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Plant diversity on coffee agroforestry land in the buffer zone of Bromo Tengger Semeru National Park in East Java, Indonesia

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Abstract. *Zayadi H, Hakim L, Sudarto, Batoro J. 2024. Plant diversity on coffee agroforestry land in the buffer zone of Bromo Tengger Semeru National Park in East Java, Indonesia. Biodiversitas 25: 1030-1036.* Bromo Tengger Semeru National Park (BTSNP) is facing threats to biodiversity due to land transfer functions and sand mining in rural areas. Land use conversion and sand mining in rural areas near BTSNP and Perhutani are threatening biodiversity through activities like land degradation, deforestation, forest depletion, and global climate change impacting local agriculture. Coffee farms in Poncokusumo and Wajak have been abandoned, leading to a decline in coffee farming and other agricultural commodities. Coffee-based agroforestry systems have been implemented to address this issue and improve soil fertility and vegetation diversity. This research aimed to identify and analyze plant diversity in coffee agroforestry land in BTNSP. The study was carried out in January-December 2022 in the village districts of Poncokusumo Sub-district (Sumberejo) and Wajak Sub-district of Malang District, which borders directly with BTSNP, collecting flora compositions and classifying them based on growth rate. The study identified 27 orders, 38 families, and 71 species of plants in the coffee fields. The presence of various plant species in the coffee fields contributes to the ecosystem's stability and the soil's quality. This research highlights the importance of the agroforestry system in promoting biodiversity conservation and sustainable coffee farming in the BTSNP area.

Keywords: Agroforestry, biodiversity, conservation, sustainability

INTRODUCTION

The Issue Bromo Tengger Semeru National Park (BTSNP) sustainability and biodiversity conservation has received considerable critical attention since its preservation depends on the surrounding landscape, particularly in Malang District, which includes Poncokusumo, Wajak, Jabung, Tirtoyudo, Dampit, and Ampelgading. The landfills encompass BTSNP and Perhutani's surrounding landscape (Buffer zone) (Nadhira and Basuni 2021). The plantation area at BTSNP has unique vegetation, altitude, and soil topography (Hakim and Soemarno 2017). Pandansari and Sumberejo are villages around Bromo Tengger Semeru National Park, and both villages have a very important role in supporting biodiversity conservation and the local economy in developing home garden-based tourism (Putri et al. 2016).

Recently, some places, especially rural areas directly surrounding BTSNP, have been impacted by the exchange of land functions in its management and sand mining, which would indirectly threaten BTSNP's biodiversity. Land degradation, deforestation, forest depletion for agricultural land and sand mining, and global climate change affect local farm productivity and may directly affect threatened biodiversity in conservation areas. (Bellard et al. 2012; Hamdy and Aly 2014; Watts et al. 2022). Coffee farms in Poncokusumo and Wajak were abandoned a few years ago due to the economic and social consequences of growing populations. This has resulted in a reduction in coffee cultivation in the region, with other crops taking its place. Insufficient forestation with sustainable ecological values will cause ecosystem degradation (Hakim et al. 2022). In addition, sand mining in river flows will result in erosion, flooding, and floods. As a result, an effort is required to return it to its previous state utilizing the notion of restoring the region based on local knowledge. There has been a lot of research on land transformation (Blackman et al. 2012; Fedele et al. 2018). Due to agricultural land shortages, communities and peasants slash and burn forest crops and bushes to create new land, making land crucial. Using coffee-based agroforestry systems is one solution (Perfecto and Vandermeer 2015). Coffee-based agroforestry has been practiced by farmers in various regions of Indonesia, including in the West Lampung (social forest and village forest), West Java, Central Java, and East Java (patterns of forest management with the community). The application of agroforestry is one of the forms that can be done around national parks. These systems can play an important role in feeding livestock, soil fertility and vegetation diversity (Hakim et al. 2019; Hakim 2021; Lugina et al. 2021; Aiko et al. 2022; Hariyati et al. 2022).

The agroforestry system has already begun to be developed by the community for example by the Tengger community adopting the agroforestry system in planting trees such as, *Toona sureni*, *Melia azedarach*, *Bambusa* sp., *Gigantochloa* sp., *Swietenia mahagoni*, *Albizia falcataria*, and *C. junghuhniana* in their gardens (Redowan 2015; Putri et al. 2016; Batoro et al. 2017; Jadid et al. 2020; Zayadi et al. 2023). The agroforestry system also improves the abundance and diversity of land invertebrates (Kinasih et al. 2016), insects (Jha and Vandermeer 2010), and birds (Imron et al. 2022). However, the implementation of agroforestry systems in some areas faces several obstacles, namely: (i) lack of knowledge in cultivating coffee-based agroforests; (ii) the lack of enterprise capital; and (iii) the uncertainty of land ownership status (Watts et al. 2022). The agroforestry system is also inefficient if applied in areas of very large scale (Blackman et al. 2012). The coffee agroecosystem is an ideal model system for studying the intensification of agriculture that has an impact on biodiversity. Thus, based on the background above, the goal of this study is to discover and analyze plant diversity in coffee agroforestry areas surrounding Bromo Tengger Semeru National Park.

MATERIALS AND METHODS

Study area

The research was carried out in January-December 2022 in the village districts of Poncokusumo Sub-district (Sumberejo) and Wajak Sub-district of Malang District, which borders directly with BTSNP (Figure 1). Map creation and analysis were carried out at the GIS Laboratory of Soil Science, Faculty of Agriculture Universitas Brawijaya, Indonesia.

Procedures

The collection of flora compositions was carried out through direct exploration in different landscape conditions. All existing types of flora were then recorded, identified, and classified according to their growth rate. Flora data is obtained by plot sampling using the belt transect method (Nasution et al. 2015).

Sampling design

The transect was made of lengthy, 20 × 200 m^2 transect sizes divided into 20 plot sizes of 10 × 10 m^2 for the tree level and 2 × 2 m^2 for ground cover plants. The trees measured were >10 cm in diameter. All kinds of plants in the plot were recorded by the number of individual species. For the tree category, the diameter measurement was the approximate height of the Diameter at Breast Height (DBH). Plot placement is done through purposive sampling for the starting point of the transect set based on different landscape conditions (Nasution et al. 2015).

Data analysis

The analysis of flora diversity is carried out by calculating the importance value index, total density, species richness, evenness, dominance index and diversity index based on the growth rate of plants found in coffee groves (*Coffea* spp.) using a modified formula from Mueller-Dombois and Ellenberg (1974). To identify the similarities of plant communities in the BTSNP Buffer area, cluster analysis is carried out using the application PAST (Paleontological Statistics Software Package for Education and Data Analysis) using Bray-Curtis index (Hammer et al. 2001). Dendrogram constructed using Unweighted Pair-Group Method with an Arithmetic mean (UPGMA) algorithm (Villanueva et al. 2022).

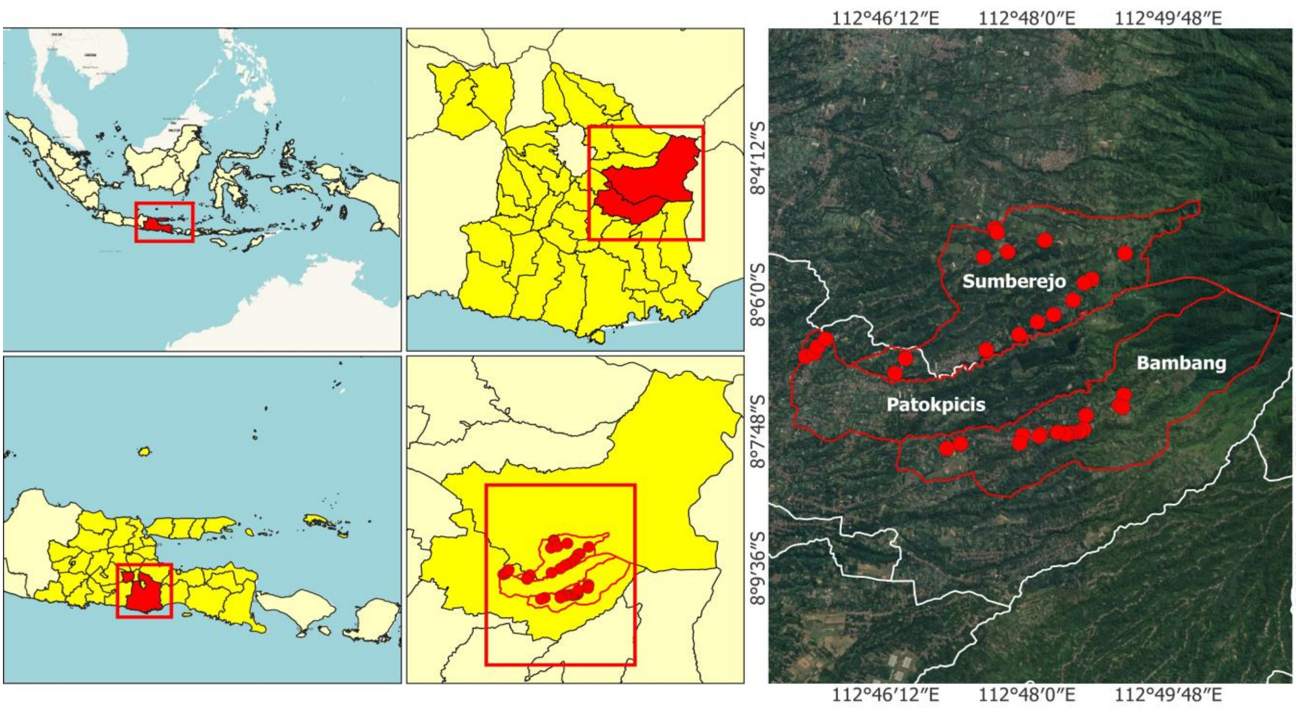

Figure 1. Map of the research study sites in the Buffer Area of Bromo Tengger Semeru National Park (red points are the sampling point), Malang District, East Java Province, Indonesia which borders directly with BTSNP

RESULTS AND DISCUSSION

Based on field observations, a study was conducted to determine the composition of plant types found in coffee fields in the three BTSNP cultivation areas. The results showed that there were 27 orders, 38 families, 67 genera, and 71 species of plants present in the coffee fields (see Table 1).

The Asterales order was found to be the most common order of plants in coffee fields, with nine species identified. Plants belonging to the Asterales order can play a significant role in coffee cultivation. Other plant orders that were abundant in the coffee fields were also identified, such as the Poales order, which had a total of 8 species. This suggests that coffee fields have a high level of diversity in terms of the types of plants that grow in them, which can have an impact on the coffee field ecosystem.

The presence of plants from the Asterales, Poales, Fabales, and Caryophyllales orders in the coffee fields can contribute to the stability of the ecosystem and the quality of the soil in the coffee field. Plants from the Asterales order can attract beneficial pollinators, while plants from the Poales order can help maintain soil moisture and reduce erosion. Plants from the Fabales order may improve soil fertility through nitrogen fixation. On the other hand, plants from the Caryophyllales order could protect against erosion and increase soil resistance to disturbances of temperature and drought (Elias and Suwarna 2019).

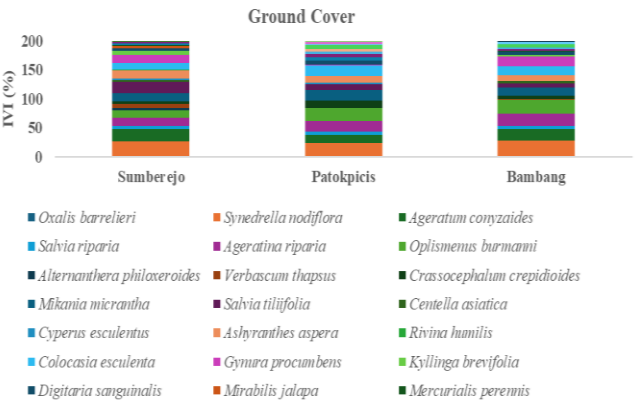

Figure 2. Species of plants that belong to the category of ground cover in the BTSNP Buffer Area, East Java Province, Indonesia

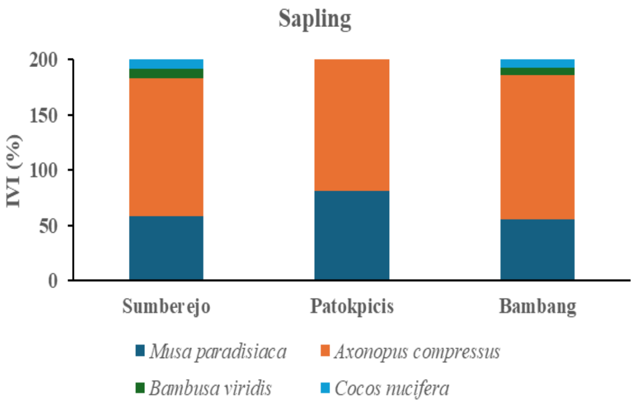

Figure 4. Species of plants that belong to the category of sapling in the BTSNP Buffer Area, East Java Province, Indonesia

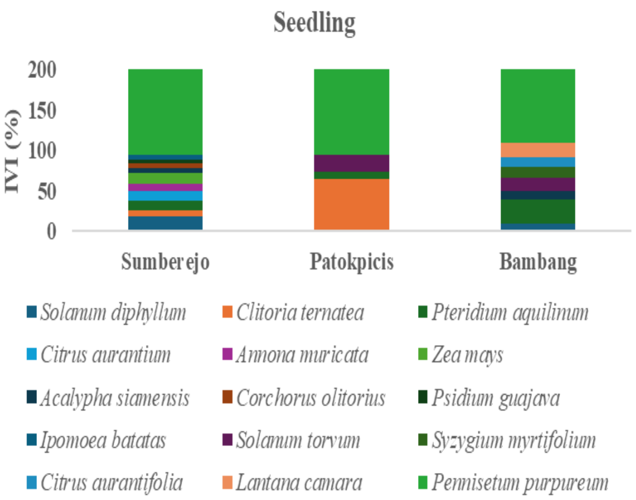

Figure 3. Species of plants that belong to the category of seedling in the BTSNP Buffer Area, East Java Province, Indonesia

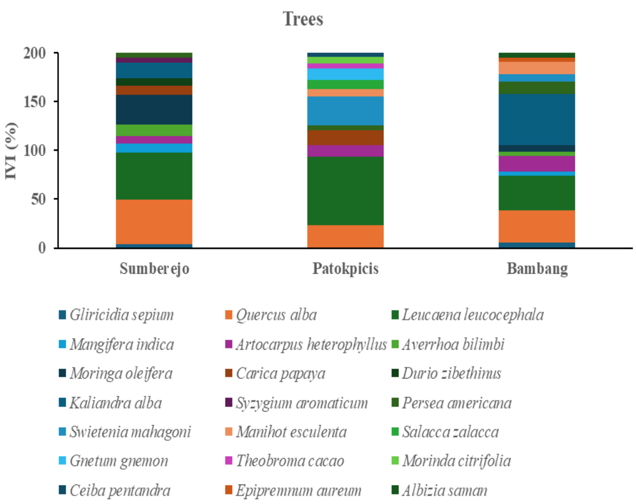

Figure 5. Species of plants that belong to the category of trees in the BTSNP Buffer Area, East Java Province, Indonesia

Table 1. Number of plants found in the 3 villages of BTSNP, East Java Province, Indonesia

Order	∑ family	∑ genus	∑ species	Species name	Local name	Status of species
Asterales	2	9	9	*Ageratina riparia*	*Tekelan*	Invasive
				Ageratum conyzaides	*Wedusan*	Invasive
				Gynura procumbens	*Tapak Liman*	Exotic
				Mikania micrantha	*Mikania*	Invasive
				Synedrella nodiflora	*legetan*	Invasive
				Tagetes erecta	*Kenikir*	Exotic
				Asystasi gangetica	*Bayaman*	Invasive
				Chromolana odorata	*Kirinyu*	Invasive
				Crassocephalum crepidioides	*Junggul*	Invasive
Poales	2	8	8	*Kyllinga brevifolia*	*Jukut pendul*	Non-invasive
				Cyperus esculentus	*Rumput teki*	Non-invasive
				Oplismenus burmanni	*Rumput lamuran*	Non-invasive
				Axonopus compressus	*Rumput Paitan*	Non-invasive
				Bambusa viridis	*Bambu Hijau*	Non-invasive
				Digitaria sanguinalis	*Sunduk gangsir*	Invasive
				Pennisetum purpureum	*Rumput Gajah*	Non-invasive
				Zea mays	*Jagung*	Non-invasive
Fabales	1	6	6	*Albizia saman*	*Sengon*	Exotic
				Gliricidia sepium	*Gamal*	Exotic
				Kaliandra alba	*Kaliandra Putih*	Invasive
				Leucaena leucocephala	*Lamtoro*	Exotic
				Trifolium repens	*Semanggi*	Non-invasive
				Clitoria ternatea	*Bunga Telang*	Exotic
Caryophyllales	3	5	5	*Alternanthera philoxeroides*	*bayam dempo*	Invasive
				Amaranthus ruber	*Bayam Merah*	Non-invasive
				Mirabilis jalapa	*Tegerat*	Non-invasive
				Rivina humilis	*getih-getihan*	Non-invasive
				Ashyranthes aspera	*Jarong*	Non-invasive
Lamiales	3	3	4	*Salvia riparia*	*Salvia*	Non-invasive
				Salvia tiliifolia	*Salvia*	Non-invasive
				Verbascum thapsus	*Tembung Rambat*	Exotic
				Lantana camara	*Tembelekan*	Invasive
Malvales	1	4	4	*Ceiba pentandra*	*Pohon Kapuk*	Non-invasive
				Theobroma cacao	*Pohon Coklat*	Non-invasive
				Corchorus olitorius	*Motokhia*	Non-invasive
				Durio zibethinus	*Durian*	Non-invasive
Sapindales	3	3	4	*Mangifera indica*	*Mangga*	Non-invasive
				Swietenia mahagoni	*Mahoni*	Non-invasive
				Citrus aurantifolia	*Jeruk Nipis*	Non-invasive
				Citrus aurantium	*Jeruk*	Non-invasive
Brassicales	3	3	3	*Moringa oleifera*	*Kelor*	Non-invasive
				Carica papaya	*Pepaya*	Non-invasive
				Cleome spinosa	*Cleome*	Non-invasive
Malpighiales	2	3	3	*Manihot esculenta*	*Singkong*	Non-invasive
				Mercurialis perennis	*merkuri anjing*	Non-invasive
				Phyllanthus niruri	*Meniran*	Non-invasive
Myrtales	1	2	3	*Syzygium aromaticum*	*Cengkeh*	Non-invasive
				Syzygium myrtifolium	*Pucuk Merah*	Non-invasive
				Psidium guajava	*Jambu*	Non-invasive
Solanales	1	2	3	*Ipomoea batatas*	*Ketela Pohon*	Non-invasive
				Solanum torvum	*Takokak*	Non-invasive
				Solanum diphyllum	*Terong-terongan*	Non-invasive
Oxalidales	1	2	2	*Oxalis barrelieri*	*Blimbing-blimbingan*	Non-invasive
				Averrhoa bilimbi	*Belimbing*	Non-invasive
Alismatales	1	2	2	*Epipremnum aureum*	*Sirih Gading*	Exotic
				Colocasia esculenta	*Talas*	Exotic
Arecales	1	2	2	*Salacca zalacca*	*Salak*	Exotic
				Cocos nucifera	*Kelapa*	Exotic
Asparagales	1	1	1	*Allium cepa*	*Bawang Merah*	Exotic
Laurales	1	1	1	*Persea americana*	*Alpukat*	Exotic
Magnoliales	1	1	1	*Annona muricata*	*Sirsak*	Exotic
Apiales	1	1	1	*Centella asiatica*	*Pegagan*	Exotic
Commelinales	1	1	1	*Commelina diffusa*	*Brambangan*	Exotic
Ericales	1	1	1	*Impatiens pudica*	*Putri Malu*	Exotic
Euphorbiales	1	1	1	*Acalypha siamensis*	*Teh-tehan*	Exotic
Fagales	1	1	1	*Quercus alba*	*Jati Putih*	Exotic
Gentianales	1	1	1	*Morinda citrifolia*	*Mengkudu*	Exotic
Gnetales	1	1	1	*Gnetum gnemon*	*Belinjo*	Exotic
Polypodiales	1	1	1	*Pteridium aquilinum*	*Pakis*	Exotic
Rosales	1	1	1	*Artocarpus heterophyllus*	*Nangka*	Exotic
Zingiberales	1	1	1	*Musa paradisiaca*	*Pisang*	Exotic
Total	38	67	71			

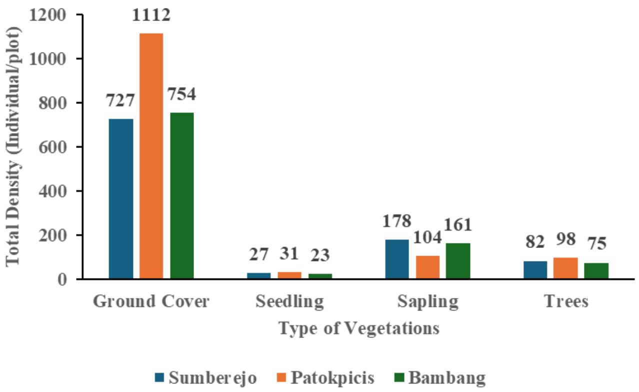

Figure 6. Total density by category growth rate in 3 locations BTSNP Buffer Area, East Java Province, Indonesia

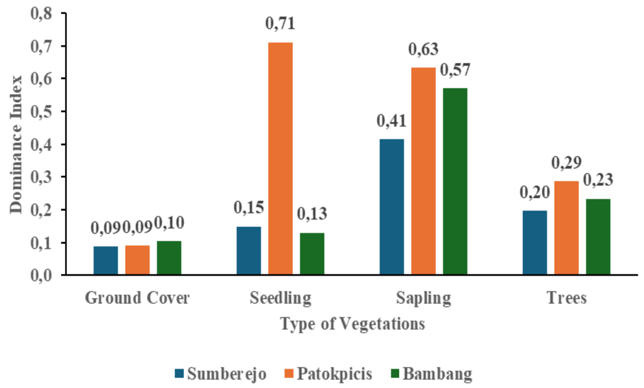

Figure 9. Dominance indices by category growth rate in 3 locations BTSNP Buffer Area, East Java Province, Indonesia

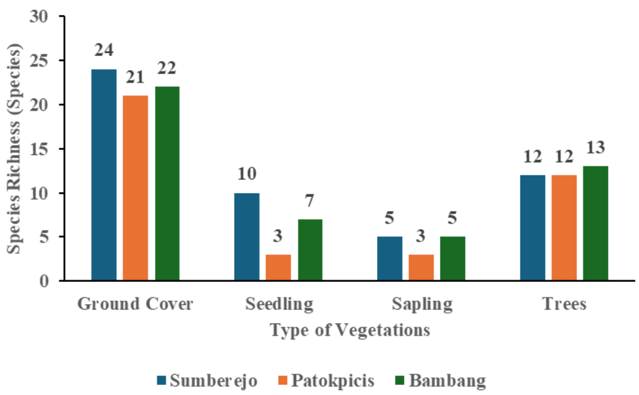

Figure 7. Species richness by category growth rate in 3 locations BTSNP Buffer Area, East Java Province, Indonesia

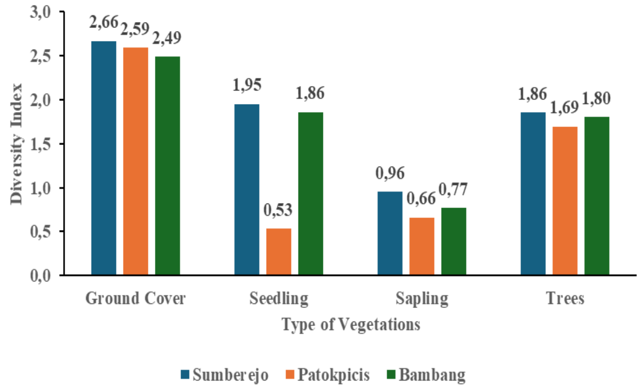

Figure 10. Diversity indices by category growth rate in 3 locations BTSNP Buffer Area, East Java Province, Indonesia

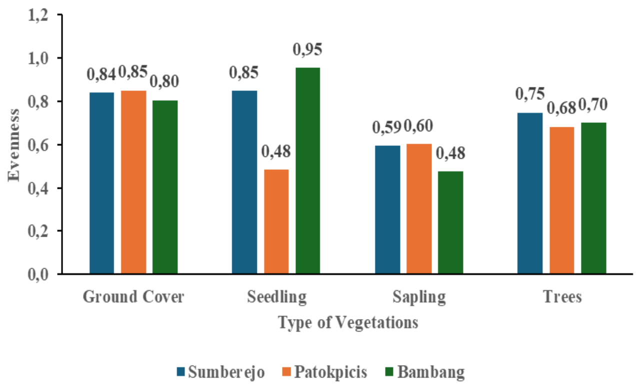

Figure 8. Evenness value by category growth rate in 3 locations BTSNP Buffer Area

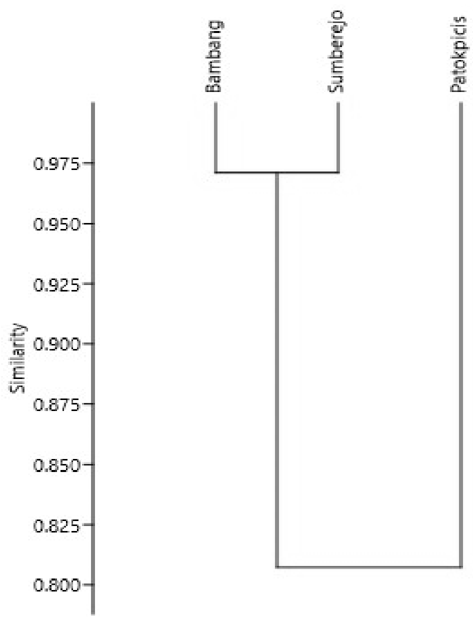

Figure 11. Results of cluster analysis of total density, species type richness, evenness, index of dominance and index of plant diversity based on growth rate

Discussion

The coffee grounds in the corridors of the BTSNP plantation area have different types of trees that can be categorized according to their rate of growth. Here are the 4 categories found in the coffee grounds at the 3 plantation areas: ground cover, seedling, sapling, and trees. Based on Figure 2, the plant species that belong to the undergrowth category are found in as many as 31 species. In the village of Sumberejo were found as many as 24 species, the village Patokpicis as 21 species, and the village Bambang as 22 species with the species that have the largest Important Value Index (IVI) on the three locations is *Synedrella nodiflora*. The presence of a plant species in each location indicates that species' adaptability to the local environment, and the Importance Value Index of that species in that community is a statement that illustrates the importance of that species in that community (Aiko et al. 2022).

Sumberejo village has a diverse range of species, with relatively even IVI. Patokpicis village was dominated by *Pennisetum pupureum*, which has a much higher IVI compared to the other species present. Bambang village, similar to Sumberejo, has a diverse range of species, with relatively even IVI. It seems to suggest that Patokpicis has a less diverse plant community or a more dominant species compared to Sumberejo and Bambang (Figure 3).

In Sumberejo, the highest contribution to IVI comes from *Axonopus compressus*, followed by *Musa paradisiaca*, and the least from *Cocos nucifera*. In Patokpicis, the contributions of *Axonopus compressus* were higher than others, with *Musa paradisiaca* contributing a smaller amount and *Cocos nucifera* contributing the least. In Bambang, *Axonopus compressus* has the highest contribution, followed by *Musa paradisiaca* and *Cocos nucifera* contributing equally and less than the other two species. *Axonopus compressus* are the dominant contributors to IVI in these categories (Figure 4).

Sumberejo has a diverse set of species, with no single species dominating. The species include *Gliricidia sepium, Mangifera indica, Moringa oleifera, Kaliandra alba, Swietenia mahagoni, Gnetum gnemon*, and *Ceiba pentandra*. Patokpicis has a lot of different species, like Sumberejo. It has *Quercus alba, Artocarpus heterophyllus, Carica papaya, Syzygium aromaticum, Manihot esculenta, Theobroma cacao,* and *Epipremnum aureum*, among others. The distribution seems slightly more even across species compared to Sumberejo. Bambang has a different set of species, with some, like *Leucaena leucocephala* and *Averrhoa bilimbi*, appearing to have a higher IVI compared to others. Other species present include *Durio zibethinus, Persea americana, Salacca zalacca, Morinda citrifolia, and Albizia saman* (Figure 5).

The highest density of individuals per plot is found in the ground cover category for Patokpicis, with 1112 individuals/plot. The seedling category has the lowest density across all three regions. Sumberejo has the highest density of trees compared to the other two regions, although the numbers are relatively close. Bambang has a higher density of saplings than the other two regions (Figure 6). Figure 7 shows that of the four categories, ground cover and seedling in the village of Sumberrejo have the highest species richness, with a total of 24 species and 10 species. For the category of sapling village, Sumberejo and Bambang each obtained 5 species, while the tree category village of Bambang has the largest number of species at 13.

The Evennes value (Figure 8) obtained indicates that the ground cover in 3 locations has a value between 0.80-0,85, for the seedling category of Bambang village has the highest value of 0.95 and Patokpicis has the lowest value is 0.48, while for the category of the three locations, the village of Patoxicis has a highest rating of 0.60. The higher value of evenness indicates that in the Area has a high diversity (Redowan 2015). A plant community with an evenness index value around one has a more uniform distribution (Aiko et al. 2022).

The dominant index (Figure 9) which has the highest value is the seedling category that is found in the village of Patokpicis with a value of 0.71 while the ground cover category has the lowest value and is located in the villages of Sumberejo and Patokpicis, with a value of 0.09. As for the diversity index (Figure 10), the ground cover category in the village of Sumberejo has the highest value of 2.66. The lowest value is in the seedling category, with a value of 0.53 in Patokpicis village, which belongs to the lower category.

The results of the analysis of the index of similarities related to total density, species richness, evenness, index of dominance, and index diversity based on the growth rate in the BTSNP buffer zone area (Figure 11), show that the villages of Sumberrejo and Bambang have the same degree of similarity compared to patokpicis.

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