for the complete species list and their categories. Family Asteraceae was the most represented with 14 species followed by Poaceae (13), Phyllanthaceae (11), Moraceae (8), Fabaceae (7), Primulaceaea (6), Rosaceae (6) and Urticaceae (6). The rest of the families were represented by one to three species (Figure S1).

The species counts by stations were presented in Figure 3. The species richness is evidently lower in pine stations ranging from 45 – 54 species. Greater species richness were observed in the depressed stations at 58 – 90 species. Consequently, greater number of endemic and indigenous species were recorded in the depressed stations compared to the pine stations. The highest species richness was recorded in depressed lower station with 90, 54 indigenous and 25 endemics. On the other hand, pine peak and pine lower stations recorded the lowest species richness at 45

Dominant Species. A total of 10 tree, 12 shrub and 11 herb species were found dominant across the six stations (Table 1). Under the tree category, *Pinus kesiya* emerged as the most dominant species particularly in the pine ridge stations. In depressed stations, other broad leaf trees like *Alnus japonica, Macaranga cumingii, Sphaeropteris glauca Sphaeropteris glauca* and *Mallotus mollissimus* and large individuals of *Deutzia pulchra*, *Eurya chinensis* and *Clethra canescens* were found co-dominant with *P. kesiya*.

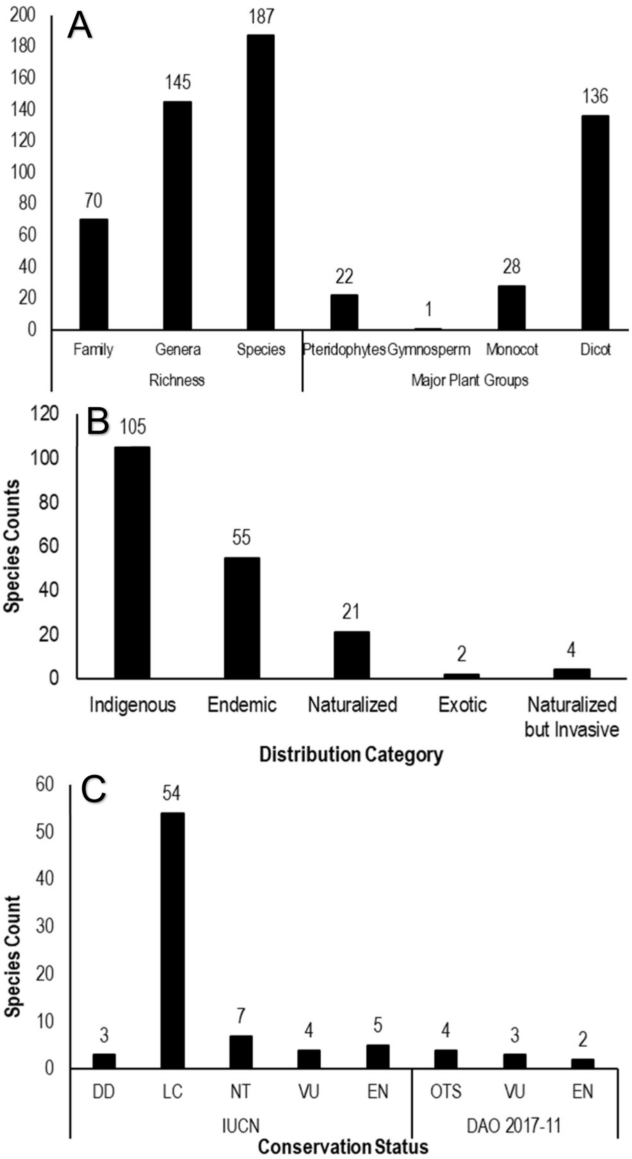

Fig. 2. Plant richness (**A**), categories (**B**) and conservation status (**C**) of floral species in Alapang Communal Forest, La Trinidad, Benguet (DD- data deficient; LC – least concern; NT – near threatened; VU – vulnerable; EN – endangered).

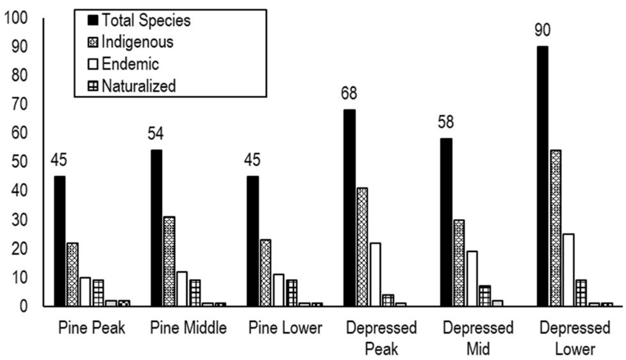

Fig. 3. The species richness and categories of floral species in Alapang Communal Forest by sampling stations.

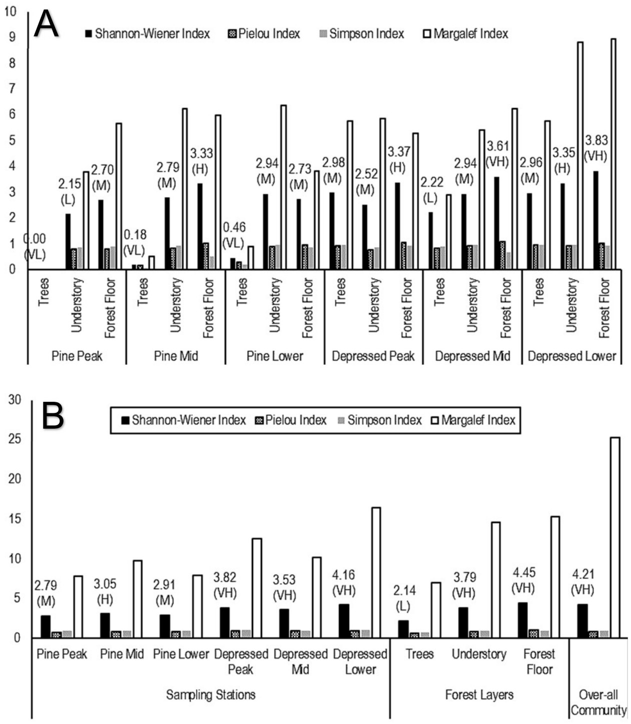

Fig. 4. Biodiversity indices by forest layers per sampling stations (**A**) and over-all stations/ layers/community (**B**) in Alapang Communal Forest (Note: low; L= Low; M = Moderate; H= High; VH= Very High*)*.

Under the shrub category, it can be readily gleaned from the table that different sets of species dominated between ridge and depressed stations. Pine ridge stations were dominated by *Melastoma malabathricum*, *Miscanthus floridulus, Psidium guajava* and saplings of *P. kesiya* and *M. mollissimus.* On the other hand, shade and moist loving species like *Ptisana sylvatica*, *Tabernaemontana pandacaqui*, *Vanoverberghia sepulchrei*, *Angiopteris evecta*, *D. pulchra* and *Leea manillensis* were the dominant shrubs in depressed stations. Similar trend was also observe under grass and herbs category wherein different sets dominated between pine and depressed stations. Common weeds like *Ageratina riparia*, *Elephantopus tomentosus, Ottochloa nodosa, Pteridium aquilinum* and *Paspalum conjugatum* were found dominant in the pine stations. On the other hand, native species like *Alocasia micholitziana*, *Begonia merrittii*, *Dicranopteris curranii*, *Rubus benguetensis* and *Selaginella involvens* dominated in the depressed stations.

Biodiversity Indices. Overall, Alapang Communal Forest exhibited high level of biodiversity with Shannon index of 4.21 (very high diversity), evenness of 0.80 (almost balanced), Simpson's index of 0.96 (highly diversity) and Margalef's index of 25.27 (high species richness, Figure 4). Between stations, ridge stations consistently had lower diversity indices compared with depressed stations. Pine stations had Shannon index of 2.79–3.05, evenness at 0.73–0.77, Simpson's at 0.89–0.91 and

Table 1. The dominant trees, shrubs and herbs in Alapang Communal Forest, La Trinidad.

Dominant Species	IVI and Rank in the Sampling Stations						
Trees	**P. Peak**	**P. Mid**	**P. Lower**	**D. Peak**	**D. Mid**	**D. Lower**	**Over-all**
Alnus japonica	-	-	-	-	**14.14**	-	2.62
Breynia cernua	-	**7.28**	-	3.15	-	-	1.14
Calliandra calothyrsus	-	-	**6.52**	-	-	-	0.79
Clethra canescens	-	-	-	**7.16**	5.027	-	
Deutzia pulchra	-	-	-	2.27	**13.75**	**8.35**	**4.08**
Eurya chinensis	-	-	**9.16**	-	-	-	0.74
Macaranga cumingii	-	**7.27**	-	4.39	13.36	-	**3.67**
Mallotus mollissimus	-	-	-	**9.38**	3.31	**9.28**	3.44
Pinus kesiya	**100.00**	**85.44**	**75.04**	**19.08**	**22.90**	7.64	**51.57**
Sphaeropteris glauca	-	-	-	3.39	5.84	**9.77**	3.36
Shrubs	**P. Peak**	**P. Mid**	**P. Lower**	**D. Peak**	**D. Mid**	**D. Lower**	**Over-all**
Angiopteris evecta	-	-	-	4.46	-	**6.18**	1.87
Clethra canescens	-	-	-	6.35	**8.36**	-	2.55
Deutzia pulchra	-	-	-	-	**11.14**	-	2.08
Leea manillensis	-	-	-	7.54	3.81	**5.30**	2.87
Mallotus mollissimus	7.18	**10.03**	**9.26**	-	7.18	1.544	5.91
Melastoma malabathricum	**20.58**	**14.20**	**13.89**	-	**8.20**	-	**8.87**
Miscanthus floridulus	**24.42**	**14.92**	1.78	-	5.41	-	**7.00**
Pinus kesiya	**13.65**	4.73	2.49	-	-	-	2.89
Psidium guajava	2.63	1.52	**9.62**	-	-	-	2.14
Ptisana sylvatica	-	-	-	**8.93**	-	1.54	1.69
Tabernaemontana pandacaqui	-	-	-	**8.23**	-	1.54	1.58
Vanoverberghia sepulchrei	-	-	-	**23.51**	2.197	**13.053**	**6.55**
Grass and Herbs	**P. Peak**	**P. Mid**	**P. Lower**	**D. Peak**	**D. Mid**	**D. Lower**	**Over-all**
Ageratina riparia	4.72	**42.28**	**16.34**	2.99	**35.23**	**12.99**	**16.31**
Alocasia micholitziana	-	-	-	**14.43**	-	2.92	2.65
Begonia merrittii	-	-	-	**9.36**	-	2.92	1.88
Dicranopteris curranii	-	-	-	**9.62**	-	-	1.39
Elephantopus tomentosus	**14.76**	**14.55**	**15.80**	-	-	1.46	**8.45**
Oplismenus hirtellus	1.03	4.60	-	-	**17.82**	**8.12**	4.72
Ottochloa nodosa	**14.76**	-	4.11	-	-	-	4.59
Paspalum conjugatum	3.25	2.68	**20.44**	-	-	-	4.22
Pteridium aquilinum	**13.57**	**16.83**	4.68	-	7.36	-	**7.51**
Rubus benguetensis	-	3.84	-	1.69	**9.63**	1.46	2.38
Selaginella involvens	-	-	-	-	-	**7.79**	1.30

Note: most dominant species (boxed), second most dominant species (underlined), third most dominant species (shaded); P. – Pine Stations; D. – Depressed Stations

Table 2. Jaccard index of similarity between sampling stations in Alapang Communal Forest, La Trinidad.

Sampling Stations	Pine Peak	Pine Mid	Pine Lower	Depressed Peak	Depressed Mid
Pine Mid	0.282	_	_	_	_
Pine Lower	0.286	0.299	_	_	_
Depressed Peak	0.075	0.127	0.140	_	_
Depressed Mid	0.156	0.267	0.137	0.243	_
Depressed Lower	0.080	0.124	0.098	0.314	0.356
Present Study and Previous Study (Lumbres et al., 2010)					0.15

Margalef's at 7.75–9.70. On the other hand, depressed stations had Shannon index at 3.53–4.16, evenness at 0.87–0.92, Simpson's at 0.96–0.98 and Margalef's at 10.18–16.38. Canopy trees were consistently lowest in diversity, but species diversity was higher in shrubs and highest in herb/ grasses. Lowest diversity values were recorded in trees of pine stations which indicates the dominance of *P. kesiya*.

Jaccard Similarity Index. The Jaccard index of similarity between stations was presented in Table 2. The index of similarity was observed to be higher among pine stations (0.28 – 0.30) and among depressed stations (0.24 – 0.36). Lower values were observed between pine and depressed stations (0.08 – 0.27). The highest of Jaccard similarity index was found between depressed lower and depressed mid at 0.36. In contrast, depressed peak and pine peak recorded the lowest Jaccard similarity index value of 0.075. Moreover, the index of similarity between this study and previous inventory of Alapang Communal Forest was found low at 0.15.

Table 3. Carbon Stock of Alapang Communal Forest, La Trinidad, Benguet.

Sampling Stations	Carbon Pools (t/ha)			
	Tree	Understory & Litter	Soil	Total Carbon Stock by Station
Pine Peak Station	271.39[c]	1.32[a]	11.60[ab]	284.31[c]
Pine Middle Station	340.93[c]	1.63[a]	13.15[ab]	355.70[c]
Pine Lower Station	232.75[bc]	1.81[a]	15.08[b]	249.64[bc]
Depressed Peak Station	83.44[ab]	1.54[a]	12.37[ab]	97.36[a]
Depressed Middle Station	105.56[ab]	1.44[a]	11.99[ab]	118.98[ab]
Depressed Lower Station	35.62[a]	2.40[a]	11.21[a]	49.23[a]
Over-all Average Carbon Stock				192.54 t/ha
Estimated Total Carbon Stock of Alapang Communal Forest				6,931.44 t

Note: Means with the same letter in a column are not significantly different at 0.05 Tukey's Test

Forest Carbon

The estimated carbon stock of Alapang Communal Forest was presented in Table 3 across the carbon pools. Between carbon pools, tree contained the highest carbon followed by soil and least in the understory & litter. Pine stations had significantly higher tree carbon (232.75–340.93 t/ha) than depressed stations (35.62–105.56). Consequently, pine stations have the highest total carbon stock at 249.64–353.70 t/ha compared to 49.23–118.98 t/ha in the depressed stations. Station 2 had the highest mean carbon stored at 355.70 t/ha^{-1}, followed by Station 1 at 284.31 t/ha^{-1} and Station 4 at 249.64 t/ha^{-1}. On the other hand, Station 5 had the lowest total carbon stock at 49.23 t/ha^{-1}. Understory & litter carbon ranged from 1.32–2.40 t/ha and did not differ significantly between stations. On the other hand, soil carbon ranged from 11.21–15.08 t/ha with slightly higher values in pine stations that depressed stations. The carbon stock between the sampling station averaged at 192.54 t/ha and multiplying that with the total area of the forest, the total carbon stock of Alapang Communal Forest was estimated at 6, 931.44 t.

Ecological Patterns in Alapang Communal Forest

Results of the Bray-Curtis analysis on Alapang Communal forest were presented in Figure 5 (A to D). The over-all similarity between stations (Figure 5A) clearly showed the clear species distinction between the pine stations and depressed stations which is consistent with the Jaccard index of similarity above. However, if the comparison is limited between understory and tree species, the species composition of between depressed and pine stations were relatively similar, hence clustering closer (Figure 5B). Several understory species of pine stations were saplings of trees in the depressed stations. Nonetheless, the distinct clustering between pine stations and depressed stations were observed in the biodiversity indices (Figure 5C) and carbon stock (Figure 5D). Depressed stations have higher biodiversity indices than

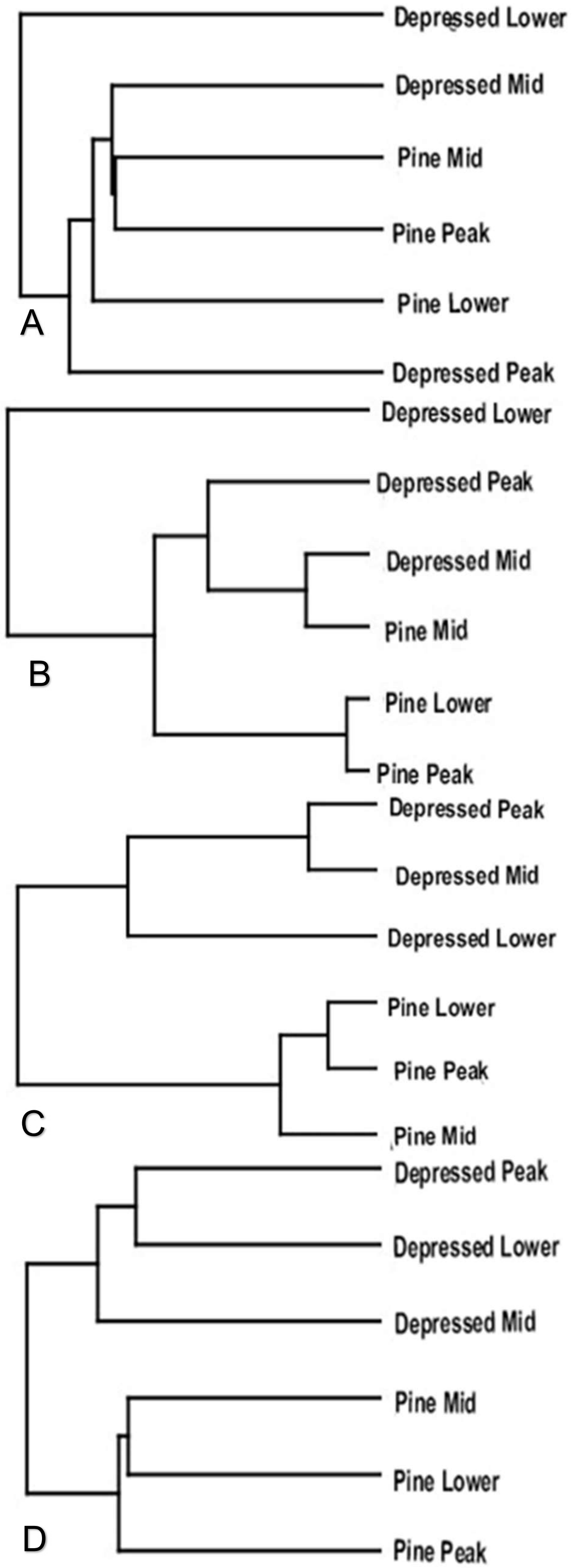

Fig. 5. Bray-Curtis Similarity in terms of all individuals (**A**), trees and sapling (**B**), biodiversity indices (**C**) and carbon stocks (**D**).

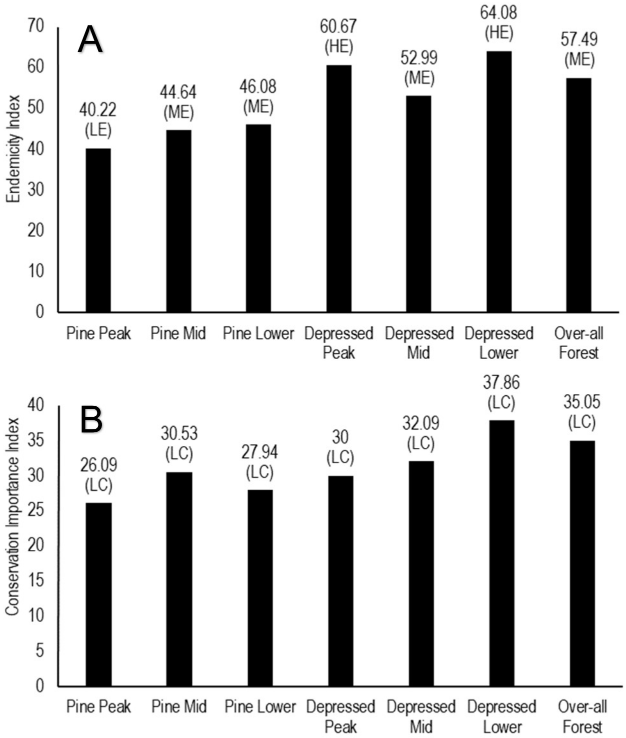

Fig. 6. The Endemicity Index (**A**) and Conservation Importance Index (**B**) in the sampling stations in Alapang Communal Forest (Note: **HE**= major presence of endemics; **ME**= moderate presence of native species; **LE** = high presence of exotic species; LC – low priority for conservation).

pine stations but the trend is opposite in terms of carbon stock, pine stations had much higher carbon than the depressed stations. Among pine stations, the Pine Mid elevation has the highest biodiversity indices and carbon stock which shows that biodiversity and carbon sequestration could be maximized together.

The endemicity index of Alapang Communal forest is at 57.49 that indicates moderate presence of native species (Figure 6A). Depressed stations had endemicity index of 53–64 indicative of generally high presence of native species while pine stations had 40–46 (low to moderate presence of native species). On the other hand, the conservation importance index of Alapang Communal Forest ranged at 26–37 (35 over-all) with lower values in pine stations and higher in depressed stations (Figure 6B)

Community Perspective on Alapang Communal Forest

Perception on Environmental Concepts. Results of the interview revealed a weighted mean score of 2.85 on level of familiarity for the term “Ecosystem” - making it the most familiar (Table 4). This was followed by “Communal Forest” and “Ecosystem Service” with a weighted mean score of 2.62 and 2.51, respectively. These implied that the respondents of the Barangay Alapang have a relatively high level of familiarity with these ecological terms.

Table 4. The Likert scale ratings on the familiarity of respondents on ecological terms (N=55).

Ecological Terms	Likert Scale				Weighted Mean	Qualitative Description
	4	3	2	1		
Communal Forest	8	23	19	5	2.62	F
Ecosystem	15	21	15	4	2.85	F
Ecosystem service	9	16	24	6	2.51	F

Legend: Qualitative Description (4-point Likert Rating Scale): VF-Very Familiar (3.25–4.0); F-Familiar (2.50–3.24); SNF-Slightly not familiar (1.75–2.49); NF-Not familiar (1.00–1.74)

Environmental Goods and Services. The respondents observed several environmental goods and services from the Alapang Communal Forest (Table 5). These include provisioning services such as clean water, raw materials, medicinal plants, and food production. Additionally, the forest provides regulating services such as carbon sequestration, erosion control, noise reduction, improved air quality, and climate regulation. The forest also contributes to cultural services through opportunities for contact with nature, outdoor recreation/ecotourism, aesthetic improvement, cultural heritage preservation, and spiritual and religious experiences. Moreover, supporting services like nutrient and water cycling, water purification, flood control, and climate regulation were recognized. While some services received slightly lower mean scores, overall, the residents perceived the forest to provide these services well. These were supported by the interviews with the Barangay Captain, MENRO, and BENRO. The Alapang Communal Forest is regarded as a crucial natural asset for La Trinidad and was established exclusively for the use of La Trinidad residents to access various forest products such as timber, firewood, resins, and stone.

The respondents perceived the provision of clean water and protection from extreme weather events as the most important ecosystem services from the communal forest. On the other hand, ecosystem services with cultural, aesthetic, and spiritual values are perceived with lower weighted mean scores. While not crucial for immediate survival, these services provide opportunities for cultural development and community building.

Perceived Threats on Alapang Communal Forest. The respondents identified habitat loss, introduction of non-native plants, pest and plant diseases, and climate change as the most significant threats to the communal forest (Table 6). These threats, although not categorized as severe, have the potential to harm the forest's health, resilience, and its ability to provide essential ecosystem services to the surrounding communities. Climate change received the highest rating among the challenges, indicating its increasing importance in the face of growing human populations. Other concerns raised include the lack of public involvement in the management and insufficient funds for forest management. These threats underscore the need for effective management strategies and community involvement to ensure the

Table 5. Perception on Ecosystem Services provided by Alapang Communal Forest (N=55).

Aspects /Services	Perceived Provision		Perceived Importance	
	Weighted Mean	Qualitative Description	Weighted Mean	Qualitative Description
Provisioning				
Clean water	3.29	PEW	3.78	MI
Raw materials (e.g timber)	3.02	PW	3.47	MI
Medicinal plants	2.78	PW	3.47	MI
Food production (e.g., fruit, nuts, wild mushroom)	2.87	PW	3.44	MI
Regulating				
Less storm runoff/flood damage	3.25	PEW	3.60	MI
Less heat in the barangay	3.27	PEW	3.47	MI
Erosion control	3.24	PW	3.47	MI
Less noise	3.15	PW	3.38	MI
Improve air quality	3.31	PEW	3.64	MI
Cultural				
Opportunities for contact with nature	3.33	PEW	3.42	MI
Public open space for outdoor recreation (Ecotourism)	3.16	PW	3.47	MI
Improve aesthetic	3.18	PW	3.29	MI
Cultural heritage	3.04	PW	3.31	MI
Spiritual and religious	2.93	PW	3.25	MI
Supporting				
Nutrient cycling	3.22	PEW	3.49	MI
Water cycling	3.31	PEW	3.51	MI
Flood control	3.16	PW	3.51	MI
Water purification	3.24	PEW	3.58	MI
Climate regulation	3.24	PEW	3.51	MI

Legend: PEW-Provided extremely well (3.25-4.00); PW-Provided well (2.50-3.24); PVP-Provided very poorly (1.75-2.49); NPA-Not provided at all (1.00-1.74); MI-Most important (3.25-4.00); I-Important (2.50-3.24); SNI-Slightly not important (1.75-2.49); NI-Not important (1.00-1.74)

Table 6. The perceived threats to Alapang Communa Forest in La Trinidad, Benguet (N=55).

Threats to Communal Forest	Likert Scale				Weighted Mean	Qualitative Description
	4	3	2	1		
Habitat loss	16	23	12	4	2.93	T
Non-native plants	13	21	16	5	2.76	T
Pest and plant diseases	12	30	9	4	2.91	T
Pesticide and herbicide use	13	23	16	3	2.84	T
Fertilizer use	9	21	14	6	2.66	T
Changes in climate	18	25	9	3	3.05	T
Increasing human population	16	25	10	4	2.96	T
Lack of public involvement in management	15	25	12	3	2.95	T
Lack of funds for management	13	26	12	4	2.87	T
Lack of public support for urban forest management	17	27	8	3	3.05	T

Legend: Qualitative Description (4-point Likert Rating Scale): ST-Severe threat (3.25-4.00); T-Threat (2.50-3.24); SNT-Slightly not threat (1.75-2.49); NTA-Not threat at all (1.00-1.74)

Table 7. Perceived Indicators for a Successful Management of Alapang Communal Forest (N=55).

Signs of successful communal forest management	Likert Scale				Weighted Mean	Qualitative Description
	4	3	2	1		
Trees and other vegetation are clearly groomed and maintained	29	26	0	0	3.53	SA
There are more trees	32	22	1	0	3.56	SA
Fewer falling tree limbs	24	31	0	0	3.44	SA
Less problems with pests	21	30	4	0	3.31	SA
More partnerships between citizen groups and urban forest managers	27	26	2	0	3.45	SA
More communal forest visitors	20	25	9	0	3.20	SA
Less/no flooding/run-off problems	26	28	1	0	3.45	SA
Increasing public access to communal forest	25	28	2	0	3.42	SA
Less trash/litter	24	29	2	0	3.40	SA
More satisfaction with the neighborhood	23	31	1	0	3.40	SA
More natural habitat for urban wildlife	27	24	4	0	3.42	SA

Legend: Qualitative Description (4-point Likert Rating Scale): SA-Strongly agree (3.25-4.00); A-Agree (2.50-3.24); D-Disagree (1.75-2.49); SD-Strongly disagree (1.00-1.74)

health and sustainability of the communal forest. Moreover, the key-informants mentioned additional threats to the Alapang Communal Forest, such as the presence of claimants and encroachers, as well as illegal wood harvesting, which were identified as severe threat. According to them, the communal forest need to be protected from any form of encroachment and illegal loggers to guarantee the availability of goods and services for the present and future generations.

Perceived Successful Indicators of Forest Management. The respondents perceived that effective communal forest management should be characterized by aesthetic and well-maintained trees and vegetation (Table 7). The presence of a greater number of trees and fewer instances of falling tree limbs were also seen as important markers of effective management. Respondents also valued the visual appearance of the communal forest and prioritize safety measures. Additionally, ecological aspects such as provision of natural habitat for urban wildlife and minimizing problems with pests were considered signs of successful management. Further, the Barangay Captain, MENRO and BENRO mentioned the crafting of a Forest Land Use Plan as a requirement for efficient planning and management of the Alapang Communal Forest and would facilitate the transfer of forest management responsibilities from DENR to the municipal LGU.

Willingness to protect. The survey results showed that all respondents are willing to protect and conserve the Alapang Communal Forest. Reasons include its role in providing clean water and fresh air, its ecological and cultural value, and its importance in maintaining the community's well-being. The forest's significance as a water source and pollution regulator is highlighted, as well as its ability to support wildlife and preserve the local ecosystem. Respondents also mention the forest's cultural heritage and its role in protection against natural disasters like floods. These findings demonstrated a high level of concern for the forest's conservation, driven by its ecological and cultural importance and its contributions to clean water and air.

DISCUSSION

Floral Diversity of Alapang Communal Forest

The floral diversity of Alapang Communal Forest in this study present some interesting trends from an ecological and biodiversity points of view. Its species richness in this study (187) is much higher than the 52 species in the previous inventory of Lumbres *et al*., (2010). Also, the dominant families in the previous inventory were Lamiaceae, Moraceae, Phyllanthaceae, Caprifoliaceae, Meliaceae, Myrsinaceae, and Rubiaceae while families Asteraceae, Poaceae and Phyllanthaceae in this inventory. The difference could be attributed to sampling intensity and focus since the previous inventory only involved three plots and focused on trees while the current inventory placed equal focus on trees, shrubs and herbs. Our result is also much higher compared to results of Lumbres *et al*. (2014) in the nearby Alno Communal Forest with 78 species under 43 families. Compared to other recent floral inventories in CCR, our result was also higher than the 68 species under 63 genera and 40 families documented by Guron *et al*. (2019) in Talinguroy Research Station, La Trinidad; the 61 species under 25 families by Batani *et al*. (2023) in Palina River, Kibungan; and the 52 species under 40 genera and 31 families by Rabena *et al*. (2015) in a muyong forest in Ifugao. This could be directly attributed to the more extensive inventory or sampling conducted in this study compared to these studies. On the other hand, our result is more comparable with other studies in CCR that involve similar intensive sampling. This include the study of Salcedo (2001) with 280 species under 180 genera and 84 families in the northern slope of Mt. Amuyao, Mountain Province; the study of Dulnuan and Napaldet (2023) with 249 vascular plant species belonging to 200 genera and 74 families in Amburayan River in Kapangan, Benguet; and, the study of Balangen *et al*. (2023) with 267 species belonging to 222 genera and 78 families in a secondary forest in Tadiangan, Tuba.

The richness of families Asteraceae and Poaceae in Alapang Communal Forest could be attributed to its secondary forest state with seasonal dry climate and its history of disturbance. The semi-temperate conditions of CCR is shown to be ideal for Asteraceae and the efficient mechanisms for rapid dispersal of their cypselae (fruit) allows their wide distribution in the region (Ladoan *et al*., 2020; Napaldet and Buot, 2019). This result is consistent with Guron *et al*. (2019) at the Talinguroy Research Station, La Trinidad that have Asteraceae and Poaceae as the most represented families. On the other, this contrast with the result of Co *et al*. (2006) in primary forest of Palanan, Isabela where the tree *Nephelium ramboutan-ake* is the most dominant plant.

The dominance of *Pinus kesiya* in Alapang Communal Forest is expected since it is basically a pine forest. This is consistent with the previous inventory of Lumbres *et al*. (2010) and their inventory (2014) in nearby Alno Communal Forest. However, the tree richness and composition is much different in depressed stations. In the ridge stations, the dominance of *P. kesiya* is thorough with few interspersed broad-leaf species but in the depressed stations, broad-leaf trees predominate. Shrub and herb species also differ significantly between ridge and depressed stations with higher species richness in the former which could be attributed to its shaded and moist conditions. These conditions could explain the high species richness of the study area. Pine forests, such as Alapang Communal Forest, are generally perceived as not highly diverse (Fernando and Cereno, 2011). However, our results show that pine forest in CCR may not be as highly diverse as the mossy forest and the lowland evergreen forest with which it shares its boundary but it may not be as poorly diverse as previously thought. An alternative explanation for this would be the secondary successioning state of Alapang Communal Forest towards a broad-leaf forest. According to Whitford (1911), prior to human impacts, the Philippines is predominantly a broad-leaf forests of one type or another. The dominance of *P. kesiya* in CCR is seen to be anti-climatic and is a by-product of the annual forest fires that kill saplings and seedlings of the broad-leaf species thereby maintaining the dominance of pine. In Alapang Communal Forest, the community aggressively protects it from forest fires and this allows the growth of varied understory flora and not just the hardy, weedy types.

These observations were also noted by Buot and Okitsu (1998) in Mount Pulag and David *et al*. (in press) in Puguis Communal Forest. The dominance of *P. kesiya* in mid-elevation areas (900–2300 masl) of CCR is argued to be a topo-edaphic climax maintained by fire which is analogous with the pure stand of *Pinus taiwanensis* in the lower montane forest of Taiwan (Hsieh *et al*., 1994). Kowal (1966) refers to this as the "Southeast Asian Tropical Pine Fire Climax Formation" which consists of a series of pyrogenic communities ranging from Assam in eastern India to the Philippines, and dominated by almost pure stands of *P. kesiya* and/or P. *merlkusii*. If the annual fire is allowed, the biodiversity of pine forest is expected to be low except in stream depressions that harbors broad-leaf species. However if the pine forest will be protected from fire, Kowal (1966) hypothesized that the montane forest would slowly expand from its relict areas in the stream depressions into the mesic pine forest, resulting in a young montane forest with its original pre-human boundaries, but probably somewhat different species composition. The pine forest would likewise develop mesic conditions and be invaded by broad-leaved trees. This could explain the relatively higher species richness in Alapang Communal Forest and it would be interesting to monitor its floral composition through time.

Biodiversity Indices. Generally, shrub and herbs have greater diversity indices than trees in Alapang Communal Forest. This is consistent with Langenberger (2004) who argued that species of understory vegetation are often more diverse than those of canopy trees. These findings suggest the need for equal focus to be given to both canopy and understory vegetation in forest inventory studies. Moreover, the diversity values were found higher in depressed stations than in the pine dominated ridge stations. The lower biodiversity indices in pine stations could be attributed to its allelopathic effect on herbs and shrubs. Nonetheless, the combination of these depressed and ridge stations further contribute to the overall high diversity indices of Alapang Communal Forest at *H*-index of 4.21, evenness of 0.80, Simpson's of 0.96 and Margalef's index of 25.27. These values indicate high diversity and are much higher compared to the previous inventory of Lumbres *et al.* (2010) at 2.66 (moderate diversity). These are also higher that those recorded in Talinguroy Research Station at 2.96, in Alno Communal Forest at 3.21 and in Mt. Kili-kili with *H*-index of 3.69, evenness of 0.50, Simpson's of 0.95 and Margalef's index of 14.60 (Batani *et al*., 2023). Our result is comparable with those recorded by Dulnuan and Napaldet (2023) in Amburayan River with *H*-index of 4.48, evenness of 0.57, Simpson's of 0.97 and Margalef's index of 31.42.

Carbon Stock of Alapang Communal Forest

The pine dominated ridge stations exhibited higher carbon content compared to the depressed stations, which could be attributed to the larger size and number of trees in the pine area. Statistical analysis confirmed the significant difference in carbon stock among the six stations, with larger trees in the pine area contributing to higher carbon storage. This is consistent with the observation of Patricio *et al.* (2010) that pine tree trunks are not only large but also are long-lived making them capable of storing a significant amount of carbon in a forest ecosystem. However, it is noted that despite its high carbon stock, the pine area had lower floral diversity compared to the depressed area, suggesting a trade-off between carbon stock and biodiversity.

The trees are the major carbon pool in Alapang Communal Forest. About 92% of the carbon mass in the forest was stored in the trees, with the soil accounting for about 6%. On the other hand, the understory and litter contributed the least to the carbon stock, with only 1% based on the gathered data. These results are consistent with a study conducted in a pine forest in Buguias, Benguet wherein majority of the carbon was stored in trees and soil (Parao *et al*., 2015).

The average carbon storage in Alapang Forest is 192.54 t/ha. This value is lower than the national average of 250 t/ha^{-1} for natural forests (Medina *et al*., 2020) and the carbon stocks of 418 t/ha reported in the Mount Makiling Forest Reserve (Lasco *et al*., 2004). Nonetheless, this shows that urban forest ecosystems like the Alapang Communal Forest play a crucial role in the climate change issue as they can act as sinks of atmospheric CO_2 (Lasco *et al*., 2002; Watson *et al*., 2000). Achieving a balance between carbon stock and biodiversity is essential for effective ecosystem management, considering the potential trade-off observed in this study.

Carbon stock helps mitigate climate change by providing a safe replacement for atmospheric carbon dioxide. The impact of climate change on ecosystems can also be determined using carbon stock studies. This is crucial for assessing how ecosystems will be affected by global warming and identifying vulnerable areas that may become a cause for concern. Identifying suitable areas for enhanced sequestration (carbon capture) will help mitigate ongoing human-induced carbon emissions. This information can create effective policies that help reduce greenhouse gas emissions. Carbon storage locations should also be identified to help implement forest management strategies that encourage the growth of specific forests capable of storing large amounts of carbon (Pechanec *et al*., 2022).

Carbon-stock assessment is necessary for the creation of stored carbon and carbon-sequestration maps, which are useful tools for providing decision-making support to prevent carbon-rich ecosystems from becoming carbon sources as a consequence of inappropriate management or land-cover changes, e.g., deforestation (Powlson *et al*., 2012). Carbon stock and sequestration belong to the regulating service categories by terrestrial ecosystems, according to The Economics of Ecosystems and Biodiversity and The Common International Classification of Ecosystem Services (CICES), respectively. They are perhaps the most recognized among all ecosystem services (Eggleston *et al*., 2006). The estimation of the carbon stock of Alapang Communal Forest in this study provides baseline information that can create effective policies that help reduce greenhouse gas emissions in the locality up to national level. Also, it is already an identified important carbon sink in the locality, both perceived by the local community and by the result of this study, due to its proximity to the town center, the carbon source.

Ecological Patterns in Alapang Communal Forest

The dendrograms from Bray-Curtis similarity further elucidate the ecological patterns in Alapang Communal Forest that were suggested from the floral diversity counts and carbon stock. A trade-off between biodiversity and carbon stock were clearly observed where depressed stations consistently have higher species richness, biodiversity indices and native species than pine stations. On the hand, the carbon stock is much higher in pine stations. This clearly shows that depressed stations are more important in terms of biodiversity while pine ridge stations are more important for carbon stock and sequestration. However, the mid pine station suggests that biodiversity and carbon sequestration could be maximized in the same area. This station is characterized by less disturbance, presence of large pine trees and saplings of broad-leaf trees. This result is one of the few evidences supporting the hypothesis of Kowal (1966) that the depressed stations were relict areas of the original montane forest in the region that would slowly expand into the mesic pine forest, resulting in a young montane forest. The pine forest would further develop mesic conditions and be eventually invaded by broad- leaved trees.

One of the major problems facing biodiversity conservation in the country or the region is habitat fragmentation wherein protection of large forest areas is no longer feasible. This consideration leads to the development of endemicity and conservation importance indices by Bullong *et al*. (2024) as guide for delineating priority spots for conservation in disturbed landscape. The endemicity and conservation importance indices of Alapang Communal Forest showed presence of several native species and some conservation important species that validates its continued protection. Further, these indices indicate the pattern of colonization of native species within the communal forest. The native and conservation important species predominantly occur in the relict areas in the stream depressions that slowly creep first into mid pine stations then into the peak and lower station. The latter colonization in the peak station could be attributed to its drier condition while the disturbed state of the farm areas near the lower stations also cause its drier condition and slower colonization by native species.

Community Perceptions

The respondents of the Barangay Alapang are fully aware on the importance and the role of ecological terms pertaining to their communal forest. However, environmental awareness alone is not sufficient to predict sustainable behaviour toward the preservation of the environment (Baral *et al*., 2019). A high level of environmental awareness does not necessarily indicate a high level of environmental behaviour (Klöckner 2013). Consequently, it may be useful in community-based programs and policies that aim to promote environmental awareness and protection of the environment in the area. Urban forests like Alapang play a vital role in addressing local environmental challenges and in providing diversified benefits, although they offer a limited range of ecosystem services compared to external ecosystems that urban populations depend on for food and energy (Jim and Chen, 2009).

Moreover, the respondents recognized the importance of considering ecosystem services in decision-making and planning for sustainable development. This is supported by the floral diversity and carbon stock result of this study showing that Alapang Communal Forest harbours high species richness including endemic and some conservation important species and also stores significant carbon that can be released if the forest is not managed properly. Managing urban forest ecosystem services and disservices at the appropriate scale and context allows communities and decision-makers to better understand the associated benefits and costs (Escobedo *et al*., 2011). By understanding the perceived value of ecosystem services, decision-makers can prioritize investments and policies that enhance community well-being while preserving environmental resilience and sustainability. The key-informant MENRO mentioned that the communal forest is an important sources of water and forest materials that help sustain the socio-economic development and welfare of the residents. This is consistent with the observation of Chechina *et al*., (2018) that if communities passively rely on forest resources such as clean water and soil qualities, then conservation in itself can be seen as beneficial with minimal attention given to livelihood development.

However, threat were also perceived by the respondents. They are recommending that decision-makers should prioritize policies that promote the forest's sustainability and resilience while considering the community's needs. By understanding the level of threat, appropriate measures can be implemented to address these concerns and protect the communal forest effectively (Mayer, 2018). Moreover, understanding the community's perspective enables planners and managers to prioritize conservation efforts and address specific issues through targeted interventions and improved forest management (Trickett, 2009). The community's active engagement and support underscore the need for inclusive decision-making processes, fostering effective forest conservation and sustainable development initiatives.

CONCLUSION

This study provided empirical evidences on the ecological role played by tropical communal forest using the specific case of Alapang Communal Forest in La Trinidad, Benguet, Philippines. Consequently, results provided scientific basis for the continued protection of this communal forest particularly its high plant diversity, presence of native and conservation important species and high carbon content. A total of 187 plant species belonging to 145 genera and 70 families were recorded in the forest with high native species, high diversity indices and an average carbon stock of 192.54 t/ha. Ridge stations were dominated by *Pinus kesiya*, with lower diversity but higher carbon stock while depressed stations were dominated by broad-leaf trees, with higher diversity but with lower carbon stock. This suggests a trade-off between carbon stock and biodiversity in pine forest like Alapang Communal Forest. Further, the floral diversity of the study area strongly suggests that pine forest in CCR may not be as highly diverse as the mossy forest and the lowland evergreen forest with which it shares its boundary but it may not be as poorly diverse as previously thought. The importance of the forest is known by the resident respondents including the forest goods and services it provides. However, some threats were still observed such as illegal logging and forest encroachment. Consequently, they all agree for the continuous protection of the communal forest. Our results affirm and provide empirical evidences on the critical importance of communal forests particularly on biodiversity conservation, carbon capture and storage and cultural relevance towards the attainment of Sustainable Development Goals (SDGs). Locally, these results need to be disseminated as baseline for conservation plans and instructional materials for biodiversity and ecology subjects.

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