

Understory Crop Diversity in Coconut-Based Agroforestry: A Case Study of Ongkaw Dua Village, Sinonsayang District, South Minahasa Regency

Euis F. S. Pangemanan*, Josephus I. Kalangi, Fabiola B. Saroinsong

Department of Forestry, Faculty of Agriculture, Sam Ratulangi University, Kampus Bahu Street, Manado 95115, North Sulawesi, Indonesia, Telp./Fax. (0431) 864386/85371.

*Email correspondence: euisfspangemanan@unsrat.ac.id

Received: Nov. 27th 2025 | Revised: Sept. 11th 2026 | Accepted: Sept. 11th 2026 | Published: Sept. 30th 2026

Abstract. Coconut-based agroforestry systems are a form of land use that integrates trees with crops. The presence of understory plants in this system plays an important ecological and economic role. This study aims to identify the types, analyze the diversity, and study the habitus of understory plants growing under coconut trees. The method used is the plot method by creating 10 x 10 meter observation plots placed in agroforestry areas. The study's results identified 31 types of understory plants, belonging to various habits, including herbs, shrubs, lianas, and epiphytes, originating from 23 families. This high diversity indicates that coconut-based agroforestry systems are capable of creating microhabitats that support the conservation of native flora. Most of the understory plants also have potential as food and medicinal plants, which adds to the economic value of this cultivation system. The results of this study demonstrate that coconut-based agroforestry is not only commercially productive but also makes a significant contribution to biodiversity conservation.

Key words: agroforestry; coconut; conservation; diversity; understory plants.

How to cite: Pangemanan, E. F. S., Kalangi, J. I., Saroinsong, F. B. 2026. Understory Crop Diversity in Coconut-Based Agroforestry: A Case Study of Ongkaw Dua Village, Sinonsayang District, South Minahasa Regency. *Jurnal Bios Logos* 16 (2): 170-179. DOI: <https://doi.org/10.35799/ydv94242>.

INTRODUCTION

Agroforestry is a system in which land is utilized by integrating trees, crops, and livestock at the same time. In various regions of Indonesia, this agroforestry system has been widely practiced and has become part of the local wisdom of the local community. Agroforestry is one of the systems considered capable of addressing land management issues, thereby enhancing biodiversity (Sanchez, 1995), providing livestock feed (Cubbage et al., 2012), reducing erosion and flooding, and increasing land productivity (Yusran, 2005)

In North Sulawesi, especially in the South Minahasa region, the agroforestry system has been practiced. This practice of agroforestry, especially coconut-based agroforestry, has long been developed among the community as part of local wisdom. The traditional agroforestry system in this region is not only an economic strategy but also a cultural heritage that reflects the harmony between the utilization of natural resources and efforts to preserve them. Based on research conducted in various villages in South Minahasa, the agroforestry system has been practiced for generations in various patterns such as agrisilviculture: a combination of agriculture and forestry (Yoman et al, 2017; Ratag et al, 2024; Laratmase et al, 2022; Rante et al, 2022), agrosilvofishery: a combination of fisheries, forestry, and agriculture (Toding et.al, 2022; Oping et al, 2023;), and agrosilvopasture : a combination of livestock and woody crops (Gusti et al, 2022; Pontoh et al, 2024; Putra et al, 2024) The implementation of this agroforestry system demonstrates the lack of understanding among the local community about how to optimize land use without neglecting ecological sustainability.

In coconut-based agroforestry, coconut (*Cocos nucifera*) often serves as the main crop that forms the upper canopy stratum. However, the importance of researching the diversity of understory plants in this system in particular is often overlooked. Nevertheless, this diversity of understory plants plays an important role in maintaining ecosystem stability and community



welfare. A study conducted in North Halmahera shows that coconut-based agroforestry systems with mixed patterns (which include other crops such as nutmeg and horticultural or food crops) provide a much higher Internal Rate of Return (IRR) (up to 117%) compared to coconut monoculture systems (48%) (Lewerissa, 2024). This data supports the hypothesis that diversity in the lower strata not only helps with water conservation and soil health but also increases income and reduces the risk of crop failure. In addition, it is known that agroforestry systems store carbon better than monoculture or scrub systems.

Although coconut-based agroforestry systems and their diversity are known to have potential and benefits, specific research on the composition, diversity, and role of understory plants in a particular location is still limited. The village of Ongkaw Dua in Sinonsayang Subdistrict, South Minahasa Regency, may be one of the areas that has been implementing this system for a long time. This village has local wisdom similar to that of neighboring villages such as Wanga and Pakuweru (Kila et al, 2021). As a result, it is very important to conduct research on the diversity of understory plants in coconut-based agroindustry in this village. This study will not only document biological diversity and traditional management techniques that may not yet have been recorded but will also find ways to lead to a more productive and sustainable agroindustrial system in the future. In addition, this research will serve as a scientific basis for local wisdom preservation policies relevant to nature conservation.

The village of Ongkaw in Sinonsayang Subdistrict, South Minahasa Regency, is a location where coconut-based agroforestry practices are widely found. However, to date, documented information on the diversity of understory plants living under the shade of coconut plantations in this village is still very limited. In fact, understanding the richness of species and the role of these understory plants is very important for developing optimal agroforestry management strategies. This identification is not only beneficial for the conservation of local biodiversity but also for revealing economic potential that has not been exploited by the community.

Based on the background described above, this study aims to identify the types of understory plants found in coconut-based agroforestry areas in Ongkaw Village, Sinonsayang District, South Minahasa. In addition, this study seeks to identify the habitus or life forms and potential uses of each understory plant species found in the study area. Furthermore, the study aims to analyze the diversity of understory plants within the coconut-based agroforestry system in Ongkaw Village, Sinonsayang District, South Minahasa.

METHODS

The research was conducted in Ongkaw Dua Village, Sinonsayang Subdistrict, South Minahasa Regency, from September to November 2025, which included determining respondents, conducting interviews, collecting data, and analyzing data. The materials and tools used included tools and materials for observing the types of undergrowth in coconut-based agroforestry, digital cameras, writing instruments, GPS, and so on. This study used an exploratory method. The collected data were analyzed using descriptive and comparative analysis and presented in the form of descriptions, tables, and figures. The method used was the plot method by creating 10 x 10 meter observation plots placed in the agroforestry area of each respondent that had been determined. All types of plants found in the sample plots were recorded by type and number. There were 6 sample plots.

The collected data was analyzed using the following ecological indices:

Shannon-Wiener Species Diversity Index

$$(H') : -\sum (p_i) \ln (p_i)$$

where Σ : Greek symbol meaning "number", $\ln$: Natural log and π_i : Proportion of the entire community consisting of species i .

Margalef Species Richness Index (R)

$$R = (S - 1) / \ln N$$

where: S is the total number of species found, N is the total number of individuals.

Pielou Species Evenness Index (E)

$$E = H' / \ln S$$

where: H' is the Shannon-Wiener Diversity Index, S is the total number of species.

RESULTS AND DISCUSSION

The people of South Minahasa have passed down knowledge about how to manage land sustainably. This local wisdom involves the use of agroforestry patterns as part of a better and more environmentally friendly agricultural system. They utilize various types of plants that grow together to create a diversity of plants that support each other, which is also in line with the value of mutual cooperation that exists in community life. Coconut, as one of the long-established crops, is planted together with other trees or plants to maintain soil fertility and reduce dependence on a single crop.

Agroforestry is a system that is considered capable of solving land management problems, thereby promoting forest expansion and increasing biodiversity (Sanchez, 1995), emission reduction (Murthy et al., 2013; Rusolono, 2006), providing animal feed (Cubbage, et al., 2012), reducing erosion and flooding, increasing land productivity (Yusran, 2005) and profitability of total farm income (Graves et al., 2007). The distribution of species is indirectly influenced by interactions between the vegetation itself, temperature, air humidity, and soil physical-chemical properties, which produce specific environmental conditions that determine the presence or absence of a species and its distribution with varying levels of adaptation (Nahdi et al., 2014).

Table 1. Diversity of Understory Plants in Coconut-Based Agroforestry in Ongkaw Dua Village, Sinonsayang Subdistrict, South Minahasa Regency and their habits.

No	Name	Species	Family	Uses
1	Rambutan	<i>Nephelium lappaceum</i>	Sapindaceae	Fruit
2	Pisang	<i>Musa sp.</i>	Musaceae	Fruit
3	Bete	<i>Colocasia esculenta</i>	Araceae	Food
4	Mangga	<i>Mangifera indica</i>	Anacardiaceae	Fruit
5	Pandan	<i>Pandanus amaryllifolius</i>	Pandanaceae	Spices
6	Katuk	<i>Sauropus androgynus</i>	Phyllanthaceae	Vegetables
7	Kacang tanah	<i>Arachis hypogaea</i>	Fabaceae	Food
8	Kunyit	<i>Curcuma longa</i>	Zingiberaceae	Medicinal plants
9	Daun afrika	<i>Vernonia amygdalina</i>	Asteraceae	Medicinal plants
10	Nilam	<i>Pogostemon cablin</i>	Lamiaceae	Essential oils
11	Ubi kayu	<i>Manihot utilissima</i>	Euphorbiaceae	Food
12	Gedi	<i>Abelmoschus manihot</i>	Malvaceae	Vegetables
13	Rica	<i>Capsicum frutescens</i>	Solanaceae	Spices
14	matoa	<i>Pometia pinnata</i>	Sapindaceae	Fruit
15	cengkih	<i>Syzygium aromaticum</i>	Myrtaceae	Essential oils
16	lamtoro	<i>Leucaena leucocephala</i>	Fabaceae	Animal feed
17	Rumpu sosapu	<i>Sida rhombifolia</i>	Malvaceae	Animal feed / essential oils
18	costus	<i>Costus spicatus</i>	Zingiberaceae	Weeds/medicinal plants
19	Wedelia	<i>Wedelia trilobata</i>	Asteraceae	Weeds/medicinal plants
20	Teki	<i>Kyllinga mlonochepala</i>	Cyperaceae	Weeds/medicinal plants

21	Pecut kuda	<i>Stachytarpheta indica</i>	Verbenaceae	Weeds/medicinal plants
22	Rumpu sopi	<i>Ageratum conyzoides</i>	Asteraceae	Weeds/medicinal plants
23	Kentangan	<i>Borreria latifolia</i>	Rubiaceae	Weeds/medicinal plants
24	Jotang	<i>Cynedrela nudiflora</i>	Asteraceae	Weeds/medicinal plants
25	Awur-awur	<i>Commelina diffusa</i>	Commelinaceae	Weeds/medicinal plants
26	Ekor kucing	<i>Acalypha indica</i>	Euphorbiaceae	Weeds/medicinal plants
27	Ekinokloa	<i>Echinochloa crusgalli</i>	Poaceae	Weeds/medicinal plants
28	Rumput israel	<i>Asystasia gangetica</i>	Acanthaceae.	Weeds/medicinal plants
29	Tagalolo	<i>Ficus septica</i>	Moraceae	Weeds/medicinal plants
30	Rfumpu kenop	<i>Hyptis capitata</i>	Lamiaceae	Weeds/medicinal plants
31	Putri malu	<i>Mimosa pudica</i>	Fabaceae	Weeds/medicinal plants

Many species are used by the community as ingredients for medicinal plants and kitchen spices. Some species are cultivated as a source of income, for example rambutan, banana, and patchouli. However, there are also many wild/weed plants that are not cultivated, but their existence is still preserved for traditional medicinal purposes. This is in line with the research by Hadi, Widyastuti, and Wahyuono (2016), who found several species from the Zingiberaceae family in the research location, and these species are used by the community as ingredients for spices, medicine, and for cultural rituals. while some species are cultivated as a source of income.

Agroforestry plays an important role in providing habitat for various plant and animal species and beneficial microorganisms, thereby conserving biodiversity within an ecosystem. Agroforestry can also increase biodiversity. Without agroforestry, many species may have become extinct. Land areas dominated by intensive agriculture still require the presence of many natural species, especially those related to soil biodiversity (Sumilia and Syarif, 2019).

The high diversity of vegetation types that make up agroforestry land shows great potential as a source of germplasm, which is very important for the development of new plant varieties and conservation efforts (Saputra et al, 2016). As for understory plants, they show an uneven distribution with more prominent dominant species (Sumilia and Syarif, 2019).

Table 2. Number of Individuals, Frequency, Usefulness, and Habitus of Understory Plants in Coconut-Based Agroforestry in Ongkaw Dua Village, Sinonsayang Subdistrict, South Minahasa Regency

No	Name	Number of Individuals	Frequency	Habitus
1	<i>Nephelium lappaceum</i>	21	4	tree
2	<i>Musa sp</i>	57	5	shrub
3	<i>Colocasia esculenta</i>	42	5	grass
4	<i>Mangifera indica</i>	3	3	tree
5	<i>Pandanus amaryllifolius</i>	23	2	shrub
6	<i>Sauropus androgynus</i>	2	1	shrub
7	<i>Arachis hypogaea</i>	12	1	shrub
8	<i>Curcuma longa</i>	7	2	grass
9	<i>Vernonia amygdalina</i>	1	1	shrub
10	<i>Pogostemon cablin</i>	35	1	shrub
11	<i>Manihot utilissima</i>	9	2	shrub
12	<i>Abelmoschus manihot</i>	3	3	shrub
13	<i>Capsicum frutescens</i>	7	3	shrub
14	<i>Pometia pinnata</i>	1	1	tree
15	<i>Syzygium aromaticum</i>	3	1	tree
16	<i>Leucaena leucocephala</i>	3	2	tree

17	<i>Sida rhombifolia</i>	4	3	shrub
18	<i>Costus spicatus</i>	1	1	grass
19	<i>Wedelia trilobata</i>	9	2	shrub
20	<i>Kyllinga monocarpala</i>	18	5	grass
21	<i>Stachytarpheta indica</i>	7	4	shrub
22	<i>Ageratum conyzoides</i>	14	6	shrub
23	<i>Borreria latifolia</i>	7	2	grass
24	<i>Cynedrela nudiflora</i>	5	2	grass
25	<i>Commelina diffusa</i>	7	3	grass
26	<i>Acalypha indica</i>	2	1	shrub
27	<i>Echinochloa crusgalli</i> ,	15	6	grass
28	<i>Asystasia gangetica</i>	7	3	herbs
29	<i>Ficus septica</i>	6	5	shrub
30	<i>Hyptis capitata</i>	6	6	shrub
31	<i>Mimosa pudica</i>	11	6	shrub

The high diversity index value (Shannon-Wiener Diversity Index $H' = 2.961$) observed at the research site indicates that the structure of the understory plant community in the coconut-based agroforestry system in Ongkaw Village is stable and balanced. This value is much higher than the findings in monoculture oil palm plantations in Riau, which only reached 1.89 (Nahlunnisa et al, 2016). This significant difference reinforces the argument that the complexity of the vertical structure in traditional agroforestry systems creates more diverse ecological niches, which can accommodate more species.

In terms of vegetation structure, there is a balanced mix of species between dominant species (such as bananas and betel nut) and other rarer species, with no excessive dominance by one or two species and fairly good uniformity. This diverse vegetation cover has the potential to reduce erosion, while varied root systems can increase soil porosity. The by-products of undercropping (cassava, chili, turmeric, katuk leaves, etc.) can increase farmers' income and control pests and diseases naturally due to the presence of refuge plants and natural enemies. However, competition for water, nutrients, and light between undercropping and coconut trees needs to be managed properly and more intensively than in monoculture systems.

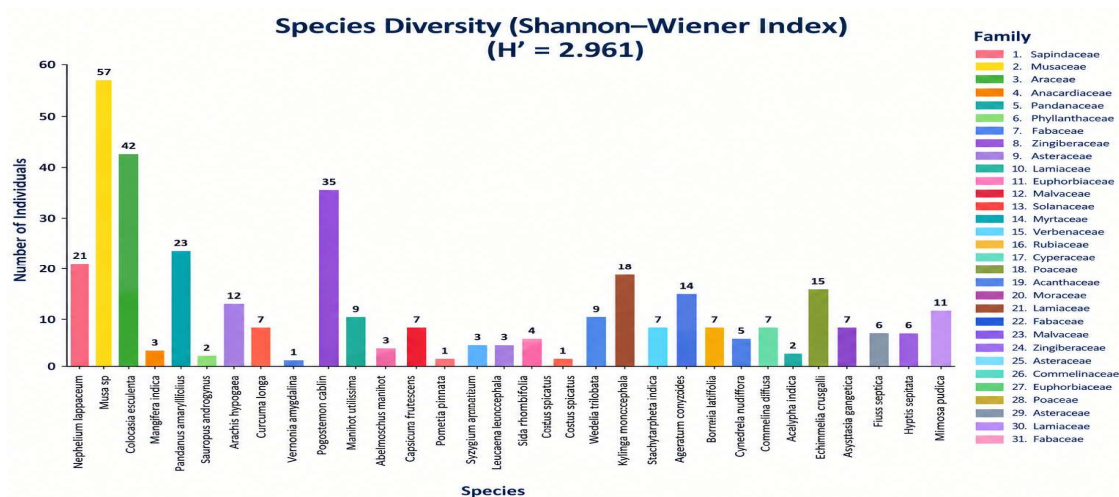


Figure 1. Shannon-Wiener Diversity Index H' (2.961) of Understory Plants in Coconut-Based Agroforestry in Ongkaw Dua Village, Sinonsayang Subdistrict, South Minahasa Regency

The H' value of 2.961 in coconut agroforestry understory plants in Ongkaw Dua Village indicates a healthy, productive, and ecologically sustainable system. This system has successfully combined the production function of coconut and understory plants with the function of biodiversity conservation, which is the core of agroforestry. Based on the results obtained, the Shannon-Wiener Diversity Index (H') value of 2.961 for the understory plant community in the coconut-based agroforestry system indicates a high level of biodiversity. This value not only reflects good species richness, marked by the presence of 31 identified species, but also a relatively even distribution of individuals among these species (evenness).

Based on the Margalef Species Richness Index (R) calculation of 5.126, this value indicates high species richness because $R > 5$. With $R = 5.126$, this agroforestry system has high species richness. This indicates the complexity of the understory plant community, with 31 recorded plant species, where this highly diverse composition exceeds most monoculture systems and demonstrates a significant level of ecological complexity. This complex habitat structure shows the presence of well-developed vegetation stratification.

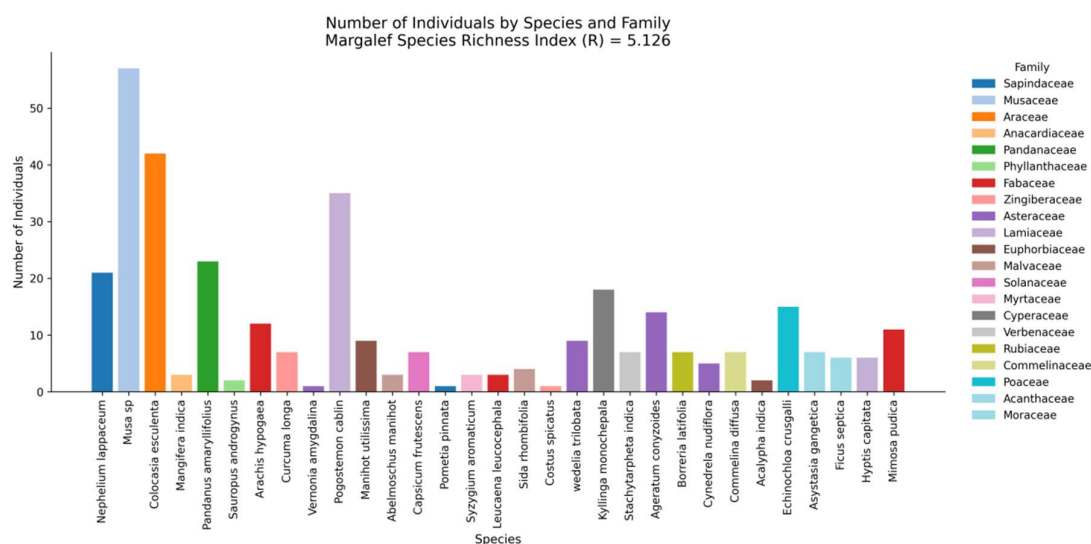


Figure 2. Margalef Wealth Index (R) (5.126) of Understory Plants in Coconut-Based Agroforestry in Ongkaw Dua Village, Sinonsayang Subdistrict, South Minahasa Regency

The Margalef Index $R = 5.126$ indicates that the coconut-based agroforestry system in Ongkaw Dua Village has: excellent underplant species richness, a complex and stable community structure, high productivity and sustainability potential, and optimal ecosystem services. This value proves that agroforestry systems can be a solution for ecological intensification that combines production with biodiversity conservation, while also demonstrating greater system resilience compared to monocultures.

The Margalef Species Richness Index (R) value of 5.126 obtained from the understory plant community in the coconut-based agroforestry system indicates a relatively high level of species richness. The Margalef Index is an effective tool for evaluating species richness in a community by considering the relationship between the number of species (S) and the total number of individuals (N) in an ecosystem. This R value of 5.126 reflects that the agroforestry system is capable of supporting a fairly complex diversity of understory plant species, which is not only indicated by the number of species recorded (31 species) but also by the distribution of individuals observed.

When compared to similar research findings in various locations, the R value of 5.13 in this agroforestry system shows quite impressive performance. Research conducted by Torres et al. (2014) in traditional Filipino agroforestry systems reported Margalef Index values for understory plants ranging from 3.8 to 4.7, which are lower than the values found in this study. Similarly, research in the agroforestry landscape of Costa Rica by Somarriba et al. (2013) recorded an average R value of 4.2 for the understory plant strata. These differences may be due to variations in management intensity, age of the agroforestry system, and local edaphic conditions.

However, when compared to more complex agroforestry systems such as those studied by Bhagwat et al. (2008) in Southeast Asia, where some systems showed Margalef values reaching 6.5, the values obtained in this study were still in the medium-high range. It should be noted that agroforestry systems that have reached an advanced stage of succession and are connected to natural forest fragments tend to exhibit higher species richness values. This finding is consistent with research in the Amazon conducted by Deheuvels et al. (2014), which reported that agroforestry systems with permanent shade and high organic inputs tend to have greater understory plant species richness.

This R value of 5.13 is also higher than that of coconut monoculture systems, where research by Nair et al. (1993) in India reported Margalef values for understory plants of only around 2.1-3.4. This reinforces the proposition that the integration of coconut trees with other vegetation in agroforestry systems significantly increases the ecosystem's carrying capacity for understory plant diversity. The practical implication of this finding is that coconut-based agroforestry systems function not only as production units but also as biodiversity buffers, which should be considered in in-situ conservation policies.

Pielou's Evenness Index (E) = 0.862 for understory plants in coconut-based agroforestry in Ongkaw Dua Village. A value of 0.862 indicates high species evenness, as it is close to 1, meaning that the distribution of individuals between species is fairly even. This means that there is a balanced distribution of individuals with no excessive dominance by one or a few species; each species gets relatively balanced space and resources, and the understory plant community is inclusive rather than exclusive.

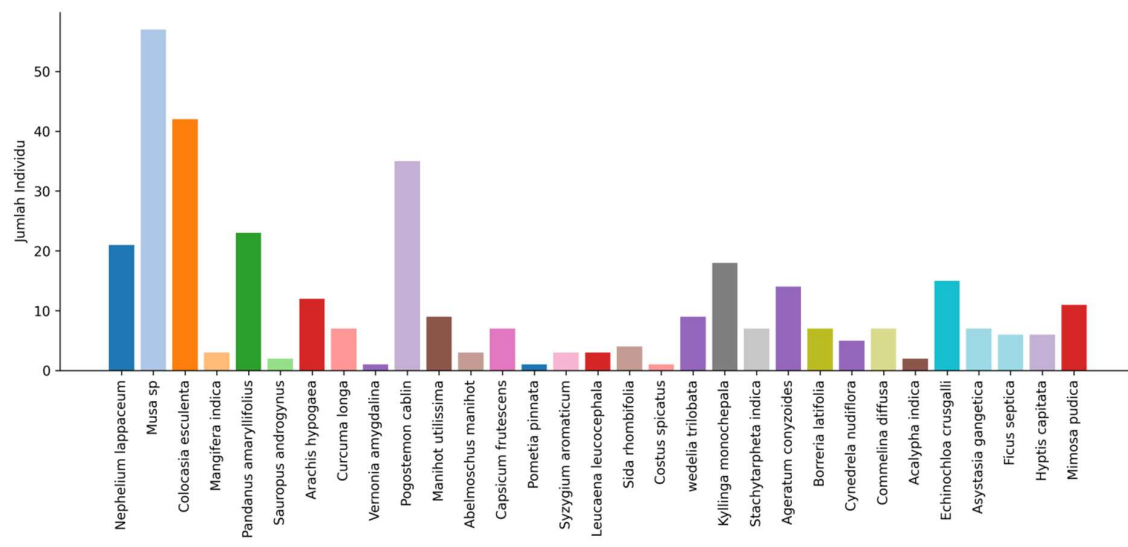


Figure 3. Pielou's Equity Index (E) = 0.862 Understory Plants in Coconut-Based Agroforestry in Ongkaw Dua Village, Sinonsayang Subdistrict, South Minahasa Regency. Number of individuals per species. Colors by family

Although there are several species with higher numbers of individuals (banana: 57, betel nut: 42, patchouli: 35), these differences are not too extreme compared to the total community. Furthermore, there is no extreme dominance, where the most abundant species is banana = 57 individuals, and the rarest species are African leaf, matoa, and costus = 1 individual, with a ratio of 57:1 indicating reasonable dominance in the natural system. The Pielou E index = 0.862 indicates that this coconut-based agroforestry system has excellent ecological balance in terms of individual distribution.

In the context of agroforestry, this condition is very advantageous. High evenness is often associated with greater community stability. This is driven by stronger complementarity effects among species in an even community, where different species can complement and support each other in utilizing resources more efficiently, especially during times of stress.

CONCLUSION

Based on the research findings and discussion, it can be concluded that: 31 species of understory plants from 23 families were identified, dominated by herbaceous plants and consisting of a mix of native species and species of economic value, particularly as medicinal and ornamental plants. These results indicate that the coconut-based agroforestry system in Ongkaw Village, Sinonsayang, has a high level of understory plant diversity, as shown by the Shannon-Wiener Diversity Index (H') = 3.256; the Margalef Species Richness Index (R) = 5.13, and the Pielou Species Evenness Index (E) = 0.862.

DECLARATIONS

CONFLICT OF INTEREST

The authors declare that they have no financial or non-financial conflicts of interest that could have influenced the results, interpretation, or publication of this study.

USE OF GENERATIVE AI

Generative artificial intelligence was used to assist with language refinement and manuscript restructuring. All scientific statements, calculations, interpretations, and references were reviewed and validated by the authors, who retain full responsibility for the submitted manuscript

ACKNOWLEDGEMENTS

We would like to thank UNSRAT for funding this research through the UNSRAT DIPA Fiscal Year 2025

REFERENCES

- Bhagwat, S. A., Willis, K. J., Birks, H. J. B., & Whittaker, R. J. (2008). Agroforestry: a refuge for tropical biodiversity?. *Trends in ecology & evolution*, 23(5), 261-267.
- Cubbage F, Balmelli G, Bussoni A, Noellemeyer E, Pachas AN, Fassola H, Colcombet L, 'n Rossner B, Frey G, Dube F, de Silva ML, Stevenson H, 41 Hamilton J, Hubbard W. 2012. Comparing silvopastoral systems and prospects in eight regions of the world. *Agroforestry System*. 86:303–314.

- Deheuvels, O., Rousseau, G. X., Soto Quiroga, G., Decker Franco, M., Cerda, R., Vilchez Mendoza, S. J., & Somarriba, E. (2014). Biodiversity is affected by changes in management intensity of cocoa-based agroforests. *Agroforestry Systems*, 88(6), 1081-1099.
- Graves AR, Burgess PJ, Palma JHN, Herzog F, Moreno G, Bertomeu M, Dupraz C, Liagre F, Keesman K, van der Werf W, Koeffeman de Nooy A, van den Briel JP. 2007. Development and application of bio-economic modelling to compare silvoarable, arable and forestry systems in three European countries. *Ecological Engineering*. 29: 434-449.
- Gusti, M. M., Ratag, S. P., & Pangemanan, E. F. (2022). Ciri-Ciri Pola Agrosilvopastura: Studi Kasus Di Desa Sumarayar Kecamatan Langowan Timur. *In Cocos*, 14(3).
- Kila, F. I., Laoh, O. E. H., & Pangemanan, L. R. J. (2021). Pemanfaatan Lahan di Bawah Pohon Kelapa di Desa Pakuweru Kecamatan Tenga Kabupaten Minahasa Selatan. *Jurnal Agribisnis dan Pengembangan Pedesaan*, 3(4), 354–364. DOI: https://doi.org/10.35791/agrirud.v3i3.37096 [https://doi.org/10.35791/agrirud.v3i3.37096].
- Laratmase, Y. C., Ratag, S. P., & Pangemanan, E. F. (2022, January). Identifikasi Pola Agroforestri Di Desa Togid, Kecamatan Tutuyan, Kabupaten Bolaang Mongondow Timur. *In Cocos*, 14(4).
- Lewerissa, E., 2024. Pola Tanam Dan Kontribusi Agroforestri Berbasis Kelapa Di Halmahera Utara. *Marsegu: Jurnal Sains dan Teknologi*, 18:866-876.
- Nair, P. K. K. 1993. *An Introduction to Agroforestry*. Kluwer Academic Publishers.
- Murthy IK, Gupta M, Tomar S, Munsu M, Tiwari R, Hegde GT, Ravindranath NH. 2013. Carbon sequestration potential of agroforestry systems in India. *Earth Science Climate Change*. 4:131.
- Nahdi, M.S., Marsono, D., Djohan, T.S., dan Baequni, M., 2014. Struktur Komunitas Tumbuhan dan Faktor Lingkungan di Lahan Kritis, Imogiri Yogyakarta. *Jurnal Manusia dan Lingkungan*, 21(1):67-74.
- Oping, M. R., Ratag, S., & Pangemanan, E. F. (2023). Agroforestry Patterns In Wanga Village, East Motoling District, South Minahasa Regency. *Jurnal Agroekoteknologi Terapan*, 4(1), 130-139.
- Pontoh, S., Ratag, S. P., Pangemanan, E. F., & Ngangi, C. R. (2024). Agrosilvopasture Pattern In Paslaten Village, Tatapaan District, South Minahasa Regency, North Sulawesi Province. *Jurnal Agroekoteknologi Terapan*, 5(1), 68-74.
- Putra, A., Pangemanan, E. F., & Ratag, S. P. (2024). Identifikasi Strata Tajuk Pola Agrosilvopastura di Desa Mopolo, Kecamatan Ranoyapo. *Silvarum*, 3(3), 131-137.
- Rante, G., Ratag, S. P., & Pangemanan, E. F. (2022). Identifikasi Strata Tajuk Agrosilvikultur di Desa Warembungan. *Silvarum*, 1(2), 40-44.
- Ratag, S. P., Pangemanan, E. F. S., Paat, F. J., Mokoagouw, S., Manginsela, E. P., Ngangi, C. R., ... & Mamuaja, C. F. (2024). the local wisdom in agroforestry systems: the case study in wanga village, east motoling sub-district, south minahasa regency, indonesia. *Environmental & Social Management Journal/Revista de Gestão Social e Ambiental*, 18(4).
- Rusolono, T. 2006. *Model pendugaan persediaan karbon tegakan agroforestri untuk pengelolaan hutan milik melalui skema perdagangan karbon*. [Disertasi]. Bogor ID): Institut Pertanian Bogor.
- Sanchez, EA. 1995. Science in Agroforestry. *Agroforestry Systems*. 30:5-55.

- Saputra, A. D., Indriyanto, I., & Duryat, D. (2016). Komposisi, Struktur, Dan Keanekaragaman Jenis Vegetasi Di Jalur Wisata Air Terjun Wiyono Atas Taman Hutan Raya Wan Abdul Rachman Provinsi Lampung. *Jurnal Sylva Lestari*, 4(3), 83-96.
- Somarriba, E., Cerda, R., Orozco, L., Cifuentes, M., Dávila, H., Espin, T., ... & Deheuvels, O. (2013). Carbon stocks and cocoa yields in agroforestry systems of Central America. *Agriculture, ecosystems & environment*, 173, 46-57.
- Suli, A. A., Husain, J., & Walangitan, H. D. (2018). Sistem Agroforestri Dataran Tinggi Dan Dataran Rendah Kabupaten Minahasa Selatan Provinsi Sulawesi Utara. *Eugenia*, 24(1).
- Sumilia, N. A., & Syarif, Z. (2019). Produktivitas kakao dan keanekaragaman tanaman dalam berbagai sistem agroforestri berbasis kakao di Kabupaten Pasaman Sumatera Barat. *Jurnal Agroforestri Indonesia*, 2(2), 51-62.
- Toding, E. M., Ratag, S. P., & Pangemanan, E. F. (2022). Pola agroforestri masyarakat di Desa Mopolo Kecamatan Ranoyapo Kabupaten Minahasa Selatan. *In Cocos*, 14(3).
- Yoman, Y., Pangemanan, E. F., & Ratag, S. P. (2017). Keragaman jenis tanaman pada sistem agroforestri pekarangan di Desa Warembungan. *In Cocos*, 9(6).
- Yusran. 2005. *Analisis performansi dan pengembangan hutan kemiri rakyat di kawasan pegunungan Bulusaraung Sulawesi Selatan*. [Disertasi]. Bogor ID): Pascasarjana Institut Pertanian Bogor.