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Vegetation Composition and Carbon Storage Potential at Tree and Pole Levels in the Gunung Leuser National Park Area, Bukit Lawang, Bahorok District, Langkat Regency, North Sumatra

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ABSTRACT

Forests play a crucial role in environmental, economic, and social sustainability by storing carbon and mitigating climate change. This study aimed to assess the vegetation composition, diversity, and carbon storage in Gunung Leuser National Park, Bukit Lawang, North Sumatra. Fieldwork, conducted using purposive and nested sampling methods, recorded 11 families and 14 plant species with 27 individuals at the tree growth level, and 11 families and 16 plant species with 30 individuals at the pole growth level. The Burseraceae family dominated tree-level composition (29%), while the Phyllanthaceae family dominated pole-level composition (28%). The highest Important Value Index (IVI) was *Santiria rubiginosa* (36.09%) for trees and *Gironniera nervosa* (55.46%) for poles. The Shannon-Wiener Diversity Index (H') was 2.45 for trees and 2.53 for poles, with evenness values (E) of 0.93 and 0.91, respectively. The total biomass was 120.240 tons/ha, with stored carbon amounting to 55.310 tons C/ha. To better estimate carbon storage potential, further research should cover larger areas and include biomass components like litter and dead wood.
Keyword: Biodiversity, carbon sequestration, community ecology.

ABSTRAK

Hutan memainkan peran penting dalam keberlanjutan lingkungan, ekonomi, dan sosial dengan menyimpan karbon dan memitigasi perubahan iklim. Penelitian ini bertujuan untuk menilai komposisi vegetasi, keanekaragaman, dan penyimpanan karbon di Taman Nasional Gunung Leuser, Bukit Lawang, Sumatera Utara. Pengumpulan data lapangan dilakukan dengan metode purposive dan nested sampling, mencatat 11 famili dan 14 spesies tumbuhan dengan 27 individu pada tingkat pertumbuhan pohon, serta 11 famili dan 16 spesies tumbuhan dengan 30 individu pada tingkat pertumbuhan tiang. Famili Burseraceae mendominasi komposisi pada tingkat pohon (29%), sedangkan famili Phyllanthaceae mendominasi pada tingkat tiang (28%). Nilai Indeks Nilai Penting (INP) tertinggi adalah Santiria rubiginosa (36,09%) untuk pohon dan Gironniera nervosa (55,46%) untuk tiang. Indeks Keanekaragaman Shannon-Wiener (H') adalah 2,45 untuk pohon dan 2,53 untuk tiang, dengan nilai kelimpahan (E) masing-masing 0,93 dan 0,91. Total biomassa sebesar 120,240 ton/ha, dengan karbon yang tersimpan mencapai 55,310-ton C/ha. Untuk memperkirakan potensi penyimpanan karbon dengan lebih baik, penelitian lanjutan harus mencakup area yang lebih luas dan termasuk komponen biomassa seperti serasah dan kayu mati.
Kata kunci: *Keanekaragaman hayati, penyerapan karbon, ekologi komunitas.*

1. Introduction

Forests are natural resources that play a vital role in life from economic, social, cultural, and environmental perspectives, acting as the lungs of the world that produce oxygen essential for human life on Earth. The decreasing forest area leads to the extinction of plant species and contributes to global warming [1]. Forest environments are considered highly productive ecosystems with large carbon storage in biomass, where their calculation and monitoring have become increasingly important due to their relevance to climate change adaptation and mitigation programs, as well as the significance of forest carbon stocks in the global cycle and studies of global environmental change [2,3]. According to the IPCC (2014), by the end of this century, the planet will warm by between 0.3 to 4.8°C, and the increase in greenhouse gas concentrations in the atmosphere is gradually causing average global warming and may alter the frequency, severity, and even the nature of extreme events such as droughts, floods, and biodiversity loss.

Vegetation is one of the factors that can reduce carbon dioxide (CO2) in the atmosphere. Trees in forests function as storage and deposition sites for carbon, a process known as carbon sinks. The storage of carbon in growing plants is referred to as carbon sequestration (Putri and Wulandari, 2015). The ability of forests to absorb and store carbon varies, influenced by several factors such as tree diameter, tree age, species diversity, plant density, tree type, forest topography, vegetation type, altitude, and other biophysical conditions [4,5]. The amount of stored carbon reserves needs to be measured to determine the size of the carbon reserves in an area and to monitor changes if activities that increase or decrease the reserves occur [6].

The Gunung Leuser National Park area in Bukit Lawang, Bahorok District, Langkat Regency, North Sumatra, is one of the well-preserved forests with high tree species diversity and a significant amount of stored carbon reserves in North Sumatra. Based on this, it is necessary to conduct practical fieldwork to obtain information and data on the state of vegetation composition and the potential stored carbon in the Gunung Leuser National Park area in Bukit Lawang, Bahorok District, Langkat Regency, North Sumatra.

2. Methods

2.1 Study site and period

This study work was conducted from May 23-26, 2024, in the Gunung Leuser National Park area, Bukit Lawang, Bahorok District, Langkat Regency, North Sumatra, with data identification and analysis performed at the Plant Systematics Laboratory, Universitas Sumatera Utara. The Gunung Leuser National Park in Bukit Lawang spans approximately 1,094,692 hectares, located 68 km northwest of Binjai and around 80 km northwest of Medan, at an altitude of 108-500 meters above sea level. The area has a tropical climate with high rainfall ranging from 4,500 to 5,000 mm per year and an average temperature of 23°C, classified as Climate Type B according to the Schmidt and Ferguson system. The surrounding forest is part of a wet tropical forest ecosystem, home to rare flora such as the Rafflesia flower and approximately 3,500 other plant species.

2.2 Field collection

The fieldwork location was determined using purposive sampling, intentionally selecting sites within the Bukit Lawang Forest. The study plots were established using nested sampling, with larger plots containing subplots. The plot size was 20 x 20 m² for tree level and 10 x 10 m² for pole level, covering a total area of 1,000 m². For vegetation analysis, plots were differentiated based on tree growth stages according to Soerianegara and Indrawan (1988): 10 x 50 m² plots for pole-sized plants with a diameter of 10-20 cm, and 10 x 100 m² plots for trees with a diameter >20 cm. In each plot, the plants were recorded by species, measured for diameter, photographed, key characteristics noted, collected, and labeled for further identification. Collected plants were photographed on black fabric with a 30 cm ruler as a reference. At each research site, physical parameters measured included air temperature with a hygrometer, light intensity with a lux meter, soil temperature with a soil thermometer, soil pH with a soil tester, air humidity with a hygrometer, rainfall with an ombrometer, and coordinates using GPS.

2.3 Data analysis

The vegetation composition was evaluated by utilizing the Importance Value Index (IVI) which is determined by adding the Relative Density, Relative Frequency, and Relative Dominance values. The Diversity Index of Shannon-Wiener (*H'*) and Uniformity Index (*E*) were used to analyze the diversity and uniformity of the vegetation species [8]. The tree biomass value was estimated by measuring the diameter at breast height (DBH) and plotted into an allometric equation as follows: dry weight (DW) = $0.11\times\rho\times DBH^{2.62}$ [9]. Note: ρ = density (g/cm^3). The specific gravity of the tree can be seen on ICRAF: (https://www.worldagroforestry.org/). The carbon stocks were measured by multiplying the tree biomass per unit area by a factor of 0.46 (ton/ha).

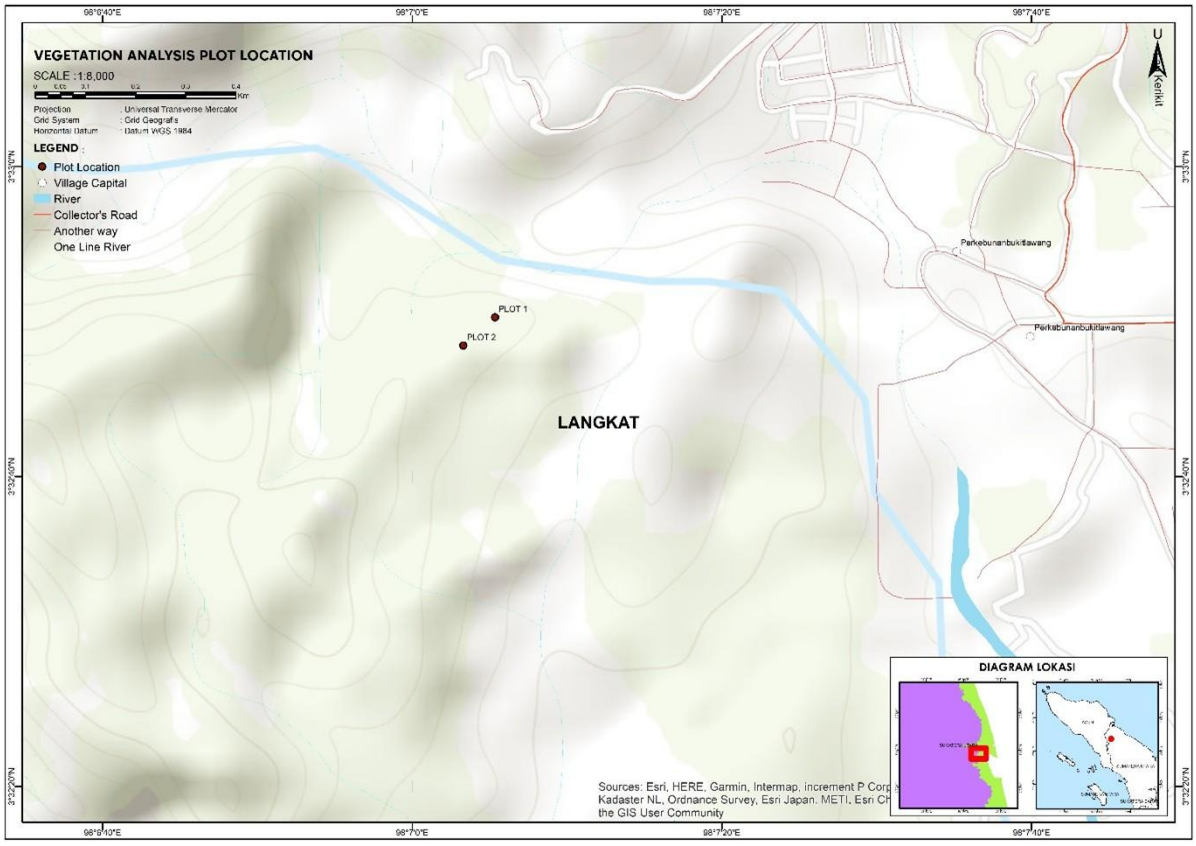

Figure 1. Map of Analysis Vegetation Plots in the Gunung Leuser National Park Bukit Lawang Area, Langkat Regency.

3. Result and discussion

3.1 Floristic composition

The diversity of vegetation species at the research site varies at each growth stage of trees and poles. A total of 27 individuals from 11 tree species, representing 14 families, were found in the Gunung Leuser National Park area, Bukit Lawang, Langkat Regency. The family with the highest number of individuals was Burseraceae, with Santiria rubiginosa and Dacryodes costata, each found with 4 individuals. Additionally, a total of 30 individuals from 16 pole species, representing 11 families, were found in the same area, with the Cannabaceae family being the most dominant. The species diversity in the Gunung Leuser National Park area, Bukit Lawang, Langkat Regency, is lower compared to the findings reported by Heriyanto (2020) in the Muara Merang Forest, South Sumatra, where 30 families and 98 species of plants were identified [7]. Meanwhile, Lufti (2021) reported 57 families and 146 species of plants in the Soraya Research Station, Leuser Ecosystem Area [8]. The differences in plant species diversity between this research site and others are due to variations in the size of the observation plots and various environmental factors that are suitable for each species' habitat. According to Dini (2018), the environmental factors influencing this diversity include topography, altitude, rainfall, and soil moisture [9].

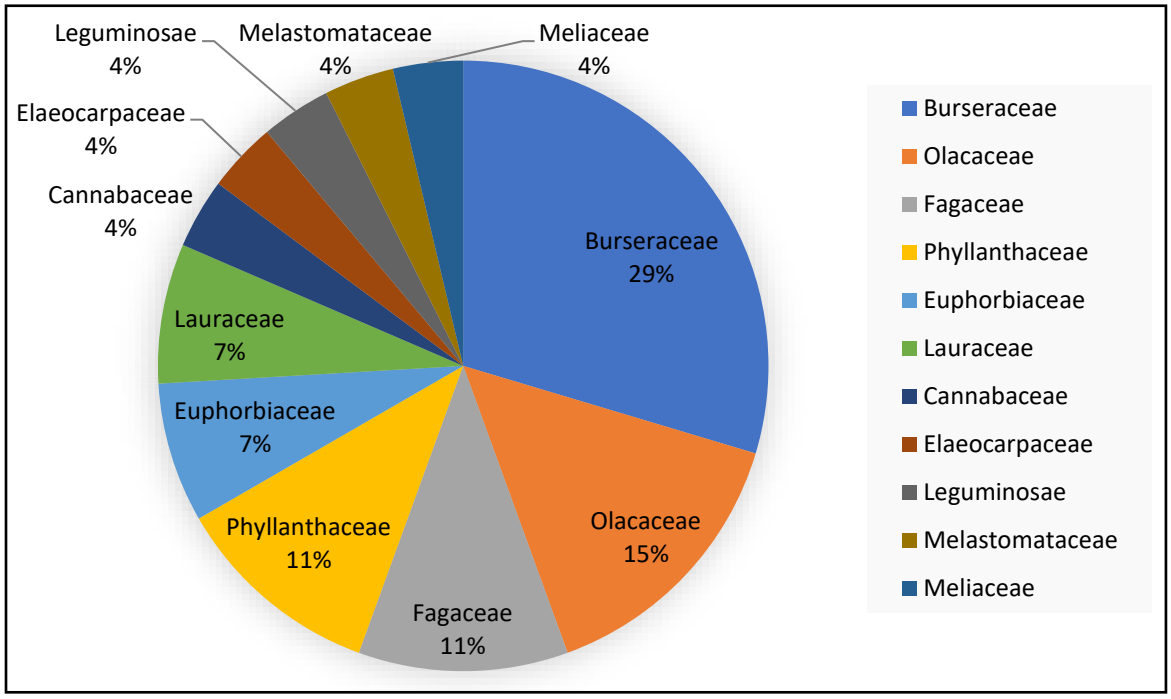

Figure 2. Tree Level Composition in the Gunung Leuser National Park Bukit Lawang Area, Langkat Regency

The tree-level vegetation composition in the Gunung Leuser National Park Bukit Lawang area, Langkat Regency, consists of 11 families. According to Figure 1, the highest percentage composition is found in the Burseraceae family at 29%, while the lowest percentages are in the Cannabaceae, Elaeocarpaceae, Leguminosae, Melastomataceae, and Meliaceae families, each at 4%. This is attributed to the nutrient-rich soil in the Gunung Leuser National Park Bukit Lawang area, which supports the growth of the Burseraceae family. The ability of plants to absorb nutrients is also influenced by the soil's pH level. Simorangkir et al. (2009) state that soils with a neutral pH, between 6.5 and 7.8, have optimal levels of organic compounds, microorganisms, nutrients, and minerals to support healthy vegetation growth [10].

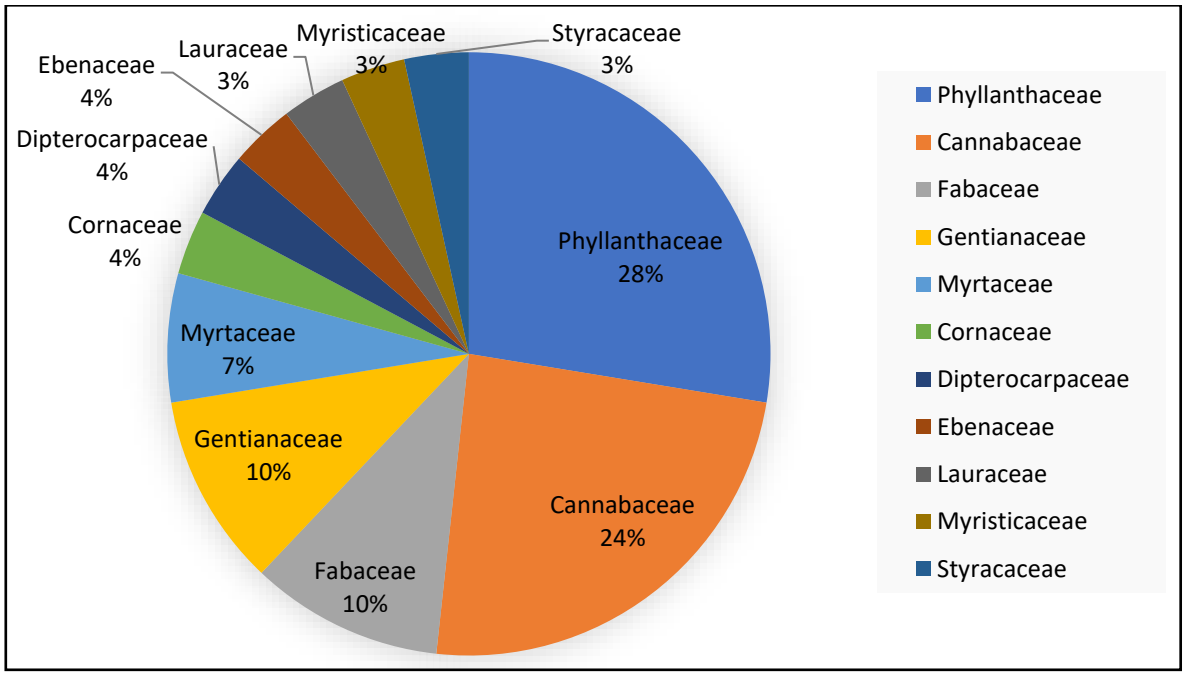

Figure 3. Pole Level Composition in the Gunung Leuser National Park Bukit Lawang Area, Langkat Regency.

The pole-level vegetation composition in the Gunung Leuser National Park Bukit Lawang area, Langkat Regency, consists of 11 families. According to Figure 2, the highest percentage composition is found in the Phyllanthaceae family at 28%, while the lowest percentages are in the Lauraceae, Myristicaceae, and Styracaceae families, each at 3%. This variation is due to environmental factors such as water availability, oxygen, pH, soil nutrients, and other interacting factors. Rahmasari (2011) and Naharuddin (2017) state that the variation in vegetation composition within a community is influenced by various environmental factors, including temperature, light, soil structure, and humidity. These factors affect the percentage composition of vegetation. Additionally, the success of each species in developing into new individuals is influenced by different levels of soil fertility, leading to variations in the composition percentages of each species [11,12].

3.2 Vegetation structure

The IVI is a measure of a species' overall importance, taking into account its relative density, relative frequency, and relative dominance in the forest. The results of the study are presented in Table 1.

Table 1. The IVI of different size classes of vegetation in Bukit Lawang, Gunung Leuser National Park.

Species	Family	RD (%)	RF (%)	RDo (%)	IVI
Tree					
Santiria rubiginosa Blume	Burseraceae	14.79	7.14	14.15	36.09
Dacryodes costata (A.W.Benn.) H.J.Lam	Burseraceae	14.79	7.14	8.44	30.37
Gironniera nervosa Planch.	Cannabaceae	3.70	7.14	5.32	16.16
Elaeocarpus sp.	Elaeocarpaceae	3.70	7.14	11.10	21.94
Elateriospermum tapos Blume	Euphorbiaceae	3.70	7.14	4.11	14.95
Endospermum diadenum (Miq.) Airy Shaw	Euphorbiaceae	3.70	7.14	4.70	15.54
Castanopsis costata (Blume) A.DC.	Fagaceae	3.70	7.14	2.23	13.07
Lithocarpus encleisacarpus (Korth.) A.Camus	Fagaceae	7.40	7.14	10.58	25.12
Lindera polyantha (Blume) Boerl.	Lauraceae	7.40	7.14	6.88	21.42
Archidendron bubalinum (Jack) I.C.Nielsen	Leguminosae	3.70	7.14	3.83	14.67
Pternandra rostrata (Cogn.) M.P.Nayar	Melastomataceae	3.70	7.14	4.70	15.54
Aglaia sp.	Meliaceae	3.70	7.14	5.21	16.06
Ochanostachys amentacea Mast.	Olacaceae	14.79	7.14	8.59	30.52
Aporosa lucida (Miq.) Airy Shaw	Phyllanthaceae	11.09	7.14	10.17	28.41
Pole					
Gironniera nervosa Planch.	Cannabaceae	23.33	9.52	22.61	55.46
Alangium sp.	Cornaceae	3.33	4.76	3.94	12.04
Dipterocarpus cf. palembanicus	Dipterocarpaceae	3.33	4.76	2.35	10.44
Diospyros sp.	Ebenaceae	3.33	4.76	2.63	10.73
Archidendron sp.	Fabaceae	10.00	4.76	13.52	28.28
Fagraea racemosa Jack ex Wall.	Gentianaceae	10.00	9.52	10.50	30.02
Alseodaphne sp. 1	Lauraceae	3.33	4.76	7.31	15.41
Alseodaphne sp. 2	Lauraceae	3.33	4.76	5.92	14.02
Knema furfuracea (Hook.f. & Thomson) Warb.	Myristicaceae	3.33	4.76	5.08	13.18
Syzygium sp.	Myrtaceae	6.67	9.52	7.82	24.01
Cleistanthus sp.	Phyllanthaceae	6.67	9.52	2.96	19.15
Baccaurea motleyana (Müll.Arg.) Müll.Arg.	Phyllanthaceae	10.00	9.52	6.15	25.67
Baccaurea parviflora (Müll.Arg.) Müll.Arg.	Phyllanthaceae	3.33	4.76	0.98	9.08
Baccaurea sp.	Phyllanthaceae	3.33	4.76	1.84	9.93
Glochidion sp.	Phyllanthaceae	3.33	4.76	2.08	10.18
Styrax sp.	Styracaceae	3.33	4.76	4.31	12.40

The Important Value Index (IVI) at the sapling level ranges from 13.07% to 36.09%. The highest IVI is for *Santiria rubiginosa* at 36.09%, while the lowest IVI is for *Castanopsis costata* at 13.07%. The high IVI of *Santiria rubiginosa* is due to its broad and even distribution, and its growth is influenced by the seed dispersal process. The IVI at the pole level ranges from 55.46% to 9.08%. The highest IVI is for *Gironniera nervosa* at

55.46%, and the lowest IVI is for *Baccaurea parviflora* at 9.08%. The high IVI of *Gironniera nervosa* is attributed to its wide and even distribution, with growth influenced by seed dispersal. Additionally, *Gironniera nervosa* is a food source for orangutans, which aids in seed dispersal by these animals.

According to Rizal (2021), the presence of wildlife in a habitat plays a crucial role in seed dispersal. Without wildlife to disperse seeds, many plant seeds would germinate under the parent tree [13]. Setia (2008) notes that seed dispersal is carried out by several types of wildlife, including through their feces. Wildlife such as birds, monkeys, squirrels, and bats contribute to seed dispersal [14]. Fruit-eating primates, particularly orangutans, are effective at dispersing plant seeds through their feces. According to Hamilton et al. (1994), the fruit of *Gironniera nervosa* accounts for 25% of the foraging time of orangutans, which is higher compared to young leaves of the same species. This fruit provides a significant protein source in the orangutan diet due to the large quantities consumed [15]. Lim et al. (2021) state that fruits provide sugar, while leaves are a source of protein. Because fruit distribution is often uneven, fruit-eating primates have larger home ranges compared to leaf-eaters [16].

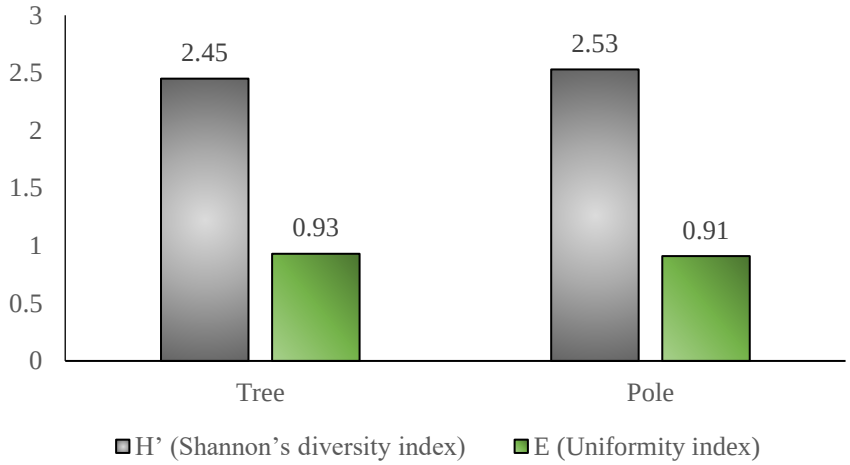

Figure 4. Bar plot of the Shannon's diversity index (*H'*) and uniformity index (*E*) of different size classes in West Batang Toru Forest Block Gunung Leuser National Park Bukit Lawang Area, Langkat Regency.

The diversity index values for the tree and pole growth levels range from 2.45 to 2.53, with the highest H' value at the pole level being 2.53, and the lowest H' value at the tree level being 2.45. This indicates that the diversity index in the Gunung Leuser National Park Bukit Lawang area is relatively low. According to Florensius et al. (2018), a high species diversity is indicated by an H' value greater than 3, which is characterized by a high number of species and individuals within a community [17]. Conversely, an H' value less than 3 indicates fewer species and individuals in the community. The evenness index values for the different growth stages range from 0.93 to 0.91, with the values being relatively high. According to Dendang and Handayani (2015), an evenness index (E) approaching one suggests that species within a community are distributed more evenly, whereas an E value approaching zero indicates a less even distribution of species within the community [18].

Table 2. Forest biomass and carbon stock in Bukit Lawang, Gunung Leuser National Park.

Size class(es)	**Biomass (ton/ha)**	**Carbon stock (tC/ha)**
Pohon	108.213	49.778
Pole	12.027	5.532
Total	120.240	55.310

The highest biomass and stored carbon across all growth stages in the Gunung Leuser National Park Bukit Lawang area are 120.240 tons/ha and 55.310 tons C/ha, respectively. The high values of biomass and stored carbon are attributed to variations in the number of individuals at a given location and the diameter of each tree, which influence the amount of carbon stored in the research area. According to Sari (2018), the size of tree stand biomass is influenced by the types of trees dominating a particular area, as certain tree species with large trunk diameters have greater biomass [19]. Forests have 70% of their total biomass from trees with diameters over 30 cm, while trees with diameters between 5 and 30 cm contribute only about 30%. According to Hairiah and Rahayu (2011) and Adinugroho (2009), carbon storage at a location varies due to several factors, including vegetation type and tree density [20]. One easily measurable factor is tree density, which can be

calculated by comparing the number of trees in a given area. Therefore, in this study, the assessment of tree stand density was conducted by comparing the number of trees present with the total observed plot area.

4. Conclusion

In the Gunung Leuser National Park Bukit Lawang area, Langkat Regency, North Sumatra Province, the following results were obtained, at the tree growth level, 11 families and 14 plant species with 27 individuals were identified, while at the pole growth level, 11 families and 16 plant species with 30 individuals were recorded. The highest vegetation composition at the tree level was the Burseraceae family at 29%, and at the pole level, it was the Phyllanthaceae family at 28%. The highest Important Value Index (IVI) at the tree growth level was *Santiria rubiginosa*, with a value of 36.09%, whereas at the pole level, it was *Gironniera nervosa*, with an IVI of 55.46%. The Diversity Index (H') was 2.45 for trees and 2.53 for poles, while the Evenness Index (E) was 0.93 for trees and 0.91 for poles. The total biomass and stored carbon across all growth stages in the Gunung Leuser National Park Bukit Lawang area were 120.240 tons/ha and 55.310 tons C/ha, respectively. To obtain a more comprehensive estimate of the carbon storage potential at this location, further research is needed with a larger plot area and by including biomass calculations for forest components such as litter and dead wood.

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