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THE ROLE OF NATIVE TREES IN TROPICAL FOREST REGENERATION: THE CASE OF *FICUS MINAHASSAE* (TEIJSM. & DE VRIESE) MIQ. (MORACEAE) IN BENGUET, PHILIPPINES

Jormene W. Abuel[1], Grazel T. Dagdagui[1], Jennifer C. Paltiyan-Bugtong[2] & Jones T. Napaldet[2, *]

[1]*Benguet State University, Philippines*
[2]*Biology Department, Benguet State University, Philippines*

**j.napaldet@bsu.edu.ph*

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Remnant focal trees that attract frugivores in disturbed landscapes, like *Ficus* spp., are now being promoted for forest regeneration in tropical forest in support for the attainment of SDG 15. In this study, we provided empirical evidence for the ecological function of *Ficus minahassae* for landscape restoration in lowland evergreen forest. Its litters provide significant nutrient return, particularly potassium (675–810 kg/ha), nitrogen (460–465 kg/ha) and phosphorus (100–120 kg/ha). The organic matter return ranges at 277.10 – 450.40 g/week under lowland evergreen forest in Tuba and 580.60–1196.20 kg/ha under pine forest in Bakun. These nutrient returns support the high density and diversity of sapling under this species. The sapling density under *F. minahassae* ranges from 0.74 to 1.12 sapling/m^2 in Tuba with 33 species and 0.27 to 0.44 sapling/m^2 in Bakun with 19 species. These sapling density and sapling diversity are higher than under *Pinus kesiya* at 0.24 to 0.32 sapling/m^2 with 11 species. Another interesting finding in the study is the role of *F. minahasssae* as shade tree for *Pterocarpus indicus*, a vulnerable species. Additionally, some cultural importance of *F. minahasssae* were documented to the Kankana-ey and Ibaloi tribe in Benguet. These findings highlight the ecological and cultural importance, in addition to its medicinal properties, of *Ficus minahassae* for forest restoration in its native range.

Keywords: Nutrient return, sapling density, sapling regeneration, associated species, cultural valuation

INTRODUCTION

The Sustainable Development Goal 15 of the 2030 Agenda for Sustainable Development is devoted to *"protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss"*. The year 2021–2030 is declared as the Decade on Ecosystem Restoration where the importance of finding nature-based solutions to restore vital ecosystems around the globe and combat global warming is stressed. Restoration design should be grounded in science and supported by extensive technical studies, including hydrodynamic modeling, sediment sampling and endangered species surveys.

Agricultural-related clearings is one of the major drivers of deforestation in tropical forests (Achard et al. 2002, Phillips et al. 2017, Dulnuan & Napaldet 2023). Consequently, large tracts of continuous rainforest have been converted to fragmented patches of remnant forest and secondary regrowth, situated amongst mosaics of agricultural land and human settlements (Gerstner et al. 2014, Elgar et al. 2014). Understanding the natural regeneration processes and dynamics of tree and shrub species are essential in sustainable management and restoration of these denuded habitats (Ge & Xie 2017, Poorter et al. 2021). Studies on natural regeneration and seedling ecology can provide options for forest development through improvements in recruitment, establishment and growth of desired seedling species (Gārtner et al. 2011, Viveiros et al. 2021). Hence, determining seedling species diversity, richness and distribution, and how these relate to environmental factors, can help guide ecosystem restoration of denuded tropical forests (Mwavu

& Witkowski 2009, Kim et al. 2022, Zhao et al. 2021, Balangen et al. 2023).

Another important factors to understand forest regeneration are litter yield and nutrient return (Ge & Xie 2017, Wang 2018, Liu et al. 2022). Leaf litter is an important survival strategy for seedlings and saplings to cope with adverse growth conditions, such as soil drying due to temperature reduction or drought (Xu et al. 2013). Also, forest litter is an important structural and functional unit of material circulation and energy flow in the forest ecosystem. Important functions of leaf litters have irreplaceable ecological roles, and a large amount of organic matter and mineral elements are transported from the canopy of plants to the soil surface through the litter (Pitman 2013). Therefore, the collection and measurement of forest litter are important means of studying the structure and function of forest ecosystems including regeneration (Aerts et al. 2012, Guo et al. 2015, Zheng et al. 2022).

Ficus trees are known to play important roles in ecological restoration (Castillo-Diaz et al. 2021). They are known as keystone species for frugivorous vertebrates. Studies have shown that fig fruits constitute over 50% of chimpanzees' diet in Africa, up to 70% for some primate species in Peru, and almost the entire diet of some Neotropical bat species (Beck 2008). Moreover, *Ficus* are important in sapling regeneration. Cottee-Jones et al. (2016) had shown that the density of saplings growing under *Ficus* trees was twice as high as the density of saplings growing under other non-*Ficus* trees.

Ficus minahassae, a native of the Philippines, Indonesia and Malaysia, is mentioned to be potential for landscape restoration by virtue of its ecological and architectural function (Saroinsong 2020). However, there is a need to properly document these functions, specifically its role in forest restoration. The medicinal properties of this tree have already been documented in several studies – with its roots being boiled by Higaonon people of Mindanao to cure fatigue or muscle pain; it containing chemicals such as steroid, flavonoid, saponin, tannin, and polyphenol (Barcelo 2015); and, its leaves showing antibacterial activity against *Staphylococcus aureus* (Talley et al. 2020).

Pocyoy and Napaldet (2024) argued for the combined ecological and cultural studies on tropical forests and tropical trees. While there have been studies on these by some authors (Lumbres et al. 2014, Chechina et al. 2018, Hugé et al. 2022), however often, these were tackled singly and not collectively and thus, a major data gap that this study aims to contribute.

This study aimed to document the role played by *F. minahassae* in forest regeneration and nutrient return in the secondary forests of Benguet, Philippines. Specifically, the study analysed the sapling diversity and density under *F. minahassae,* its NPK and organic matter return and its cultural importance to the surrounding community. Documenting these ecological and cultural importance, in addition to its medicinal properties, would highlight the importance of *Ficus minahassae* for forest restoration in its native range. Also, the study hopes to contribute in presenting a more holistic view on the ecological and cultural aspect of tropical trees and start building these up as important baseline for tropical forests.

MATERIALS AND METHODS

Study site

Two sites were identified for the conduct of the study, namely Dalipey, Bakun and Camp 4, Tuba in the province of Benguet, Northern Philippines (Figure 1). The area falls under tropical savanna climate of the Köppen climate classification, with rainy days from May to October followed by the dry spells from November to April (Balangcod et al. 2011, Balangen et al. 2023). Average temperature ranges at 23.3–26.9 ˚C while the average rainfall is 4107.39 mm/year.

Tree density and tree diameter at breast height

The study is limited to characterising the sapling diversity and density under *F. minahassae,* its NPK and organic matter return and its cultural importance to the surrounding community. However, other factors could affect the abovementioned characters such as such as tree density and tree dbh characters but were not included as additional treatment in the study. Hence here, these characters are given as intervening variable. The study site in Dalipirip, Bakun is a secondary pine forest

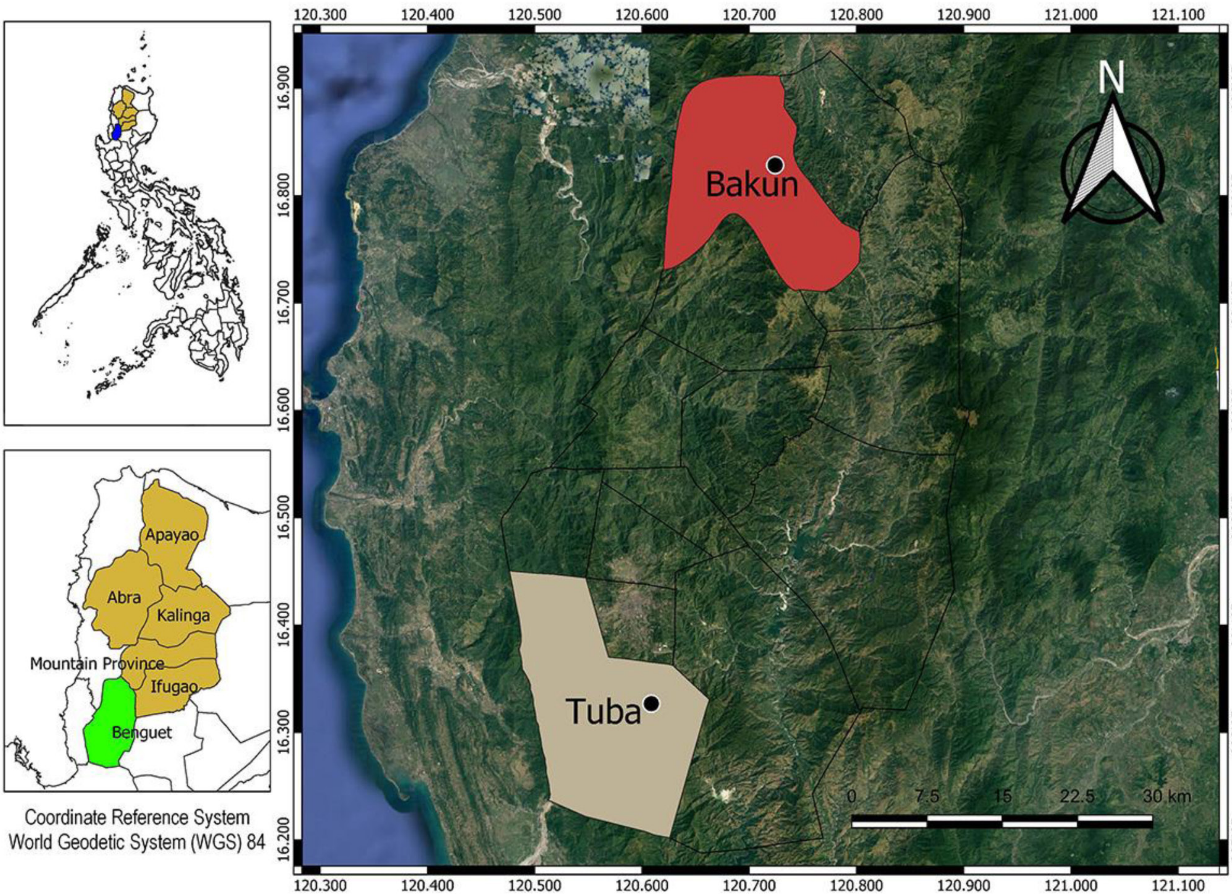

Figure 1 Map of Benguet showing the sampling sites of the study

while the site in Camp 4, Tuba is a secondary lowland evergreen forest – the two most common forest types in Benguet. Generally, pine forest in Benguet has an estimated tree density of 1079 trees ha^{-1} and basal area of 44.95 m^2 per ha (Pocyoy & Napaldet 2024) while lowland evergreen forest has tree density of 562 trees per ha and basal area of 42.97 m^2 per ha (Balangen et al. 2023). In Bakun station, *F. minahassae* has a stem density of 100 per ha and basal area of 9.28 97 m^2 per ha while *P. kesiya* has a stem density of 750 per ha and basal area of 34.43 m^2 per ha. These corresponds to *F. minahassae* contributing 9.27% to the stem density and 20.65% to the basal area while *P. kesiya* constitutes 69.51% of the stem density and 76.59% of the basal area. On the other hand, *F. minahassae* in Tuba station has a stem density of 125 per ha and basal area of 13.87 m^2 per ha constituting 22.24% and 32.27% of the stem density and basal area, respectively. By comparing the two sites, we can have an idea on how *F. minahassae* affects sapling regeneration between two types of secondary forest. In every site, three relatively same-sized *F. minahassae* trees were randomly selected as focal tree for nutrient return and sapling regeneration analysis. Bakun trees have dhb of 17.51, 17.83 and 19.74 cm with height of 7.67, 7.26 and 8.51 m while Tuba trees have dbh of 21.65, 23.87 and 18.78 with height of 8.42, 9.12 and 6.69.

Sapling density and regeneration analysis.

Sapling sampling is used to assess the importance of *Ficus minahassae* in forest restoration. In this sampling, the researchers compared the sampling density under the canopy of *F. minahassae* and *Pinus kesiya*, the dominant tree in the area. This was done by conducting population counts of saplings (<5 cm dbh and <3 m height) under the canopy of each focal tree. Three 3 × 3 m plots were laid-out randomly at 3 meter, 6 meter, and 9-meter circular annulus from each focal tree (Figure 2) for a total of 9 plots. The species identified in the field were verified in Co's Digital Flora (Pelser et al. 2011-), the authority on Philippine flora.

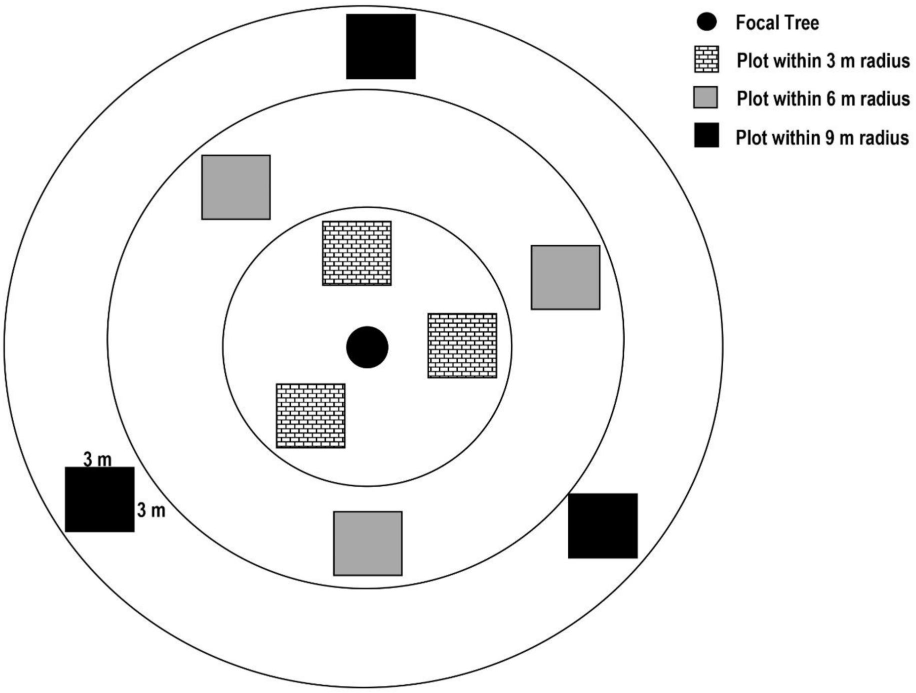

Figure 2 Lay-out of the sapling sampling in the study sites

Additionally, the sapling regeneration was assessed through diversity indices, namely, species richness (SR), Shannon Index (SI) and Shannon Evenness Index (SEI) as adapted from Boakye et al. (2012). Species richness represents the measure of the species variability based simply on the number of species in a particular sample (Fedor & Zvaríková 2019). Supplementary SI was also assessed to estimate the diversity of the species since species richness alone is not sufficient to conclude the diversity of the species in an area. Species evenness was also calculated, since it is a measure of the relative abundances of species within a community (Ostfeld & Keesing 2017). The diversity of saplings is an indicator on the extent and capability of the *F. minahassae* to contribute to forest regeneration.

Evaluation of nutrient return from litterfall of *F. minahassae.*

Litterfalls were collected for three months (September–November 2021) using a net with an area of 1 m^2 (Bao-idang et al. 2016) placed just above the ground in the same plots where sapling density were analysed. *Ficus minahassae* is a small evergreen tree with intermittent leaf fall throughout the year. Nine (9) litter collection baskets were randomly positioned under the individual tree canopies. The leaf litter were collected in a week for three consecutive months. The collected leaf litters were separated from the reproductive parts, fine woody materials and residue, discarding any animal material or scarce adhering mineral material. The samples were then weighed, oven dried, and stored for treatment. The biomass and nutrient return of the litterfall were determined.

For biomass determination, the leaf litters were oven dried at 65 °C for 48 hours and weighed to measure the dry weight and moisture content. On the other hand, the nitrogen, phosphorus and potassium (NPK) content were analysed in the Department of Agriculture at Sta. Barbara, Pangasinan. The total nitrogen (N) was determine thru Kjeldahl method, total phosphorous (P) by Vanadomolybdate method, and total potassium (K) by Flame Atomic Emission Spectroscopy. All tests were done in three replicates. From these values, the amount of nutrients released (ANR) in the forest floor was determine using the formula of Luna (1988) then converted to kg/ha. This is done by multiplying the oven-dry weight of the collected leaf litter with the corresponding nutrient content (%). The data between the two sampling sites were compared using t-test.

Cultural Importance of *Ficus minahassae*.

The socioeconomic importance of *Ficus minahassae* was documented through interview. In each site, 15 purposively-selected respondents were interviewed. The respondents were those identified knowledgeable on the local flora particularly elders. The data from the interview was treated using ethnobotanical indices such as use-value (UV) index, factor of informant consensus (FIC) and fidelity level. These were computed using the following formulae:

$$\text{Use} - \text{Value Index (UV)} = \frac{\text{Number of Particular Use (U)}}{\text{Number of Informants (N)}} \quad (1)$$

$$\text{Factor of Informant Consensus (Fic)} = \frac{\text{Nur}-\text{Nt}}{\text{Nur}-1} \quad (2)$$

where Nur = number of mention per particular use and Nt = number of groups of particular use

$$\text{Fedility Level (Fl)} = \frac{\text{NP}}{\text{N}} \times 100 \quad (3)$$

where NP = number of informants who cited the species for the particular use and N = is the total number of informants that mentioned the plant for any use

High UV indicates high use reports for a plant implying its relative importance to the local community. Low UV indicates few reports related to its use (Polat et al. 2015). On the other hand, factor of informant consensus (F_{IC}) refers to the total usage of plant species according to culture applicability. Lastly, the fidelity level quantifies the importance of a species for a given purpose and is calculated with the formula.

RESULTS

Sapling diversity and regeneration under *Ficus minahassae*.

A total of 33 species were recorded in Tuba stations and 19 in Bakun stations that are much higher compared to 11 species recorded under pine (Table 1). In Tuba stations, several sapling of native species were found dominant under *F. minahassae* such as *Pterocarpus indicus, Tabernaemontana pandacaqui*, *Cipadessa baccifera, Oreocnide rubescens*, *Ficus variegata* and *Ficus septica.* The Bakun stations have dominant sapling of native species like *Grewia multiflora* and *Mallotus mollissimus* intermix with cultivated plants like *Coffea arabica* and *Persea americana.* On the other hand, the dominant saplings under pine are *Mallotus mollisimus, Alnus japonica*, *Prunus rubiginosa* and *Grewia multiflora.*

Table 1 Species Diversity under *Ficus minahassae* and Pine tree

Ficus minahassae (Tuba)		*Ficus minahassae* (Bakun)		*Pinus kesiya* (Bakun)	
Sapling Species	IV	Sapling Species	IV	Sapling Species	IV
Acalypha amantaceae	1.13	*Breynia macrantha*	5.37	*Alnus japonica*	13.06
Aglaia accuminata	0.89	*Coffea arabica*	6.78	*Clethra canescens* var. *luzonica*	5.05
Aglaia cumingiana	0.89	*Cypholophus moluccanus*	5.31	*Cypholopus moluccanus*	5.93
Anaxagorea luzonensis	0.89	*Debregeasia longifolia*	3.58	*Ficus benguetensis*	2.96
Ardisia elliptica	0.89	*Eurya chinensis*	3.58	*Ficus septica*	6.97
Atalantia racemosa	1.79	*Ficus ampelas*	3.58	*Grewia multiflora*	10.98
Breynia cernua	0.89	*Ficus benguetensis*	6.08	*Leucaena leucocephala*	2.96
Canarium ovatum	1.79	*Ficus septica*	6.08	*Maesa indica*	12.90
Cipadessa baccifera	8.13	*Gliricidia sepium*	1.79	*Mallotus mollisimus*	24.20
Clausena anisum-olens	2.77	*Grewia multiflora*	14.21	*Prunus rubiginosa*	12.02
Coffea canephora	0.89	*Leucaena leucocephala*	3.58	*Viburnum luzonicum*	2.96
Drypetes maquilingensis	0.89	*Maesa indica*	6.78		
Elaeagnus triflora	3.15	*Mallotus mollissimus*	7.87		
Ficus septica	3.85	*Morus alba*	1.79		
Ficus variegata	4.04	*Mussaenda benguetensis*	1.79		
Kanapia monstruosa	2.68	*Neonauclea reticulata*	1.79		
Leea guineensis	1.13	*Persea americana*	12.86		

Ficus minahassae (Tuba)		*Ficus minahassae* (Bakun)		*Pinus kesiya* (Bakun)	
Sapling Species	IV	Sapling Species	IV	Sapling Species	IV
Litsea cordata	0.89	*Psidium guajava*	3.58		
Macaranga tanarius	2.02	*Turpinia ovalifolia*	3.58		
Maesa indica	0.89				
Mallotus mollissimus	0.89				
Melanolepis multiglandulosa	0.89				
Melia azedarach	2.02				
Micromelum minutum	2.02				
Oreocnide rubescens	4.70				
Pipturus arborescens	2.25				
Pittosporum pentandrum	0.89				
Polyalthia lanceolata	0.89				
Pterocarpus indicus	33.06				
Senna siamea	1.79				
Senna spectabilis	0.89				
Tabernaemontana pandacaqui	9.20				

Bold font = dominant saplings

Table 2 Saplings Density within the 3 meter, 6 meter, and 9 meter distance radius from *Ficus minahassae* and Pine tree

Shade Tree	Sapling Density (n/m^2)			Sapling Density (n/ha^{-1})		
	3 m radius	6 m radius	9 m radius	3 m radius	6 m radius	9 m radius
Ficus minahassae (Tuba)	$0.74^{a\ II}$	$0.76^{a\ II}$	$1.12^{a\ II}$	7400	7600	11200
Ficus minahassae (Bakun)	$0.27^{a\ I}$	$0.36^{a\ I}$	$0.44^{a\ II}$	2700	3600	4400
Pinus kesiya (Bakun)	$0.24^{a\ I}$	$0.32^{a\ I}$	$0.24^{a\ I}$	2400	3200	2400

Means with the same letter in the row are not significantly different at 0.05 Tukey's test; means with the Roman numeral in the column are not significantly different at 0.05 Tukey's test

The sapling diversity is more similar between *Ficus minahassae* (Bakun) and *Pinus kesiya* (Bakun). This could be readily attributed to their similar general biome – them being located in a pine forest. Much of their sapling difference is due to difference in shading tolerance. Several saplings under *Ficus minahassae* (Bakun) are known shade tolerant under broad-leaf streams while saplings under *Pinus kesiya* (Bakun) are known sun-exposed species along pine forest ridges and openings. On the other hand, the sapling diversity is much different under *F. minahasae* in Tuba stations which could be attributed to its different forest biome – a secondary lowland evergreen forest.

Several saplings were recorded under *F. minahassae* with increasing number the farther from the tree bole (Table 2). The increasing number of sapling the farther from tree bole is expected because of the close canopy of *F. minahassae* with minimal light penetration under it. The highest sapling numbers were recorded in Tuba at 60–91 individuals with sapling density of 0.74–1.12 sapling/m^2. Lower number of sapling and sapling density was observed in Bakun stations but is still higher compared to the saplings under pine.

The diversity indices of sapling under *F. minahassae* in comparison with those under *Pinus kesiya* are presented in Figure 3. Amidst the high species richness in Tuba stations, its Shannon index falls under low diversity because of the high dominance of *Pterocarpus indicus*. Consequently, its evenness falls under

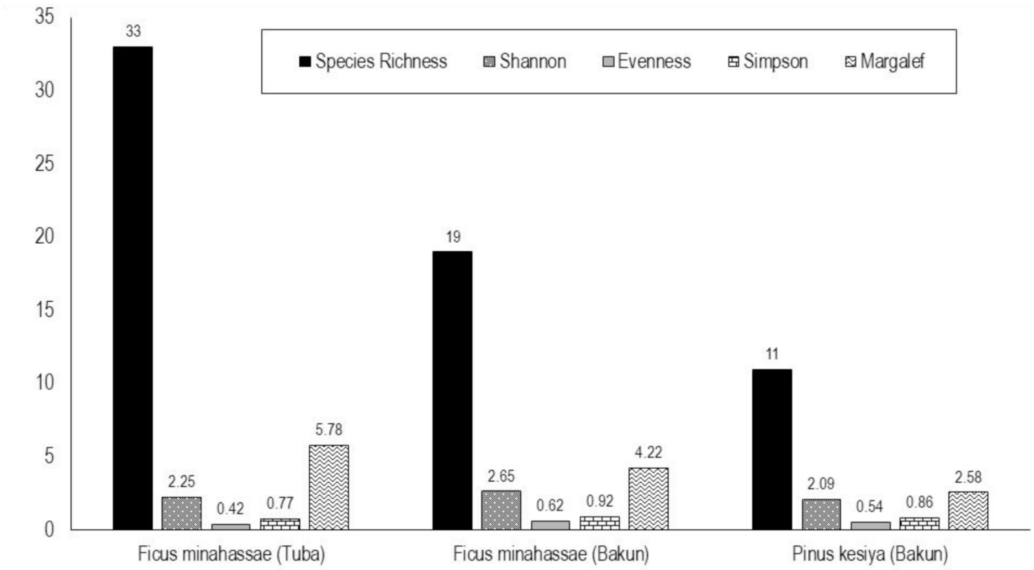

Figure 3 Diversity indices for Sapling under *Ficus minahassae* vis-à-vis Pine tree

Table 3 The monthly litterfall, NPK and amount of nutrients released (ANR) from *Ficus minahassae*

Collection month	BAKUN (Secondary Pine Forest)		TUBA (Secondary Lowland Evergreen)	
	Litterfall (kg/ha/month)		Litterfall (kg/ha/month)	
September	2280.0$^{ns\ a}$		1090.4$^{ns\ a}$	
October	4000.0$^{**\ ab}$		1261.3$^{**\ a}$	
November	4386.7$^{**\ b}$		1795.3$^{**\ a}$	
Nutrient Total	BAKUN (Secondary Pine Forest)		TUBA (Secondary Lowland Evergreen)	
	Nutrient Content (%)	ANR (kg/ha)	Nutrient Content (%)	ANR (kg/ha)
Nitrogen (N)	0.93^{ns} (±0.22)	99.20	0.92^{ns} (±0.05)	38.98
Phosphorus (P)	0.20^{ns} (±0.04)	21.33	0.24^{ns} (±0.03)	10.09
Potassium (K)	1.35^{ns} (±0.12)	48.12	1.62^{ns} (±0.34)	67.32

ns = no significant difference between rows at 0.05 t-test; ** = highly significant difference between rows at 0.05 t-test; means with same letter in a column are not significantly different at 0.05 Tukey's Test

less balanced but its Margalef's index is high species richness. The sapling under Bakun station has moderate diversity at Shannon index, semi-balanced evenness and high diversity under Simpson's index. On the other hand, the sapling under pine has low diversity at Shannon index and low species richness at Margalef's index.

Nutrient Return

The nitrogen (N), phosphorous (P), and potassium (K) content of the collected litterfall of *Ficus minahassae* are presented in Table 3. The percent N, P and K per 50g litterfall for Bakun are 0.93, 0.20, and 1.35 respectively while 0.92, 0.24, and 1.62 for Tuba. The NPK content between the two sites did not differ significantly ($p>0.05$). On the other hand, the amount of nutrients released (ANR) for the three-month observation time is estimated at 99.20 kg/ha N, 21.33 kg/ha P, and 48.12 kg/ha K in Bakun while 39.98 kg/ha N, 10.09 kg/ha P, and 67.32 kg/ha K in Tuba.

On the other hand, the moisture content, and biomass of *F. minahassae* litters were

Table 4 General perceptions by the surrounding community on *Ficus minahassae*

Community perceptions	Tuba	Bakun
F. minahassae local name		
"Alumit"	15	15
Known habitat of *F. minahassae*		
Hillside	0	3
Near streams	13	10
Rocky areas	0	5
Near springs	0	2
Wetland	1	0
Shaded area	1	0
Observed ecological uses of *F. minahassae*		
Water source	14	13
Animal (e.g Bird food)	11	8
Carbon sequestration	9	2
Soil erosion reduction	13	6
Water ways purification	9	9
Animals shelter	12	11
Compost	3	0
Passers-by shade	2	0

monitored for 3 consecutive months. Both sites showed a decreasing trend of moisture content which would indicate that as the month progresses from September to November, the climate is starting to rain less. The litterfall ranges from 2280–4386.7 kg/ha in Bakun while significantly lower at 1090.4 1795.3 kg/ha in Tuba. The litterfall increases as the month reaches November with significantly higher values in Bakun.

Cultural importance of *Ficus minahassae.*

The cultural importance of *F. minahassae* was compared between the two sampling stations (Table 4). Tuba is primarily an Ibaloi community while Bakun is a Kankana-ey community. In both communities, the local name of *F. minahassae* is "alumit". The community observed it to commonly occur near streams while some respondents added that *F. minahassae* are also found thriving along wet places, shaded areas or near springs.

In terms of ecological importance, the community acknowledge its role as source of water during summer, its contribution in reducing soil erosion and its importance to wildlife. Additionally, some of the respondents also noted it as source of compost and the shade it provides for passers-by. It is also important as foodsource to wildlife and as shelter to various animals. Lastly, the fruit of *Ficus minahassae* is edible not only for animals but also to humans.

The most common uses of *F. minahassae* in Tuba and Bakun are as compost, firewood and as food to wildlife (Table 5). The leaves and fruits that fall to the ground are naturally composted and are being collected to be sold or personal use for houseplants. The compost is collected each time it is available. Aside from compost, the fruits serve as food to animals especially birds in the area. The roots are also used as compost and as sources of water and the branches are used as firewood when thoroughly dried.

When ranked according to importance, majority of the Tuba residents regarded the fruit as the most important part. Even though the respondents do not harvest water from the tree, the residents still consider it as the second most important characteristic. Third in rank is the

Table 5 Particular uses of *Ficus minahassae* by the surrounding community in Tuba and Bakun

Plant part	Use/s	No. of mentions	Time of collection	Used fresh or dried	Rank according to importance				
					1	2	3	4	5
Particular uses of *Ficus minahassae* in Tuba									
Leaf	Compost	3	once composted	Dried	3				
Branch	Firewood	3	throughout the year	Dried	2		1		
Fruit	Compost	14	once composted	Dried		2			
	Bird food	1		Fresh	12				
Root	Water Source	4	throughout the year	Fresh	4				
	Compost	1	once composted	Dried	1				
Particular Uses of *Ficus minahassae* in Bakun									
Branch	Firewood	2	throughout the year	Dried		1	1		
Fruit	Food	10	every time it bears fruit	Fresh	10				
Over-all	Compost	1	once composted	Dried		1			

Table 6 Ethnobotanical Indices for *Ficus minahassae* in Tuba and Bakun

Specific uses	Use Value (UV)	Factor of Informant Consensus (FIC)	Fidelity Level (FL)
Ficus minahassae in Tuba			
Compost from Leaves	0.20	1.50	20.00
Firewood	0.20	1.50	20.00
Compost from Fruit	0.87	0.58	86.67
Bird food from fruits	0.07	0.00	6.67
Water from roots	0.20	1.50	20.00
Compost from roots	0.07	0.00	6.67
Ficus minahassae in Bakun			
Food	0.67	0.78	66.67
Firewood	0.13	1.00	13.33
Compost	0.06	0.00	6.67

leaf as compost followed by branch as firewood. The compost from the tree was ranked as the most important asset of the tree. On the other hand, residents of Bakun ranked the food aspect as the most important use for the tree, followed by firewood, then compost.

The ethnobotanical indices, namely, use value (UV), factor of informant consensus (FIC) and fidelity level (FL) for *Ficus minahassae* are presented in Table 6. In Tuba, the UV ranges at 0.07–0.87 with the highest value for fruit as compost (0.87) followed by firewood (0.20), water from the roots (0.20) and compost from leaves (0.20). The least used were the fruit for bird food (0.07) and compost from roots (0.07). Although compost is also from leaves and roots of the plant, the compost from the fruit had the most use value because it consists the majority of the harvested compost. Compost from roots and bird food from fruits were least because these were not usually observed by the people in their daily activities. In Bakun, the highest UV is the fruit as food (0.67) followed by firewood (0.13) and least as compost (0.06). This indicates that residents of Bakun have commonly benefited from *F. minahassae* as food.

Factor informant consensus (FIC) values ranges from 0 to 1.5 indicating that the exchange of information on the uses of *F. minahassae* is not evident in both communities. This can be associated to the weak cultural importance of the species to the Ibaloi and Kankana-ey people. On the other hand, the fidelity level (FL) in Tuba shows that the compost from the fruit has the highest importance with 86.67 followed by the compost from leaves (20), firewood (20), and water from roots (20), then bird food from fruits and compost from roots (6.67). Thus, the composted fruit of *Ficus minahassae* is the most preferred and most important use in Tuba. On the other hand, the fidelity level in Bakun ranges from 6.67 to 66.67. Relative to UV, the most preferred use for *F. minahassae* is the fruit as food followed by the use of branches as firewood and as compost. Most residents of Bakun gather *F. minahassae* as food due to the great number of its fruits. But unlike in Tuba where compost was the most used and considered most important asset of *F. minahassae*, the Bakun residents seldom gather compost from it because they prefer to gather instead from *Alnus japonica*.

DISCUSSION

Sapling density regeneration.

Significant number and diversity of sapling were documented under *Ficus minahassae*. The sapling diversity and density is much higher than those documented in *Pinus kesiya* which is the dominant tree in pine forest ecosystems in the region. One of the interesting findings in the study is the abundance and dominance of *Pterocarpus indicus* saplings, a vulnerable species, under *F. minahassae*. This result indicates the *F. minahassae* serves as shade tree in the natural propagation of *Pterocarpus indicus* in the wild. Our result is consistent with the study of Cottee-Jones et al. (2016) that found *Ficus* trees to have more sapling species around them than non-Ficus trees. Their results plus ours suggest that large *Ficus* trees are more effective forest restoration agents than other remnant trees in disturbed landscapes, and therefore the conservation of these trees should be prioritised.

Ficus species generally produce several fruits providing a rich feast that attracts a host of mammals and birds. When *Ficus* grows as isolated trees, they act as stepping-stones for forest animals in open habitats (Martin et al. 2009, Rafidison 2020). They also function as nuclei accelerating plant succession, as the frugivorous animals that visit them disperse seeds of forest plants in their droppings. These seeds germinate and establish, forming small patches of vegetation around these focal trees (Carrière 2002, Rafidison 2019, Castillo-Diaz et al. 2021). The same could be said for the case of *F. minahassae* that supports 33 species in lowland evergreen forest and 19 species in pine forest. These results provide direct evidences for the ecological function of *F. minahassae* as mentioned by Saroinsong (2020).

Restoring degraded lands to forest cover is an increasingly important conservation priority in the tropics (Poorter et al. 2021, Chazdon et al. 2009). In areas where remnant trees have survived deforestation, these structures can play an important role *in* forest recovery (Holl et al. 2013). Remnant trees attract frugivores across disturbed landscapes, thereby facilitating seed dispersal, stabilizing local microclimatic conditions and providing nutrients under their canopies – that improve seedling recruitment rates (Zahawi & Augspurger 2006, Liu et al. 2022). Additionally, seed dispersal has often been cited as a limiting factor in forest restoration (Zahawi et al. 2013, Chen et al. 2021) that could be remedied by fleshy-fruited trees that attracts frugivores over disturbed habitats and thus prove to be more effective restoration nuclei than other species (Slocum 2001). *Ficus* in particular is believed to be a very important genus of fleshy-fruited tree for a wide range of frugivores including over 1200 tropical birds and mammals that have been recorded consuming *Ficus* fruit (Kinnaird & O'Brien 2005, Peabotuwage et al. 2019).

Nutrient return

In forest ecosystems, litterfall is an important component of nutrient cycle that regulates the accumulation of soil organic matter (SOM), the input and output of the nutrients, nutrient replenishment, biodiversity conservation, and other ecosystem functions. Therefore, a profound understanding of the major processes (litterfall production and its decomposition rate) in the cycle is vital for sustainable forest management

(SFM). Despite these facts, there is still a limited knowledge in tropical forest ecosystems, and further researches are highly needed. This shortfall of research-based knowledge may be a contributing factor to the lack of understanding on the role of plant litter in the forest ecosystem function for sustainable forest management, particularly in the tropical forest landscapes (Castillo-Diaz et al. 2021, Poorter et al. 2021, Giweta 2020). Hence, our results on nutrient return from the litters of *Ficus minahassae* could contribute to this limited knowledge on litters of tropical forest landscapes.

Potassium has the highest ANR value from *F. minahassae* followed by nitrogen and phosphorus. This is expected because potassium is the nutrient most easily released from leaves, while much of the nutrients are part of the organic structure of the plant tissue and require microbial decomposition to release them such as the nitrogen fixing bacteria for nitrogen and the mycorrhizal fungi for phosphorus (Tripler et al. 2006). These results show that nutrient return from *F. minahassae* serve as a significant source of nutrients in its immediate vicinity within the tropical forest ecosystems. This also justifies why the community gather compost from the tree because of the significant nutrient return from its litters.

Our result is consistent with the study of Tegegne (2008) that shows another *Ficus* species, *Ficus thonningii*, to be useful in soil fertility maintenance and fodder production in Ethiopia. The tree contributes 1623.5 and 877 kg N ha^{-1} respectively under and outside the tree canopy in 0–10 cm soil layer. Similarly, 945.5 and 847 kg P ha^{-1} and 24,700 and 16,800 kg C ha'^{-1} respectively, were found under and outside the tree canopy. The amounts of exchangeable cations of soils under *F. thonningii* were also higher than in the open both in the 0–10cm and in 10–20cm depth, for all cations except Mg and Al. For Mg and Al lower contents were registered at one crown radius distance away from the base of trees and higher contents in the open pasture than under tree canopy. The CEC of the soils was greater than 40 mmoU/100g and generally, soils under canopy had higher CEC than the outside canopy soils. The species has no adverse effects on the soil physical and chemical properties. These results suggest that *F. thonningii* can widely be used in association with crops and pasture in agroforestry systems.

Our results showed the increasing litterfall contributed by *Ficus minahassae* as the time progresses towards drier months. Much greater litterfall was observed in Bakun which could be attributed to its drier climate. The plant need to shed the biomass that it cannot support or the damaged ones that fall as litters. This agree with other studies showing that litter and their effects are affected by temperature, moisture, and other microclimate factors. Several authors (Pant & Tiwari 1992, Devis & Yadav 2007, Tripathi et al. 2009) have reported that the rate of litter decomposition was slow in winter and fast during rainy season, and the major reasons for the higher litter decomposition rate in rainy season could be the presence of sufficient rainfall, suitable moisture, and higher micro-fungal populations. Pant & Tiwari (1992) and Kumar et al. (2010) also concluded that there is a high rate of litter decomposition and an increase in weight loss in rainy seasons due to high rainfall, soil moisture, and microbial load. Nonetheless, this shows that litter provides readily available nutrients to plants because it incorporates organic carbon into soil through nutrient cycling processes. Furthermore, litter plays a great role in improving soil quality by transferring nutrients from the aboveground biomass to the soil (Vitousek & Sanford 1986, Zheng et al. 2022, Zhao et al. 2022), increasing the cation exchange capacity and water holding capacity of the soil (Argao et al. 2009).

Cultural importance of *Ficus minahassae*

In several regions, *Ficus* trees have enhanced cultural status through their associations with major religions, local faiths, or traditional belief systems. *Ficus* trees are used as sites of worship in many faiths, and taboos on cutting down large *Ficus* trees have been reported from several sites across Asia (Wilson & Wilson 2013). The cultural standing of *Ficus* trees may be instrumental in conserving their populations in rural landscapes by lowering mortality from direct felling, potentially increasing their importance as food sources for frugivores and restoration sites for plants. These cultural considerations also mean that *Ficus* trees are commonly found on public land: along roads, in markets, in town squares, and at temple sites

(Cottee-Jones et al. 2015).

Ficus minahasssae is considered a valuable fig because every part of it is useful (Philstar 2011). This fig is believed to enhance water availability in rice-cultivated landscapes (Borelli & Conigliaro 2014). It has also been traditionally used in the Visayas as a water source by wounding near the trunk base or root cutting. During periods of drought in the nineteenth century, this species was a lifesaver for the local people of Cebu, often as the only source of water (Blanco 1845).

However, our study shows *F. minahasssae* to be of some cultural importance only to Kankanaey and Ibaloi tribe in Benguet. No significant belief system or tradition was centered on this species but at the same time, it is not threatened rather encouraged to grow as it was believed to be associated with water production. Its cultural importance, though limited, provides further incentive for it to be conserved and promoted as a focal tree for natural forest regeneration.

CONCLUSION

Our study provided direct evidences for the ecological function of *Ficus minahasssae* on forest regeneration. One interesting finding in the study is the role of *F. minahasssae* as shade tree for *Pterocarpus indicus*, a vulnerable species. Its litters provide significant nutrient return particularly potassium, nitrogen and organic matter content. These nutrient returns, in turn, support the high density and diversity of sapling under this species. These results affirm the general observation that *Ficus* spp. have higher sapling density compared to non-*Ficus* species. Additionally, some cultural importance of *F. minahasssae* were documented to the Kankana-ey and Ibaloi tribe in Benguet. These findings highlight the ecological and cultural importances, in addition to its medicinal properties, of *Ficus minahassae* for forest restoration in its native range.

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