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Relationship Between Tree Diversity and Carbon Stock in Muhammad Sabki Urban Forest, Jambi City, as Baseline Information for Regional Carbon Economic Value Development

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Abstract
Introduction: *Urban forests play a critical role in biodiversity conservation, carbon storage, and climate change mitigation. Baseline data on vegetation diversity and carbon stock are essential for sustainable urban forest management and Carbon Economic Value (CEV) development* ***Objective:*** *This study aimed to analyze the relationship between tree vegetation diversity and carbon stock in Muhammad Sabki Urban Forest, Jambi City.* ***Method:*** *A quantitative descriptive-analytic approach was applied through a census of all trees with DBH ≥ 10 cm. Biomass, carbon stock, and CO_2-eq were estimated using allometric equations and standard conversion factors. The relationship between vegetation diversity and carbon stock was analyzed using Pearson correlation and simple linear regression.* ***Results and Discussion:*** *A total of 1,130 trees representing 29 species were recorded. Total aboveground biomass reached 269.531 tons, with carbon stock of 126.679 tons C equivalent to 464.913 tons CO_2-eq. Zone 2 had the highest carbon stock while Zone 3 showed the greatest species diversity. All vegetation diversity indices were positively correlated with carbon stock, with the Shannon-Wiener index showing the strongest relationship (r=0.592), followed by the Margalef index (r=0.441) and Pielou index (r=0.201).* ***Conclusion:*** *Tree vegetation diversity was positively associated with carbon stock in Muhammad Sabki Urban Forest. Carbon storage was influenced by both vegetation diversity and stand structure. The results provide baseline information for carbon inventory and regional Carbon Economic Value development.*

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Introduction

Global climate change is one of the major environmental issues facing the world today, mainly driven by increasing concentrations of greenhouse gases, particularly carbon dioxide (CO_2), in the atmosphere (Irma & Gusmira, 2024); (Daeli, 2024); (Irma & Gusmira, 2023). Land-based sectors, including forests and urban vegetation, play an important role in climate change mitigation because they absorb atmospheric CO_2 and store it as biomass carbon (Ngasim, 2025); (BP, Witno, & Defara, 2025). Within the Agriculture, Forestry and Other Land Use (AFOLU) framework, forest land is an important category in greenhouse gas inventories because it includes carbon changes in biomass, dead organic matter, and soil (IPCC, 2006; IPCC, 2019).

Urban forests are green open spaces that provide ecological benefits in urban environments, including carbon storage, CO_2 absorption, microclimate regulation, air pollutant filtration, runoff reduction, and habitat provision (Safitri, Putri, Fajri, & Rindiani, 2024). In the context of climate change mitigation, the ability of urban tree vegetation to store carbon makes urban forests an important component of sustainable city management (Bana, Gandri, Hasani, Flamin, & Mubarak, 2025). Carbon stock in tree vegetation is influenced by stand structure and species characteristics, such as stem diameter, tree height, wood density, stand density, dominance, and species composition (Donsi, Baderan, Hamidun, Ahmad, & Rosalia, 2025); (Paradika, Kissinger, & Rezekiah, 2021). Biomass estimation in tropical trees commonly uses diameter, height, and wood density because these variables are closely related to aboveground biomass. Therefore, measuring biomass and carbon stock is necessary to evaluate the ecological function of urban forests as carbon sinks.

Vegetation diversity may also influence carbon stock through differences in species traits, canopy structure, rooting systems, and resource-use patterns (Sari, Ishaq, Purnamasari, & Saputra, 2025). However, the relationship between vegetation diversity and carbon stock is not always linear, because carbon storage is strongly affected by tree size, wood density, stand age, site condition, and land-use intensity (Azurianti, Lestariningsih, Prijono, Anggara, & Lathif, 2023). Areas with low species richness may store high carbon if they are dominated by large-diameter or high wood-density trees, whereas areas with high species richness may have lower carbon stock if the trees are relatively small or sparse (Utomo & Baskara, 2026); (Madapuri, 2020). This indicates the need for field-based analysis to understand the relationship between vegetation diversity and carbon stock in specific urban forest conditions. Vegetation carbon stock data are also relevant to the development of Carbon Economic Value (CEV) in Indonesia. Regulation of the Minister of Environment and Forestry Number 21 of 2022 provides a policy basis for carbon trading, results-based payments, measurement, reporting, verification, and carbon registry systems. In this context, carbon stock and CO_2-eq data from urban forests can support baseline development, monitoring, and regional climate change mitigation planning.

Muhammad Sabki Urban Forest in Jambi City is one of the forested green open spaces that provides ecological, social, educational, and recreational functions. This area has different land-use intensities, which may affect vegetation structure, species composition, diversity, biomass, and carbon stock. However, comprehensive tree-level data on vegetation diversity, biomass, carbon stock, and CO_2-eq in this area remain limited. Therefore, this study aimed to analyze the relationship between tree vegetation diversity and carbon stock in Muhammad Sabki Urban Forest, Jambi City. A census inventory was conducted for all tree vegetation with diameter at breast height (DBH) ≥ 10 cm. Each tree was identified by species, measured for diameter and clear bole height, and georeferenced. The findings are expected to provide scientific baseline information for sustainable urban forest management and to support regional climate change mitigation and Carbon Economic Value policy development.

Method

This study used a descriptive-analytic quantitative approach to describe tree vegetation, biomass, carbon stock, and CO_2-eq, and to analyze the relationship between vegetation diversity and carbon stock in Muhammad Sabki Urban Forest, Jambi City. The study was conducted from March to April 2026 in Muhammad Sabki Urban Forest, located in Kenali Asam Village, Kota Baru District, Jambi City, Jambi Province. The study area covers approximately ±11 ha and was divided into three zones based on utilization intensity: Zone 1 representing low utilization, Zone 2 representing moderate utilization, and Zone 3 representing high utilization and supporting facilities. For analytical comparability, each zone was divided into 700 m² analysis units, resulting in 157 units: 30 units in Zone 1, 52 units in Zone 2, and 75 units in Zone 3.

Data were collected using a census method of all tree individuals with diameter at breast height (DBH) ≥ 10 cm. The recorded variables included species name, number of individuals, DBH, clear bole height, wood density, and tree coordinates. Field instruments included a diameter tape, tree height measuring device, GPS or digital mapping application, documentation camera, and observation sheets. The data were tabulated by zones and analysis units to develop a tree-level vegetation database. Vegetation structure was analyzed using tree density and dominance, while vegetation diversity was assessed using the Shannon–Wiener index. Aboveground biomass was estimated using the Chave et al. (2014) allometric equation, with wood density, DBH, and clear bole height as parameters. Carbon stock was calculated using a biomass conversion factor of 0.47, and CO_2-eq was calculated using a conversion factor of 3.67. The relationship between vegetation diversity and carbon stock was analyzed using Pearson correlation and simple linear regression to determine the direction and strength of the relationship in each analysis unit. Biomass, carbon stock, and CO_2-eq were also analyzed descriptively for each zone to describe ecological characteristics and provide preliminary information for regional Carbon Economic Value development

Result and Discussion

Structure and Composition of Tree-Level Vegetation

Muhammad Sabki Urban Forest, Jambi City, was divided into three research zones, namely Zone 1, Zone 2, and Zone 3. Zone 1 is characterized as a low-utilization zone with an area of 2.10 ha, Zone 2 is characterized as a moderate-utilization zone with an area of 3.64 ha, while Zone 3 is characterized as a high-utilization zone with supporting facilities and covers an area of 5.26 ha. Based on the census of tree-level vegetation, a total of 1,130 tree individuals were recorded and used in the analysis. The spatial distribution of tree individuals was visualized in the form of a map showing tree locations and species, as presented in Figure 1.

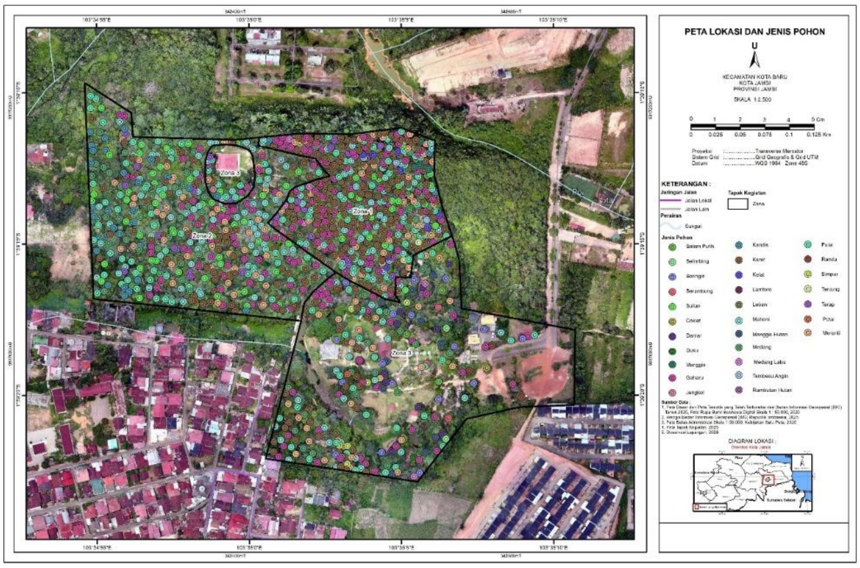

Figure 1. Map of tree locations and species in Muhammad Sabki Urban Forest.

The census results showed that the number of tree individuals differed among the research zones. Zone 1 had the highest number of tree individuals, totaling 460 individuals or 40.71% of all recorded trees. Zone 2 contained 417 individuals or 36.90%, while Zone 3 had the lowest number of individuals, totaling 253 individuals or 22.39%.

Table 1
Summary of the Number and Distribution of Tree Individuals by Zone

Zone	Zone Area (ha)	Number of Analysis Units	Number of Tree Individuals	Percentage (%)
Zone 1	2.10	30	460	40.71
Zone 2	3.64	52	417	36.90
Zone 3	5.26	75	253	22.39
Entire Area	11.00	157	1.130	100.00

Based on Table 1, the number of tree individuals was not directly proportional to the area of each zone. Zone 3 had the largest area but the lowest number of tree individuals. In contrast, Zone 1 had a smaller area but the highest number of tree individuals, indicating a denser stand condition compared to the other zones. The vegetation identification results showed that a total of 29 tree species were found across the entire study area. Zone 1 contained 15 tree species, Zone 2 contained 11 tree species, while Zone 3 had the highest number of species, with 23 tree species.

Table 2
Number of Tree Species by Zone

Zone	Number of Tree Individuals	Number of Tree Species
Zone 1	460	15
Zone 2	417	11
Zone 3	253	23
Entire Area	1.130	29

The tree species composition at the study site was dominated by several major species, namely Rubber (*Hevea brasiliensis*), Agarwood (*Aquilaria malaccensis*), Devil Tree (*Alstonia scholaris*), Mahogany (*Swietenia macrophylla*), and Meranti (*Shorea* sp.). These species had the highest numbers of individuals and were found in all research zones.

Table 3
Tree Species Composition in Muhammad Sabki Urban Forest.

No.	Local Name	Scientific Name	Number of Individuals	Zone Found
1	Rubber	*Hevea brasiliensis*	282	Z1, Z2, Z3
2	Agarwood	*Aquilaria malaccensis*	186	Z1, Z2, Z3
3	Devil Tree	*Alstonia scholaris*	133	Z1, Z2, Z3
4	Mahogany	*Swietenia macrophylla*	130	Z1, Z2, Z3
5	Meranti	*Shorea* sp.	106	Z1, Z2, Z3
6	Bornean Ironwood	*Eusideroxylon zwageri*	70	Z1, Z2, Z3
7	Medang	*Litsea* sp.	69	Z1, Z2, Z3
8	Kandis	*Garcinia xanthochymus*	33	Z1, Z2, Z3
9	Terap	*Artocarpus odoratissimus*	23	Z1, Z2, Z3
10	Weeping Fig	*Ficus benjamina*	17	Z3
11	Damar	*Agathis dammara*	10	Z3
12	Forest Mangosteen	*Garcinia bancana*	10	Z3
13	Kelat	*Syzygium ochneocarpum*	8	Z1
14	Medang Labu	*Endospermum malaccense*	8	Z1, Z3
15	Laban	*Vitex pubescens*	6	Z1
16	Simpur	*Dillenia indica*	6	Z3
17	Tembesu	*Fagraea fragrans*	6	Z1, Z2
18	Mangosteen	*Garcinia mangostana*	5	Z1
19	Kapok	*Ceiba pentandra*	4	Z3
20	Balam Putih	*Madhuca ovata*	3	Z3
21	Berumbung	*Adina minutiflora*	3	Z3
22	Tanjung	*Mimusops elengi*	3	Z1
23	Starfruit	*Averrhoa carambola*	2	Z3
24	Forest Rambutan	*Nephelium mutabile*	2	Z3
25	Cacao	*Theobroma cacao*	1	Z3
26	Duku	*Lansium domesticum*	1	Z3
27	Jengkol	*Archidendron pauciflorum*	1	Z3
28	Leucaena	*Leucaena leucocephala*	1	Z2
29	Petai	*Parkia speciosa*	1	Z3
	Total		**1.130**	**-**

The characteristics of tree-level vegetation in each zone were summarized based on the number of individuals, number of species, density, stem diameter, clear bole height, and vegetation dominance.

Table 4
Summary of Tree-Level Vegetation Characteristics by Zone.

Parameter	Zone 1	Zone 2	Zone 3
Zone area (ha)	2.10	3.64	5.26
Number of analysis units	30	52	75
Number of tree individuals	460	417	253
Number of tree species	15	11	23
Tree density (individuals/ha)	219.05	114.56	48.10
Average diameter (cm)	24.48	30.76	28.12
Average clear bole height (m)	6.64	7.59	7.13
Vegetation dominance (m^2/ha)	11.88	11.13	3.85

Based on Table 4, Zone 1 had the highest tree density, whereas Zone 2 had the highest average diameter and clear bole height. Zone 3 had the highest number of tree species but a lower density compared to the other zones. These differences in vegetation characteristics indicate variations in stand structure and species composition among zones, which subsequently influence biomass, carbon stock, and CO_2-eq within the study area.

Biomass, Carbon Stock, and CO_2-eq of Tree-Level Vegetation

Tree-level vegetation biomass is one of the important parameters used to assess the ability of vegetation to store carbon. In this study, biomass was calculated based on the tree census results, including stem diameter, clear bole height, and wood density of each species. The biomass calculation results were used as the basis for determining carbon stock and carbon dioxide equivalent (CO_2-eq) values.

Biomass of Tree-Level Vegetation

Based on the calculation results, the total aboveground biomass of tree-level vegetation in Muhammad Sabki Urban Forest was 269.531 tons. Zone 2 had the highest biomass, amounting to 139.926 tons, followed by Zone 1 with 71.545 tons and Zone 3 with 58.059 tons. A summary of tree-level vegetation biomass by zone is presented in Table 5.

Table 5
Summary of Tree-Level Vegetation Biomass by Zone

Zone	Number of Tree Individuals	Zone Area (ha)	Total Biomass (tons)	Biomass per ha (tons/ha)
Zone 1	460	2.10	71.545	34.069
Zone 2	417	3.64	139.926	38.441
Zone 3	253	5.26	58.059	11.038
Entire Area	1.130	11.00	269.531	24.503

Source: Processed primary data, 2026.

Based on Table 5, Zone 2 had the highest biomass even though the number of tree individuals was lower than in Zone 1. This condition indicates that biomass is influenced not only by the number of tree individuals but also by tree diameter and clear bole height. Zone 2 had the highest average diameter and tree height, resulting in greater biomass.

Zone 1 had the highest number of tree individuals, but its biomass was lower than that of Zone 2 because the trees were relatively smaller. Meanwhile, Zone 3 had the lowest biomass because its number of tree individuals and tree density were lower than those of the other zones. The spatial distribution of tree-level vegetation biomass is presented in Figure 2.

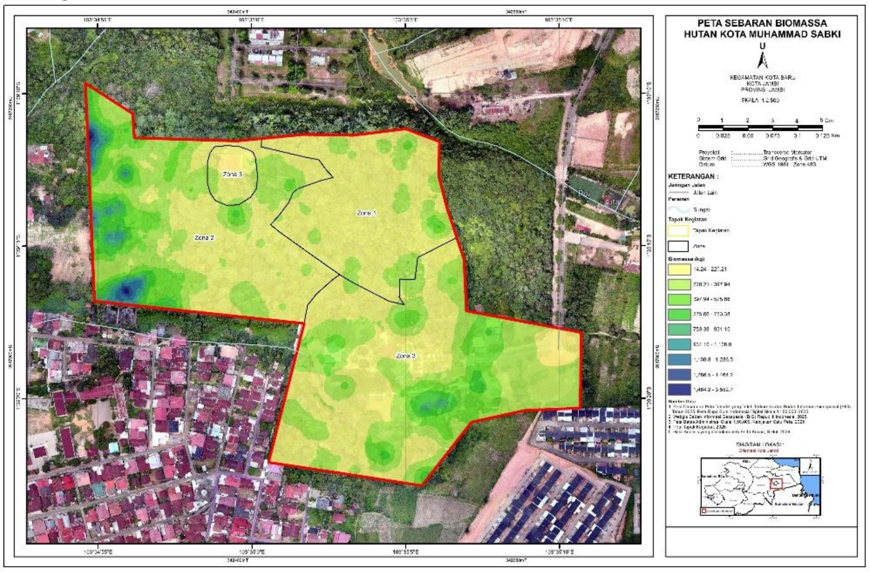

Figure 2. Spatial Distribution Map of Tree-Level Vegetation Biomass in Muhammad Sabki Urban Forest

The biomass distribution map shows that biomass values were higher in areas with denser stands and larger trees. Chave et al. (2014) explained that stem diameter, tree height, and wood density are the main parameters used in estimating tropical tree biomass.

Carbon Stock and CO_2-eq of Tree-Level Vegetation

The calculation results showed that the total carbon stock of tree-level vegetation in Muhammad Sabki Urban Forest was 126.679 tons C, equivalent to 464.913 tons CO_2-eq. The highest carbon stock was found in Zone 2, amounting to 65.765 tons C, equivalent to 241.359 tons CO_2-eq. A summary of carbon stock and CO_2-eq of tree-level vegetation by zone is presented in Table 6.

Table 6

Summary of Carbon Stock and CO_2-eq of Tree-Level Vegetation by Zone

Zone	Total Biomass (tons)	Carbon Stock (tons C)	Carbon Stock per ha (tons C/ha)	CO_2-eq (tons CO_2-eq)	CO_2-eq per ha (tons CO_2-eq/ha)
Zone 1	71.545	33.626	16.012	123.408	58.766
Zone 2	139.926	65.765	18.067	241.359	66.307
Zone 3	58.059	27.288	5.188	100.146	19.039
Entire Area	269.531	126.679	11.516	464.913	42.265

Source: Processed primary data, 2026.

Based on Table 6, Zone 2 had the highest carbon stock and CO_2-eq compared to the other zones. The high carbon stock in Zone 2 was associated with its larger average diameter and clear bole height compared to the other zones. Ran et al. (2017) and Mahdavi et al. (2020) explained that stem diameter and tree height are important factors in determining biomass and carbon stock. Zone 1 had the highest number of tree individuals, but its carbon stock was lower than that of Zone 2 because the trees were relatively smaller. Meanwhile, Zone 3 had the lowest carbon stock because its tree density was lower and part of the area was used for supporting facilities. The spatial distribution of carbon stock and CO_2-eq of tree-level vegetation is presented in Figures 3 and 4.

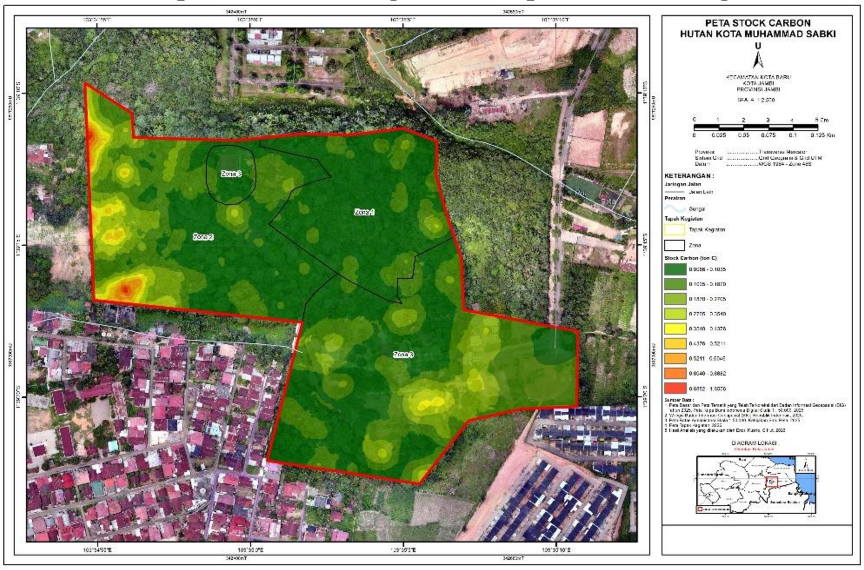

Figure 3. Spatial Distribution Map of Tree-Level Vegetation Carbon Stock in Muhammad Sabki Urban Forest

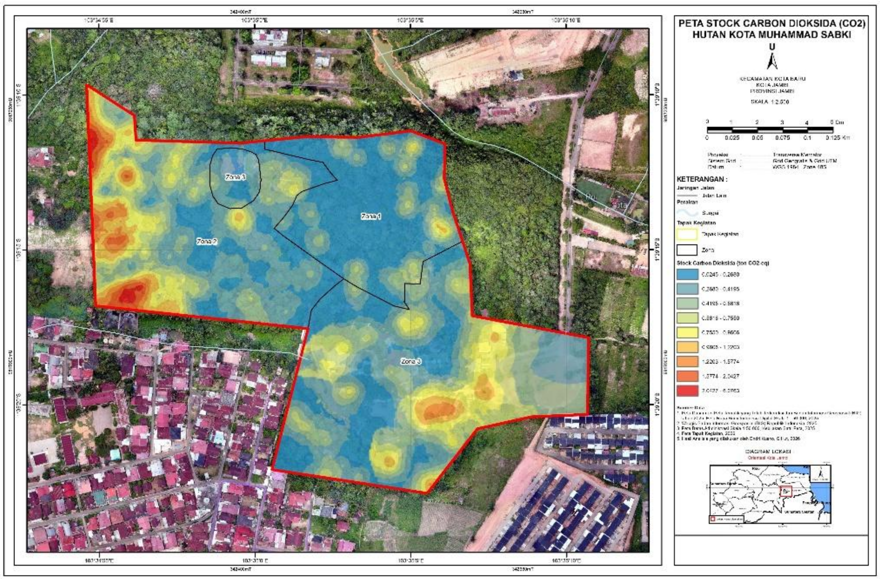

Figure 4. Spatial Distribution Map of Tree-Level Vegetation CO_2-eq in Muhammad Sabki Urban Forest

The maps show that carbon stock and CO_2-eq were concentrated in areas with higher biomass and larger stand sizes. These results indicate that stand structure has an important influence on the magnitude of carbon stock in tree-level vegetation within Muhammad Sabki Urban Forest.

Urban Environmental Health Implications of Carbon Stock Findings

Beyond their role as carbon sinks, the biomass and carbon stock distribution patterns identified in this study carry direct implications for urban environmental health in Jambi City. Zones with higher canopy density and larger tree sizes—particularly Zone 2—are expected to generate greater microclimatic regulation through shading and evapotranspiration, which can substantially reduce ambient air temperatures in surrounding areas. Urban heat island effects, which are prevalent in rapidly developing cities like Jambi, have been associated with increased risks of heat-related illnesses, cardiovascular stress, and respiratory morbidity among urban populations. Denser and structurally complex tree stands, such as those observed in Zone 1 and Zone 2, are also more effective in filtering particulate matter and gaseous air pollutants including CO_2, ozone, and nitrogen dioxide, thereby reducing population exposure to ambient air pollution—a major environmental determinant of respiratory and cardiovascular disease. Furthermore, Zone 3, despite having the highest species diversity, recorded the lowest canopy density and carbon stock per hectare due to high land-use intensity. From an urban health perspective, this condition may indicate a reduced capacity for air pollutant filtration and thermal comfort provision precisely in the zone most frequently accessed by visitors and the public. These findings underscore the importance of integrating vegetation structure management—not merely species preservation—into urban health and spatial planning strategies, so that urban forests can maximally contribute to population health outcomes alongside their ecological and carbon storage functions.

Comparison of Carbon Contribution by Zone and Tree Species

A comparison of carbon contribution was conducted to identify the zones and tree species that contributed the most to the total carbon stock of tree-level vegetation in Muhammad Sabki Urban Forest. The largest contribution came from Zone 2, amounting to 65.765 tons C or 51.92% of the total carbon stock of the area. The carbon stock contribution by zone is presented in Table 7.

Table 7
Carbon Stock Contribution by Zone

Zone	Number of Individuals	Carbon Stock (tons C)	Contribution Percentage (%)	CO_2-eq (tons CO_2-eq)
Zone 1	460	33.626	26.54	123.408
Zone 2	417	65.765	51.92	241.359
Zone 3	253	27.288	21.54	100.146
Total	**1.130**	**126.679**	**100.00**	**464.913**

Source: Processed primary data, 2026.

Based on Table 7, Zone 2 was the zone with the largest carbon contribution because it had larger stand sizes compared to the other zones. Zone 1 had the highest number of individuals, but its carbon contribution was lower than that of Zone 2. Meanwhile, Zone 3 had the lowest carbon contribution because its number of individuals and tree density were lower. In addition to zone-based analysis, carbon contribution was also analyzed by tree species. The species with the highest carbon stock contributions were Kandis

(*Garcinia xanthochymus*), Pulai (*Alstonia scholaris*), Bulian (*Eusideroxylon zwageri*), Gaharu (*Aquilaria malaccensis*), and Meranti (*Shorea* sp.). The tree species contributing the largest carbon stocks are presented in Table 8.

Table 8

Tree Species Contributing to Carbon Stock from Highest to Lowest

No	Local Name	Scientific Name	Number of Individuals	Wood Density ρ (g/cm³)	Average Diameter (cm)	Average Height (m)	Carbon Stock (tons C)	CO_2-eq (tons CO_2-eq)	Contribution (%)
1	Kandis	*Garcinia xanthochymus*	33	0.750	58.96	9.28	24.702	90.657	9.75
2	Pulai	*Alstonia scholaris*	133	0.370	37.80	8.06	19.483	71.501	7.69
3	Bulian	*Eusideroxylon zwageri*	70	0.800	34.41	8.81	16.813	61.702	6.64
4	Gaharu	*Aquilaria malaccensis*	186	0.400	29.39	7.62	14.409	52.882	5.69
5	Meranti	*Shorea* sp.	106	0.600	29.01	8.03	12.280	45.069	4.85
6	Beringin	*Ficus benjamina*	17	0.490	65.72	10.22	9.458	34.710	3.73
7	Karet	*Hevea brasiliensis*	282	0.500	19.81	6.11	9.390	34.462	3.71
8	Terap	*Artocarpus odoratissimus*	23	0.540	43.51	9.36	6.253	22.948	2.47
9	Mahoni	*Swietenia macrophylla*	130	0.480	18.38	6.00	3.675	13.487	1.45
10	Tembesu	*Fagraea fragrans*	6	0.730	43.26	8.17	2.233	8.195	0.88
11	Damar	*Agathis dammara*	10	0.490	35.13	7.75	2.064	7.576	0.81
12	Tanjung	*Mimusops elengi*	3	0.790	50.74	9.93	1.589	5.833	0.63
13	Medang	*Litsea* sp.	69	0.470	16.84	5.24	1.385	5.081	0.55
14	Randu	*Ceiba pentandra*	4	0.310	66.48	9.30	1.340	4.917	0.53
15	Kelat	*Syzygium ochneocarpum*	8	0.650	16.40	5.25	0.199	0.730	0.08
16	Manggis Hutan	*Garcinia bancana*	10	0.700	13.89	4.80	0.176	0.645	0.07
17	Rambutan Hutan	*Nephelium mutabile*	2	0.720	24.68	6.80	0.167	0.612	0.07
18	Simpur	*Dillenia indica*	6	0.560	17.41	5.63	0.154	0.566	0.06
19	Medang Labu	*Endospermum malaccense*	8	0.390	17.64	5.68	0.151	0.555	0.06
20	Berumbung	*Adina minutiflora*	3	0.660	19.43	6.13	0.122	0.448	0.05
21	Balam Putih	*Madhuca ovata*	3	0.630	19.11	6.00	0.114	0.417	0.04

No	Local Name	Scientific Name	Number of Individuals	Wood Density ρ (g/cm³)	Average Diameter (cm)	Average Height (m)	Carbon Stock (tons C)	CO_2-eq (tons CO_2-eq)	Contribution (%)
22	Laban	*Vitex pubescens*	6	0.570	15.34	4.82	0.105	0.386	0.04
23	Lamtoro	*Leucaena leucocephala*	1	0.630	25.16	9.20	0.095	0.350	0.04
24	Jengkol	*Archidendron pauciflorum*	1	0.450	28.98	7.20	0.071	0.261	0.03
25	Manggis	*Garcinia mangostana*	5	0.780	12.10	4.54	0.071	0.260	0.03
26	Petai	*Parkia speciosa*	1	0.440	28.98	7.20	0.070	0.256	0.03
27	Belimbing	*Averrhoa carambola*	2	0.550	17.83	5.75	0.054	0.198	0.02
28	Coklat	*Theobroma cacao*	1	0.420	20.70	6.30	0.030	0.111	0.01
29	Duku	*Lansium domesticum*	1	0.597	17.20	5.60	0.027	0.097	0.01
	Total		**1.130**	**-**	**-**	**-**	**126.679**	**464.913**	**100.00**

Based on Table 8, the carbon stock contribution of each tree species was influenced by stem diameter, clear bole height, wood density, and the number of individuals. Kandis (*Garcinia xanthochymus*) had the highest carbon stock contribution despite having a relatively small number of individuals because it possessed a high average diameter and wood density. Pulai (*Alstonia scholaris*) and Gaharu (*Aquilaria malaccensis*) contributed substantially to carbon storage due to their relatively high numbers of individuals and large tree sizes. Bulian (*Eusideroxylon zwageri*) had a high carbon contribution because of its high wood density, while Meranti (*Shorea* sp.) made an important contribution due to its number of individuals and tree size, which supported biomass accumulation. Chave et al. (2014) explained that stem diameter, tree height, and wood density are the primary parameters used in estimating biomass and carbon stock of tropical trees. In general, the results indicate that stand structure, tree size, wood density, and the number of individuals are important factors influencing the magnitude of carbon stock in tree-level vegetation within Muhammad Sabki Urban Forest.

Relationship Between Tree-Level Vegetation Diversity and Carbon Stock

The relationship between tree-level vegetation diversity and carbon stock was analyzed to determine the association between vegetation community structure and carbon storage capacity in Muhammad Sabki Urban Forest, Jambi City. The analysis used vegetation diversity indicators, namely the Margalef species richness index (Dmg), the Shannon–Wiener diversity index (H'), and the Pielou evenness index (J'). These variables were then analyzed in relation to the carbon stock of tree-level vegetation within vegetated analysis units.

Density, Dominance, and Vegetation Diversity

Vegetation density and dominance were used to describe stand structure in each research zone. The calculation results showed that Zone 1 had the highest density value, whereas Zone 2 had relatively high vegetation dominance supported by larger tree sizes. Zone 3 had lower density and dominance due to higher land-use intensity. A summary of tree-level vegetation density, dominance, and diversity indices by zone is presented in Tables 9 and 10.

Table 9
Density and Dominance of Tree-Level Vegetation by Zone

Zone	Zone Area (ha)	Number of Individuals	Density (individuals/ha)	Dominance (m²/ha)
Zone 1	2.10	460	219.05	11.88
Zone 2	3.64	417	114.56	11.13
Zone 3	5.26	253	48.10	3.85
Entire Area	11.00	1,130	102.73	7.76

Source: Processed primary data, 2026.

Table 10
Species Richness, Diversity, and Evenness Indices of Vegetation by Zone

Zone	Number of Individuals	Species Richness Index (Dmg)	Diversity Index (H')	Evenness Index (J')
Zone 1	460	2.283	1.982	0.732
Zone 2	417	1.658	2.132	0.889
Zone 3	253	3.976	2.523	0.805
Entire Area	1.130	3.983	2.337	0.694

Source: Processed primary data, 2026.

Based on Tables 9 and 10, Zone 1 had the highest density, reaching 219.05 individuals/ha, whereas Zone 2 had relatively high vegetation dominance of 11.13 m²/ha. Zone 3 showed the highest species richness and diversity values, with a Dmg value of 3.976 and an H' value of 2.523. These conditions indicate that each zone possessed different vegetation community characteristics. The high diversity value in Zone 3 indicates that areas with varying land-use patterns are still capable of maintaining vegetation species diversity. However, high diversity is not always accompanied by high biomass and carbon stock. Stand structure variables such as stem diameter, clear bole height, and vegetation dominance remain important factors in determining the magnitude of carbon stock within the area. Hooper et al. (2005) explained that biodiversity can influence ecosystem functions through species composition and the functional characteristics of vegetation. In addition, Sun et al. (2019) stated that the contribution of urban green spaces to carbon storage is influenced by vegetation characteristics and green space structure. Therefore, the relationship between vegetation diversity and carbon stock should be understood together with vegetation stand structure.

Pearson Correlation and Linear Regression between Vegetation Diversity and Carbon Stock

Pearson correlation and simple linear regression analyses were conducted to determine the direction and strength of the relationship between vegetation diversity indicators and the carbon stock of tree-level vegetation. The analysis was performed on 153 vegetated analysis units. The results of the Pearson correlation and linear regression analyses between vegetation diversity indicators and carbon stock are presented in Table 11.

Table 11

Results of Pearson Correlation and Linear Regression between Vegetation Diversity and Carbon Stock

No	Variable Relationship	n	Pearson r	R²	Adjusted R²	t-value	t-table α = 0.05	Significance	Regression Equation	Relationship Category
1	Species Richness Index (Dmg) and carbon stock	153	0.441	0.195	0.190	6.046	1.976	Significant	Y = 0.013 + 0.473Dmg	Moderate
2	Diversity Index (H') and carbon stock	153	0.592	0.350	0.346	9.022	1.976	Significant	Y = -0.188 + 0.825H'	Moderate
3	Evenness Index (J') and carbon stock	153	0.201	0.041	0.035	2.522	1.976	Significant	Y = 0.337 + 0.566J'	Weak

Source: Processed primary data, 2026.

Based on Table 11, all vegetation diversity indicators showed positive and significant relationships with carbon stock. The strongest relationship was demonstrated by the Shannon–Wiener index (H') with a correlation coefficient of 0.592 and an R^2 value of 0.350. This value indicates that approximately 35.0% of the variation in carbon stock can be explained by the Shannon–Wiener diversity index. The Margalef species richness index (Dmg) showed a moderate positive relationship with an r value of 0.441 and an R^2 value of 0.195. Meanwhile, the Pielou evenness index (J') had the weakest relationship, with an r value of 0.201 and an R^2 value of 0.041. These results indicate that vegetation diversity is related to carbon stock, but it is not the only determining factor.

The positive relationship between vegetation diversity and carbon stock indicates that more diverse vegetation communities tend to have greater potential for biomass accumulation and carbon storage. Fargione et al. (2007) explained that the relationship between diversity and biomass productivity can be influenced by the presence of particular species with large biomass contributions, as well as by the ability of different species to utilize resources in complementary ways. The findings of this study are also consistent with those of Nizamani et al. (2021), who reported a positive relationship between aboveground biomass, tree species diversity, and urban green space management. Nevertheless, the magnitude of carbon stock remains strongly influenced by stand structure variables such as stem diameter, clear bole height, wood density, number of individuals, and vegetation dominance.

Thus, the results indicate that tree-level vegetation diversity has a positive relationship with carbon stock in Muhammad Sabki Urban Forest, Jambi City. The Shannon–Wiener index (H') was the indicator most strongly associated with carbon stock compared to the other indices. These findings suggest that urban forest management should not only maintain species diversity but also preserve stand structure and large trees to sustain the carbon storage function over time.

Relevance of Carbon Stock as Preliminary Information for Carbon Economic Value Development

The results of biomass, carbon stock, and CO_2-eq calculations indicate that Muhammad Sabki Urban Forest plays an important ecological role as a local carbon sink. Tree vegetation absorbs carbon dioxide through photosynthesis and stores it in biomass, which can subsequently be quantified as carbon stock and converted into CO_2-eq. According to Nowak et al. (2013), urban trees contribute significantly to carbon storage and sequestration; however, accurate estimation of urban carbon requires continuous inventory and long-term monitoring to better understand changes in carbon stocks. The contributions of biomass, carbon stock, and CO_2-eq by zone are presented in Table 12.

Table 12

CO_2-eq as Baseline Carbon Information by Zone

Zone	Total Biomass (ton)	Carbon Stock (ton C)	CO_2-eq (ton CO_2-eq)	Percentage (%)
Zone 1	71.545	33.626	123.408	26.54
Zone 2	139.926	65.765	241.359	51.92
Zone 3	58.059	27.288	100.146	21.54
Entire Area	269.531	126.679	464.913	100.00

Source: Processed primary data, 2026.

Based on Table 12, the total carbon stock of tree-level vegetation in Muhammad Sabki Urban Forest reached 126.679 tons C, equivalent to 464.913 tons CO_2-eq. Zone 2 contributed the largest share, amounting to 241.359 tons CO_2-eq (51.92%), followed by Zone 1 with 123.408 tons CO_2-eq (26.54%) and Zone 3 with 100.146 tons CO_2-eq (21.54%). The substantial contribution of Zone 2 indicates that carbon storage is influenced more by stand structure, particularly tree diameter and height, than by species richness or zone area. The CO_2-eq value obtained in this study should not be interpreted as an actual carbon economic value or as tradable carbon units. Instead, it represents biophysical information describing the amount of carbon stored at the time of measurement. Under the Carbon Economic Value (CEV) framework, carbon utilization in carbon trading mechanisms requires additional stages, including baseline establishment, monitoring, reporting, verification, and registration within the national registry system. Therefore, the biomass, carbon stock, and CO_2-eq data generated in this study can serve as preliminary information for regional Carbon Economic Value development. These data may be used for carbon inventory preparation, monitoring changes in carbon stock, and supporting the management of Muhammad Sabki Urban Forest as a regional ecological asset for climate change mitigation efforts.

Conclusion

Muhammad Sabki Urban Forest, Jambi City, contains 1,130 tree individuals belonging to 29 species distributed across three study zones. Zone 1 had the highest number of individuals, whereas Zone 3 exhibited the highest species richness. Differences in vegetation characteristics among zones reflected variations in stand structure that influenced biomass accumulation and carbon storage capacity. The total aboveground biomass reached 269.531 tons, resulting in a carbon stock of 126.679 tons C or 464.913 tons CO_2-eq. Zone 2 contributed the largest share of biomass, carbon stock, and CO_2-eq among all zones. These findings indicate that carbon storage is influenced more by stand structure, particularly tree diameter, tree height, and vegetation dominance, than by the number of individuals or species richness alone.

All vegetation diversity indicators showed positive relationships with carbon stock. The Shannon–Wiener diversity index (H') exhibited the strongest relationship ($r = 0.592$; $R^2 = 0.350$), followed by the Margalef richness index ($r = 0.441$; $R^2 = 0.195$) and the Pielou evenness index ($r = 0.201$; $R^2 = 0.041$). Furthermore, the carbon stock and CO_2-eq values obtained in this study can serve as preliminary information for regional Carbon Economic Value (CEV) development, although they should not yet be interpreted as actual economic carbon value or directly tradable carbon units.

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