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Floristic Composition and Diversity of Agroforestry Based Agarwood (*Gyrinops versteegii*) in Bantul, Yogyakarta

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ABSTRACT

Gyrinops versteegii is one of the agarwood-producing trees with high economic value, however including CITES appendix II, quotas limit trade. This research aims to determine the composition and diversity of the species that make up agarwood-based home garden agroforestry practices and to determine the similarity of communities in two sites, namely in Parangtritis village and Sawo hamlet, Bantul district, Yogyakarta. The research was conducted in Parangtritis village, Kretek District and Sawo hamlet, Banguntapan District, Bantul Regency, Yogyakarta. Sampling was used using the plot method with a plot measuring 20 x 20 m2, which was placed purposely. The species diversity index uses Shannon's index formula, while the evenness index uses the Alatalo index. The species of richness index used is Margalef's index. Meanwhile, community similarity is used by Sorensen's index and Jaccard's index. This research found that the number of species that make up gaharu-based home garden agroforestry practices is 24 tree species, with 296 individuals belonging to 22 genera and 18 families. The diversity index of home garden species in Parangtritis and Sawo is categorized as medium with an H" value of 1.46 and 1.87, respectively. Likewise, the index values for the evenness of home garden species in Parangtritis and Sawo are 0.59 and 0.65, respectively, categorized as moderate. The species richness index in Parangtritis (2.015) is lower than in Sawo (4.119). The Sorensen similarity index value of 0.4 is categorized as medium, while according to the Jaccard index of 0.25, it is categorized as low. These findings suggest the need for improved species selection and management practices to enhance agroforestry sustainability and biodiversity conservation.

Keyword: Diversity Index, Evenness Index, Home Garden, Richness Index, Similarity Index

1. Introduction

Gyrinops versteegii is an agarwood-producing tree with high economic value [1], [2], so it attracts people's interest in planting it. This species is included in CITES Appendix II [3]. Agroforestry system is an alternative source of income for people who have limited land. This system has advantages from economic and ecological aspects [4]. Agroforestry systems contribute significantly to rural livelihoods by providing diverse income sources, food security, medicinal plants, and other ecosystem services while maintaining environmental sustainability [5], [6]. A form of agroforestry practice for small land areas is the home garden. Homegarden practice is a very strategic form of developing the *G. versteegii* species.

The combination of tree species and *G. versteegii* plants must be correct so that each can grow well [7]. Mixing inappropriate plants can cause a decrease in both wood and non-wood productivity. On the other hand, the right combination of plants will increase growth and productivity [8]. Plant selection in home garden practices is not only based on suitability for physical conditions but also considers meeting community needs, both short and long-term [4]. This is because the harvest period for *G. versteegii* plants is at least ten years (long term), so people must get the results before the *G. versteegii* plants are harvested.

The diversity of species that comprise home garden practices indicates an ecosystem's stability. Ecologists argue that the scope of species diversity includes the evenness and richness of species [9]. The diversity index is an indicator to determine how much a home garden can fulfill community needs. Home gardening practices provide opportunities for people to grow plants they need for both the short and long term. Maintaining species diversity in agroforestry systems is crucial for ecological resilience, sustainable productivity, and adaptation to climate change [10], [11].

Despite the importance of agarwood-based agroforestry systems, limited studies have examined the floristic composition and diversity of these systems in Indonesia, particularly in Yogyakarta region. This study aims to fill this knowledge gap by analyzing species composition, diversity patterns, and community similarities in agarwood-based home gardens. The research hypothesis is that environmental factors and cultural practices significantly influence species composition and diversity patterns in different locations.

Parangtritis Village, Kretek District and Sawo Hamlet, Banguntapan District, Bantul Regency have planted *G. versteegii* species using an agroforestry pattern in home garden land. The home garden practice model in these two locations is very interesting for studying the species of trees combined and the species diversity, evenness, and richness. Apart from that, it is also necessary to research the level of similarity of the tree vegetation in the two locations.

2. Research Method
2.1. Location and Time
The research was conducted on January 2024 at *G. versteegii* home garden of practice land in Parangtritis village, Kretek District and Sawo hamlet, Banguntapan district, Bantul Regency, Yogyakarta Special Region Province, Indonesia. Parangtritis Village is geographically located at coordinates 8°0'30.5"S 110°19'15.5"E with an altitude of 10-15 meters above sea level. Rainfall is 1000-2000 mm/year with a ratio of wet to dry months of 50-100%. Entisol soil type. The Sawo hamlet is at coordinates 7°50'51"S; 110°23'57"E. Rainfall is 1,000-2,000 mm/year with a height of 100 meters above sea level. Soil type is regosol.

2.2. Materials and Tools
The materials used in this research are land managed using an agroforestry system with home garden practices in Parangtritis village and Sawo hamlet. The equipment used in the study is GPS, roll meter, measuring pole, phi band, species identification, counter meter, price meter, etc. Before going to the field, all equipment was checked and calibrated using the Instiper Yogyakarta central laboratory equipment.

2.2.1. Sampling/data collection
Data collection used systematic sampling with a purposive start, using measuring plots measuring 20×20 m². The distance between measuring plots is 10m. The number of measuring plots in Parangtritis was 7, while the measuring plots in Sawo were 3. The total number of measuring plots is 10. Each tree in the measuring plot was recorded with the name of the species, number and use. Tree identification was conducted with the help of local botanical experts and reference materials. The equipment used in the study included GPS, roll meter, measuring pole, diameter tape, and field identification guides.

2.3. Data Analysis
Field data were recorded in a tally sheet, and then the data were recapitulated on a computer. The diversity index, evenness index, species richness index and similarity index were calculated manually with the help of the Excel application. The calculation stages for each index are explained below.

2.3.1. Species diversity index
The diversity of species that make up gaharu-based agroforestry at the research location is calculated using the Shannon index formula [12] as follows:

$$H' = -\sum p_i \ln p_i \; ; \; p_i = \frac{n_i}{N} \tag{1}$$

H': Shannon diversity index; ni: number of ith individuals; N: total number of individuals.

Diversity variance can be calculated using the following formula [12]:

$$\text{Var } H' = \frac{\sum p_i (\ln p_i)^2 - (\sum p_i \ln p_i)^2}{N} - \frac{S\text{-}1}{2N^2} \tag{2}$$

$$t = \frac{H'_1 - H'_2}{\left(\text{Var } H'_1 + \text{Var } H'_2\right)^{1/2}} \tag{3}$$

$$df = \frac{\left(\text{Var } H'_1 + \text{Var } H'_2\right)^2}{\left[\frac{\left(\text{Var } H'_1\right)^2}{N_2} + \frac{\left(\text{Var } H'_2\right)^2}{N_2}\right]} \tag{4}$$

The values of the Shannon diversity index are usually found to fall between 1.5 and 3.5 and only rarely exceed 4.5 [13]. An index value of 0.00-1.17 is categorized as low; 1.18-2.33 is in the medium category, and 2.34-3.50 is in the high category.

2.3.2. Species evenness index

$$E' = \frac{H}{H \max} = \frac{H'}{\ln S} \tag{5}$$

Where E' is the evenness index, H' is the diversity index, and S is the number of species. According to Magurran [12] and Ludwig & Reynolds [9], the evenness index range is usually between 0 and 1. The species evenness value categories are as follows: 0.00-0.33 low; 0.34-0.67 is categorized as medium, and 0.68-1.00 is classified as high.

2.3.3. Species richness index
The richness index is calculated using the Margalef (1958) formula [9] as follows:

$$R = \frac{S\text{-}1}{\ln(N)} \tag{6}$$

Where S: number of species; N: number of individuals of the species

2.3.4. Species similarity index

$$S = \frac{2C}{A+B} \quad \text{and} \quad J = \frac{C}{A+B\text{-}C} \tag{7}$$

Where S: Sorensen similarity index; A: Jaccard similarity index; C: number of species found in communities A and B; A: number of all species in community A; B: the number of all species in community B.

The Sorensen index and Jaccard index values are in the range 0 to 1. If the similarity index is close to 0, it indicates that the level of similarity between the two communities is shallow, while a value of 1 indicates that the two communities being compared are the same. The similarity index is categorized as 0.00-0.33, low; 0.34-0.67 is in the medium category, and 0.68-1.00 is in the high category.

3. Results and Discussions
The tree-level vegetation comprising the home garden at both research locations includes 24 species belonging to 22 genera and 18 families dominated by Rutaceae, Leguminosae, and Sapotaceae. The species that dominates in both research locations is *G. versteegii*. The density of tree was found 335.7 trees/ha for *G. versteegii* species that grows in the Parangtritis home garden compared to the Sawo home garden, which is 291.7 trees/ha. Table 1 shows that the species with the most significant tree density in the Parangtritis home garden after gaharu are banana, coconut, melinjo and rosewood with densities of 271.4, 135.7, 46.4, and 21.4 trees per hectare respectively. Meanwhile, for home garden land in Sawo, the species of tree that has the most excellent density after *G. versteegii* is followed by papaya (33.3 trees/ha), banana (25.0 trees/ha), melinjo (16.7 trees/ha), durian (16.7 trees/ha), sapodilla (16.7 trees/ha), avocado (16.7 trees/ha) and longan (16.7 trees/ha).

The density of species in a population significantly influences the role of spatial control of species in the ecosystem. Density is essential in determining a species's Importance Value Index (IVI). Species with a high density indicate that they can adapt to the surrounding environment. Furthermore, the density of a species is an indicator of success in competition for growing space [14]. These findings are comparable to similar

agroforestry studies in Central Java, where dominant species typically represent 40-60% of total tree density [15].

The combination of plants in agroforestry practices represents community needs from various aspects, both economic, ecological and social [16]. From a financial aspect, crop combinations meet community needs in the short, medium, and long term [17]. *G. versteegii* plants can be harvested to increase income in the long term (at least ten years) as raw materials for oil and sapwood. Coconut, melinjo and banana plants produce fruit that can be used to meet short-term needs. Both research locations show similarities where the dominant plant is G. versteegii, followed by Musa acuminata and Gnetum gnemon plants. Agarwood plants can also be combined with oil palm plants [18].

Table 1. Composition of home garden species found at the research location and their uses

Nu	Local Name	Scientific Name	Family	Species density (∑ individual/ha)		Utilization
				Parangtritis	Sawo	
1	Gaharu	*Gyrinops versteegii*	*Tymelaeaceae*	335.7	291.7	Oil
2	Kelapa	*Cocos nucifera*	*Palmae*	135.7	0	Fruit, Wood
3	Pisang	*Musa acuminata var. balbisiana*	*Musaceae*	271.4	25.0	Fruit
4	Melinjo	*Gnetum gnemon*	*Gnetaceae*	46.4	16.7	Vegetable, Fruit
5	Mangga	*Mangifera indica*	Anacardiaceae	3.6	8.3	Fruit
6	Pepaya	*Carica Papaya L*	*Caricaceae*	3.6	33.3	Fruit
7	Jambu air	*Syszygium samarangense aqueum*	*Myrtaceae*	3.6	0.0	Fruit
8	Johar	*Senna siamea*	*Leguminosae*	3.6	0.0	Fruit
9	Pulai	*Alstonia scholaris*	*Apocynaceae*	3.6	0.0	Medicine, Wood
10	Sonokeling	*Dalbergia latifolia*	*Leguminosae*	21.4	0.0	Fruit
11	Mahoni	*Swietenia macrophylla*	*Meliaceae*	7.1	0.0	Fruit
12	jati	*Tectona grandis*	*Verbenaceae*	3.6	8.3	Fruit
13	Asam	*Tamarindus indica L*	*Leguminosae*	0.0	8.3	Fruit
14	Durian	*Durio zibethinus (Murr)*	*Malvaceae*	0.0	16.7	Fruit
15	Jeruk Keprok	*Citrus reticulata*	*Rutaceae*	0.0	8.3	Fruit
16	Cendana	*Santalum album*	*Santalaceae*	0.0	8.3	Fruit
17	Kelengkeng	*Dimocarpus longan)*	*Sapindaceae*	0.0	16.7	Fruit
18	Sawo Beludru	*Chrysophyllum cainito*	*Sapotaceae*	0.0	8.3	Fruit
19	Sawo	*Manilkara zapota*	*Sapotaceae*	0.0	16.7	Fruit
20	Sawo Putih	*Casimiroa edulis*	*Sapotaceae*	0.0	8.3	Fruit
21	Alpukat	*Persea americana*	*Lauraceae*	0.0	16.7	Fruit
22	Jeruk Peras	*Citrus sinensis*	*Rutaceae*	0.0	8.3	Fruit
23	Jeruk Bali	*Citrus grandis*	*Rutaceae*	0.0	8.3	Fruit
24	Buta-buta	*Excoecaria agallocha*	*Euphorbiaceae*	0.0	8.3	Wood
	Total			839.3	516.7	

Figure 1 shows that the number of species, genera, and families of tree vegetation in Parangtritis's home garden land is less than the species, genera, and families of home garden practices in Sawo. The choice of plant species in home gardens is greatly influenced by the bio-physical characteristics of the growing place [19], culture, market access and community needs [20]. From a bio-physical aspect, the two locations have different conditions; the Parangtritis location is significantly influenced by a typical coastal environment with water containing salt levels, while the Sawo location is approximately 27 km from the beach with an altitude of 100 meters above sea level. Biophysical/habitat differences influence the species that grow. From a cultural aspect, these two locations have slightly different cultures; the culture of the Parangtritis community generally grows coconut plants because this species can grow well; besides that, young coconuts are a trendy commodity for sale at the Parangtritis beach location. From a market aspect, bananas, coconut, and other fruit plants have a relatively broad market reach, especially in tourist locations. Then, to meet community needs, we also determine the species planted in the home garden.
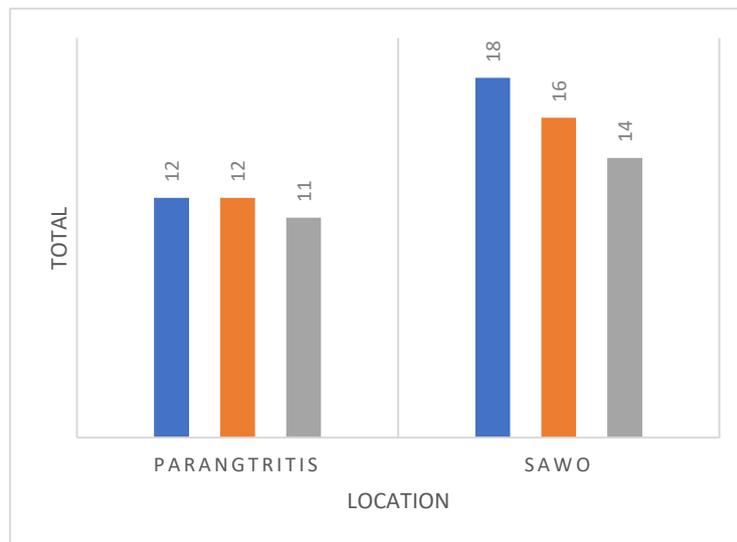
Figure 1. Number of species (blue), genus (orange) and families (silver) that make up home gardens in Parangtritis and Sawo

3.1. Species Diversity

Diversity or species diversity is a very significant indicator of the stability of an ecosystem [21]. For example, tropical forest ecosystems have been recognized and proven to be the most stable ecosystems with high productivity in the world because they have a very high diversity of flora and fauna, known as megadiversity. High species diversity will affect the efficiency of nutrients and light entering an ecosystem and prevent nutrient leakage through erosion or runoff [22]. Thus, high species diversity will improve the environment and habitat where it grows. Therefore, species diversity is a significant indicator to maintain in agroforestry practices that want to imitate nature (close to nature). Agroforestry with high species diversity will ensure the stability of the built ecosystem formed compared to agroforestry practices with low species diversity.

The value of the Shannon diversity index for home garden practices in Parangtritis is 1.460, while in Sawo it is 1.866. According to Magurran [12], the diversity index of home garden types in both locations is categorized as medium. The Shannon diversity index found in home garden land in Sawo was higher than the diversity index found in 5 villages in Vietnam, namely Tea Garden, Meitei Manupuri, Bishnupriyo Manipuri, Butman, and Khasi villages, respectively at 1.63; 1.44; 1.52; 1.32 and 0.80 [23]. Likewise, the results of the home garden diversity index in Parangtritis were 1.46, close to the Vietnam Meitei village diversity index.

Table 2. Species diversity according to Shannon index of home garden species in Parangtritis, Bantul, Yogyakarta

Nu	Local Name	∑ individu	pi	ln pi	pi x ln pi	pi (ln pi)^2
1	Gaharu	94	0.4	-0.91629	-0.36652	0.335835
2	Kelapa	38	0.161702	-1.822	-0.29462	0.5368
3	Pisang	76	0.323404	-1.12885	-0.36508	0.412116
4	Melinjo	13	0.055319	-2.89464	-0.16013	0.463515
5	Mangga	1	0.004255	-5.45959	-0.02323	0.126839
6	Pepaya	1	0.004255	-5.45959	-0.02323	0.126839
7	Jambu air	1	0.004255	-5.45959	-0.02323	0.126839
8	Johar	1	0.004255	-5.45959	-0.02323	0.126839
9	Pulai	1	0.004255	-5.45959	-0.02323	0.126839
10	Sonokeling	6	0.025532	-3.66783	-0.09365	0.34348
11	Mahoni	2	0.008511	-4.76644	-0.04057	0.193353
12	Jati	1	0.004255	-5.45959	-0.02323	0.126839
	Total	235	1	-47.9536	-1.45995	3.04613

Table 2 shows that the value of the Shannon diversity index for home garden practices in Parangtritis is 1.866. According to Magurran (1989), the diversity index of home garden types in Parangtritis is categorized as medium. The Shannon diversity index found in home garden land in Sawo (Table 3) was higher than the diversity index found in 5 villages in Vietnam, namely Tea Garden, Meitei Manupuri, Bishnupriyo Manipuri, Butman, and Khasi villages, respectively at 1.63; 1.44; 1.52; 1.32 and 0.80 [17]. Likewise, the results of the home garden diversity index in Parangtritis were 1.46, close to the Vietnam Meite village diversity index.

Table 3. Species diversity according to Shannon index of home garden species in Sawo, Bantul, Yogyakarta

| Nu	Local Name	∑ individu	pi	ln pi	pi x ln pi	pi (ln pi)^2
1	Mangga	1	0.016129	-4.12713	-0.06657	0.27473
2	Asam	1	0.016129	-4.12713	-0.06657	0.27473
3	Durian	2	0.032258	-3.43399	-0.11077	0.380396
4	Jeruk Keprok	1	0.016129	-4.12713	-0.06657	0.27473
5	Cendana	1	0.016129	-4.12713	-0.06657	0.27473
6	Kelengkeng	2	0.032258	-3.43399	-0.11077	0.380396
7	Sawo Beludru	1	0.016129	-4.12713	-0.06657	0.27473
8	Sawo	2	0.032258	-3.43399	-0.11077	0.380396
9	Sawa putih	1	0.016129	-4.12713	-0.06657	0.27473
10	Alpukat	2	0.032258	-3.43399	-0.11077	0.380396
11	Jeruk Peras	1	0.016129	-4.12713	-0.06657	0.27473
12	Jeruk Bali	1	0.016129	-4.12713	-0.06657	0.27473
13	Gaharu	35	0.564516	-0.57179	-0.32278	0.184563
14	Buta-Buta	1	0.016129	-4.12713	-0.06657	0.27473
15	Melinjo	2	0.032258	-3.43399	-0.11077	0.380396
16	Pisang	3	0.048387	-3.02852	-0.14654	0.443804
17	Pepaya	4	0.064516	-2.74084	-0.17683	0.484658
18	Jati	1	0.016129	-4.12713	-0.06657	0.27473
	Total	62	1	-64.7824	-1.86569	5.7623

3.2. Evenness and Richness of Species

Evenness and species richness are indicators that cannot be separated from species diversity. Species evenness shows how evenly the number of individuals of each species is distributed. The evenness index value of tree species that comprise home garden practices in Parangtritis is 0.588 (Table 4), while in Sawo, it is 0.645 in the medium category. The value of species wealth in the two research locations is different. Richness is directly proportional to the number of species; the greater the number of species, the greater the value of this index. The richness index for the species of home garden practice in Parangtritis is 2.015, lower than the richness of the species in Sawo, which is 4.119. The species richness index found in Sawo was greater when compared to research conducted by [23] on five villages, namely Tea Garden, Meitei Manupuri, Bishnupriyo Manipuri, Butman, and Khasi villages respectively at 3.49; 3.17; 2.7; 2.8; and 2.71.

Table 4. Index of diversity, evenness, and richness of home garden practices in Parangtritis and Sawo

Indices		Site	Value	Category
Diversity index	H'	Parangtritis	1,460	Medium
		Sawo	1,866	Medium
Evenness Index	E	Parangtritis	0,588	Medium
		Sawo	0,645	Medium
Richness index	R	Parangtritis	2,015	-
		Sawo	4,119	-

3.3. Community Similarity

Figure 2 shows that the similarity of the trees that make up home garden practices in Parangtritis and Sawo, according to the Sorensen index, is 0.4 in the medium category, while based on the Jaccard index, it is 0.25 in the low category. The similarity of the constituent species in the two research locations depends on community considerations in selecting the species planted. Biophysical environmental conditions are a factor considered in selecting species, known as species matching. Besides that, the choice of species is also influenced by the value of the commodity. Both research locations are dominated by *G. versteegii* species with high economic value as an oil ingredient and agarwood product.
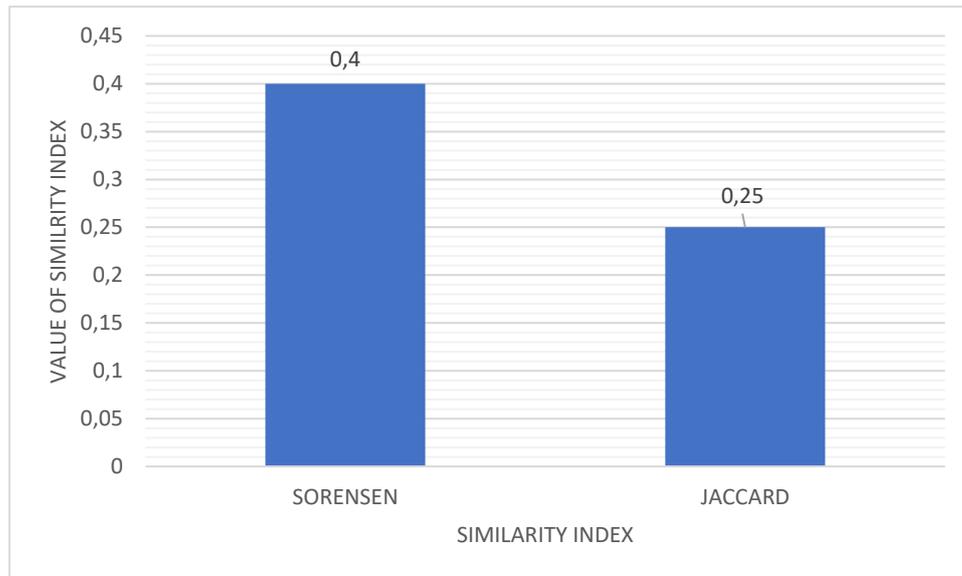
Figure 2. The value of Sorensen and Jaccard index

4. Conclusion

There were 24 species of gaharu-based home garden practices in Parangtritis and Sawo found in 22 genera and 18 families. The species that dominate in the Parangtritis home garden are *Gyrinops versteegii*, *Musa acuminata, Cocos nucifera, Gnetum gnemon,* and *Dalbergia latifolia*. Meanwhile, the dominant species in Sawo are *Gyrinops versteegii, Musa acuminata, Gnetum gnemon, Carica papaya, Durio zibethinus, Dimocarpus longan,* and *Persea americana*. The diversity and evenness index at both locations is categorized as moderate. The species richness index in Sawo is higher than in Parangtritis. The similarity index of the two research locations is classified as low.

Based on these findings, we recommend: (1) increasing species diversity through introduction of compatible native species to enhance ecosystem stability, (2) improving management practices to optimize the integration of short-term and long-term productive species, (3) developing species-specific guidelines for different environmental conditions to maximize both economic returns and ecological benefits, and (4) conducting long-term monitoring to assess the sustainability of these agroforestry systems.

Acknowledgments

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