

CARBON STOCK ESTIMATION IN FABACEAE TREE STANDS WITHIN THE URBAN FORESTS OF BANDA ACEH

Wira Dharma^{1*}, Yekki Yasmin¹, Nada Ariqah¹, Essy Harnelly¹, Alia Rizki¹, Amirunnas¹, Anita Rauzana², and Rahmad Zakaria³

¹Biology Department, Faculty of Mathematics and Natural Sciences, Universitas Syiah Kuala, Banda Aceh 23111, Indonesia

²Civil Engineering Department, Faculty of Engineering, Universitas Syiah Kuala, Banda Aceh 23111, Indonesia

³School of Biological Sciences, Universiti Sains Malaysia, 11800 Penang, Malaysia

ARTICLE HIGHLIGHTS

- Identified four Fabaceae tree species across three urban forests in Banda Aceh.
- Total estimated potential carbon stock in Fabaceae stands reached 292.08 tonnes/ha.
- Trembesi Urban Forest contributed the highest carbon stock at 124.14 tonnes/ha.
- *Samanea saman* is the dominant carbon contributor, storing 248.44 tonnes/ha.
- Stem diameter serves as a highly reliable predictor for urban tree carbon stocks.

ABSTRACT

Urban forests play a crucial role in absorbing carbon emissions through the biomass carbon stocks stored in vegetation. The Fabaceae family is a potential group of tree for carbon storage, but its contribution to the Banda Aceh urban forest area remains understudied. This study aimed to identify tree species from the Fabaceae family and estimate the potential carbon stocks stored in stands of this family in the Banda Aceh urban forest. The study was conducted in three urban forest locations: Putroe Phang (PP), Trembesi (TR), and BNI Urban Forests (BNI). Carbon stocks were estimated using a non-destructive method with an allometric equation approach. The results showed that there were four tree species from the Fabaceae family, namely *Samanea saman*, *Pterocarpus indicus*, *Tamarindus indica*, and *Delonix regia*, with a total of 197 individuals recorded. The total potential carbon stocks stored in Fabaceae stands in the three urban forest areas reached 292.08 tonnes/ha, with the largest contribution coming from the Trembesi (TR) Urban Forest at 124.14 tonnes/ha. The tree species that provides the largest contribution to carbon biomass is *Samanea saman* with an estimate of 248.44 tonnes/ha.

Keywords: biomass, carbon emissions, carbon stocks, Fabaceae, *Samanea saman*

Article Information

Received : 14 September 2025

Revised : 30 January 2026

Accepted : 20 February 2026

Available online : 20 July 2026

***Corresponding author, e-mail:**

wira_dharma@usk.ac.id



Copyright (c) 2026@author(s).

INTRODUCTION

Climate change affects not only the economy but also a variety of other fields as well (Sun 2023). One of the main causes of climate change is the increase in greenhouse gas (GHG) concentrations in the atmosphere due to anthropogenic activities such as forest fires (Sutthichaimethee *et al.* 2025), industrial waste and transportation activities. Continuously increasing GHG emissions have had significant impacts on environmental and socio-economic sustainability. At the 26th Climate Change Conference (COP) in Glasgow, the Intergovernmental Panel on Climate Change (IPCC) emphasized the importance of limiting global warming to 1.5 °C and achieving a net-zero emissions target by 2050 to minimize negative impacts on agriculture, health, and the economy (Mountford *et al.* 2021).

As the center of government and economic activity in Aceh Province, Banda Aceh City is faces increasing pressure from global warming. The increase in motorized vehicles, which reached 275,639 units (Municipal Government of Banda Aceh 2019), have led to higher emissions of carbon dioxide and other air pollutants. These emissions cause a decline in air quality in the city. At the same time, the accumulation of greenhouse gases in the atmosphere has contributed to a measurable increase in local temperature, as confirmed by findings from the Meteorology, Climatology, and Geophysics Agency regarding a temperature increase of 0.3 – 0.5 °C in the Aceh Province region (BMKG 2022). Anthropogenic land use and land cover changes (LULCC) have a large impact on the global terrestrial carbon sink (Tagesson *et al.* 2020). In the context of climate change mitigation, vegetation plays a crucial role as a carbon dioxide (CO₂) absorber through photosynthesis, which is then stored in the form of biomass (Duveiller *et al.* 2018). This process makes vegetation an effective carbon sink, helping control GHG concentrations in the atmosphere. Urban forests, as a form of Green Open Space, have an ecological function in absorbing carbon, regulating the microclimate, and maintaining air quality in urban areas. According to the Municipal Government (2009), the minimum area of green open space in urban areas is set at 30% of the total area, making the presence of vegetation in urban forests crucial as carbon storage areas.

According to Gielen *et al.* (2018) aboveground biomass (AGB) comprises the biomass of plant parts above the soil, such as stems, branches, leaves, and fruits. AGB is essential for estimating the carbon stock of forests and plays a crucial role in carbon sequestration and climate regulation (Chen *et al.* 2023). Beyond carbon sequestration, AGB serves as a crucial metric for evaluating ecosystem productivity, monitoring deforestation and forest degradation, informing sustainable forest management practices, and developing effective climate change mitigation strategies (Abbas *et al.* 2020).

Banda Aceh has several urban forest that serve as green area of the city to reduce CO₂ and urban heat. In Banda Aceh urban forest are composed of a mix of native and introduced plants. Notably, trees from the Fabaceae (legume) family are a significant component. Fabaceae trees are common in urban forests and possess ecological advantages, including adaptability to marginal land and nitrogen fixation through root nodules (Sukma 2019). Studies also highlight their high potential for CO₂ absorption and air quality improvement (Santoso *et al.* 2021). However, research on Fabaceae species and their contribution to urban forest carbon stocks, particularly in Banda Aceh, remains limited. This study addresses this gap by identifying Fabaceae tree species and estimating their carbon storage potential in several Banda Aceh urban forests.

MATERIALS AND METHODS

Study Site

This research was conducted in Putroe Phang (PP), Trembesi (TR), and BNI Urban Forest with distinct ecological characteristics and representative Fabaceae trees for assessing carbon storage.

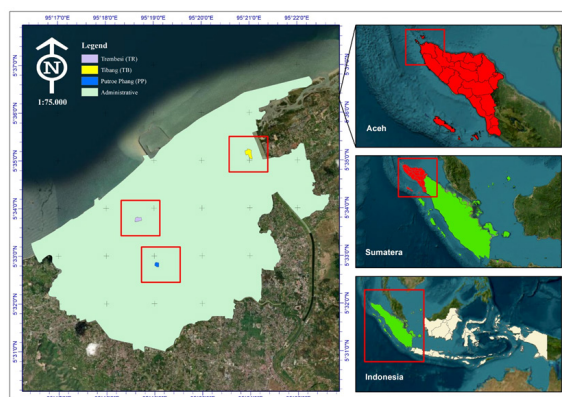


Figure 1 Map of research locations in Banda Aceh Urban Forest, Indonesia

Table 1 Number of plots placed at each location

No	Name of urban forest	Size of area (ha)	Size of area (m2)	Number of plots
1.	Putroe Phang (PP)	2.42	24,200	7
2.	BNI (BNI)	6.22	62,200	12
3.	Trembesi (TR)	2.50	25,000	7
	Total	11.14	111,400	26

Determination of Sampling

Plots were established using purposive sampling based on the presence of Fabaceae trees. Each plot measured 20 m × 20 m, with the number of plots per location determined to be proportional to urban forest area (Table 1). Within each plot, all Fabaceae trees were identified, their diameters measured, and species recorded for analysis.

Tree Data Collection

Tree biomass measurement included species identification, Diameter at Breast Height (DBH) measurement at 1.3 m. Fabaceae trees with DBH ≥ 20 cm were sampled according to SNI (2019), with adjustments for leaning or irregular stems. Biomass was non-destructively estimated using DBH-based tropical allometric equations and then converted to carbon stocks (Jilo *et al.* 2025).

Data Analysis

Biomass and Carbon Storage Calculations

Allometric models for aboveground biomass (AGB) are linear regression equations based on the relationships between biomass and diameter at breast height (DBH), tree height (H), and/or wood density (Pipite 2022). Species names and diameters were entered into Excel using formulas adapted from relevant studies (Wang *et al.* 2021). AGB was calculated using Brown's (1997) DBH-based model.

$$AGB = 13.2579 - (4.8945 \times D) + (0.6713 \times D^2) \quad (1)$$

where:

AGB = Aboveground biomass (tonnes)

D = Diameter at breast height (DBH) (cm)

The belowground biomass (BGB) ratio for tropical forests (0.221) was adopted from Luo *et al.* (2012), based on 17 samples (n = 17) with R² = 0.816, indicating a strong relationship between BGB and aboveground biomass (AGB).

$$BGB = 0.221 \times AGB \quad (2)$$

where:

AGB = Aboveground biomass (ton)

BGB = Belowground biomass (ton)

The overall green weight of the biomass is estimated to be 120% of the AGB value, based on the assumption that the BGB, which comprises the tree's root system, accounts for approximately 20% of the AGB (Shadman *et al.* 2022). From these formulas, the total biomass (TB) of a tree can be estimated as follows for carbon stock analysis:

Total Dry Biomass (TDB)

$$TDB = AGB + BGB \quad (3)$$

$$TDB = AGB + 0.221 \times AGB \quad (4)$$

Carbon occupies 50% of the total dry weight. Since carbon makes up about 50% of dry biomass, carbon stocks can be estimated by multiplying biomass by 0.5. Therefore, the formula is as follows.

$$\text{Total Carbon (TC)} = TDB \times 0.5 \quad (5)$$

The CO₂ equivalent sequestered in a tree was calculated by multiplying its carbon content by 3.67, based on the molecular weight ratio of CO₂ to C (44/12), where carbon's atomic weight is 12 u and oxygen's is 16 u.

$$CO_2 \text{ weight} = TC \times 3.67 \quad (6)$$

$$W = \frac{\sum_{i=1}^n W P_i}{A} \times 10,000 \quad (7)$$

Furthermore, the carbon measured through the allometric equation above is used to measure the total biomass (W) tonnes per hectare in the equation below (Passal 2019):

where:

W = Total biomass (tonnes/ha)

W_{pi} = Tree biomass (tonnes)

A = Plot area (ha)

n = Number of trees

Vegetation Importance Assessment

Data were analyzed descriptively using Mueller-Dombois and Ellenberg (1974) formulas for density, frequency, dominance, and the Importance Value Index (IVI), which ranks species by ecological significance. Species diversity was assessed with the Shannon–Wiener index, and IVI was calculated following Soerianegara and Indrawan (1988) as follows.

$$\text{Density (D)} = \frac{\text{Number of individuals of a type}}{\text{Area of whole plot}} \quad (8)$$

$$\text{Relative Density (RD)} = \frac{\text{Density of a type}}{\text{Density of all type}} \times 100\% \quad (9)$$

$$\text{Frequency (F)} = \frac{\text{Number of plots found of a type}}{\text{Total of plots}} \quad (10)$$

$$\text{Relative Frequency (RF)} = \frac{\text{Frequency of a type}}{\text{Frequency of all type}} \times 100\% \quad (11)$$

$$\text{Dominance (D)} = \frac{\text{Area basal area of a type}}{\text{Area of whole sample plot}} \quad (12)$$

$$\text{Relative Dominance (RDo)} = \frac{\text{Dominance of a kind}}{\text{Dominance of all type}} \times 100\% \quad (13)$$

$$\text{IVI (Important value index)} = \text{RF} + \text{RD} + \text{RB} \quad (14)$$

RESULTS AND DISCUSSION

Total Carbon Stock

Carbon stock values estimated based on biomass and Total Dry Biomass (TDB) calculations for each plot in each urban forest showed varying results. A summary of the estimated TDB and carbon stocks for the Fabaceae family across the entire study area is presented in Figure 2.

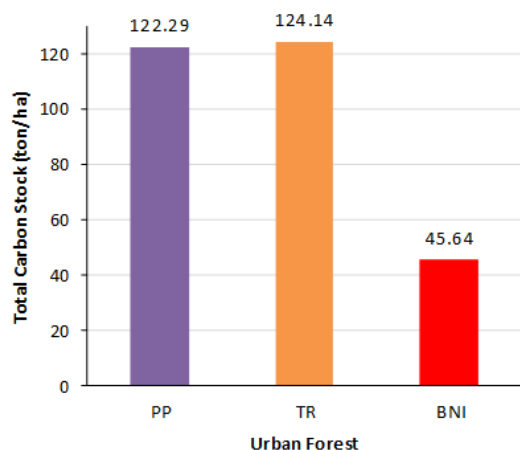


Figure 2 Carbon stock value in the Fabaceae family in three urban forest in Banda Aceh

TR had the highest value (124.14 tonnes/ha), slightly above PP (122.29 tonnes/ha) with a difference of 1.85 tonnes/ha (Fig. 2). BNI was much lower (45.64 tonnes/ha), about one-third of TR and PP. Variations in Fabaceae species composition significantly influenced carbon stock values. Across all sites, the Fabaceae family contributed 292.08 tonnes/ha, exceeding the 220.52 tonnes/ha recorded in Jakarta's urban forests (Lubis *et al.* 2013).

Differences in carbon stock values among the urban forests are influenced by land area and dominant tree species. Muluneh & Worku (2022) reported that carbon stock capacity increases with land area. Based on Table 2 and Figure 2, the total carbon stock of four tree species across PP, TR, and BNI reached 292.08 tonnes/ha. *Samanea saman* dominated with 248.44 tonnes/ha (85.06%), followed by *Tamarindus indica* with 30.55 tonnes/ha (10.46%), *Pterocarpus indicus* with 11.87 tonnes/ha (4.06%), and *Delonix regia* with 1.22 tonnes/ha (0.42%). The dominance of *Samanea saman* highlights its key role in carbon absorption and storage in urban forests.

The dominance of *Samanea saman* demonstrates its important role in absorbing and storing carbon within urban forest environments (Ow *et al.* 2019). *Samanea saman* was identified as the most dominant species in terms of biomass contribution and carbon storage potential across all urban forest areas in Banda Aceh (Dharma & Zakaria 2022). Compared with research by Santoso *et al.* (2021) in three urban forests in Jakarta, *Samanea saman*, a tree species from the Fabaceae family, also had the highest carbon stocks in all three urban forests.

Plant biomass is a measure of plant growth or the weight of organic matter produced by plants. The larger the tree diameter, the greater the tree's biomass. Biomass growth is most strongly influenced by diameter, followed by relative height, basal area, climatic conditions, and tree species diversity (Forrester 2021).

Table 2 Distribution of plant species in each research location based on their ability to store carbon

Urban forest	Species	AGB (tonnes/ha)	BGB (tonnes/ha)	Total carbon (tonnes/ha)	Percentage (%)
Putroe Phang (PP)	<i>Delonix regia</i>	0.25	0.05	0.39	0.13
	<i>Pterocarpus indicus</i>	0.54	0.11	0.84	0.29
	<i>Samanea saman</i>	64.31	12.86	99.91	34.21
	<i>Tamarindus indica</i>	13.62	2.72	21.15	7.24
Trembesi (TR)	<i>Pterocarpus indicus</i>	2.07	0.41	3.21	1.10
	<i>Samanea saman</i>	77.30	15.46	120.10	41.12
	<i>Tamarindus indica</i>	0.54	0.11	0.84	0.29
BNI (BNI)	<i>Delonix regia</i>	0.91	0.18	0.83	0.28
	<i>Pterocarpus indicus</i>	8.63	1.73	7.82	2.68
	<i>Samanea saman</i>	31.38	6.28	28.44	9.74
	<i>Tamarindus indica</i>	9.44	1.89	8.56	2.93
Total		208.99	41.80	292.08	100.00

Notes: AGB = Aboveground biomass; BGB = Belowground biomass.

Table 3 Contribution of diameter to total carbon stored in three urban forests in Banda Aceh

Research site	Species	Diameters (cm)	Biomass (tonnes/ha)	Carbon (tonnes/ha)
Putroe Phang (PP)	<i>Delonix regia</i>	22.93	0.30	0.39
	<i>Pterocarpus indicus</i>	31.85	0.65	0.84
	<i>Samanea saman</i>	572.29	77.17	99.91
	<i>Tamarindus indica</i>	463.28	16.34	21.15
Trembesi (TR)	<i>Pterocarpus indicus</i>	83.12	2.48	3.21
	<i>Samanea saman</i>	3,730.10	92.76	120.10
	<i>Tamarindus indica</i>	31.85	0.65	0.84
BNI (BNI)	<i>Delonix regia</i>	74.20	1.09	0.83
	<i>Pterocarpus indica</i>	413.69	10.36	7.82
	<i>Samanea saman</i>	1,511.78	37.65	28.44
	<i>Tamarindus indica</i>	425.48	11.33	8.56
Grand Total		7,360.57	250.78	292.08

Contribution of AGB and BGB to Total Carbon Stored In Urban Forests

Carbon stock analysis of Banda Aceh urban forests (Putroe Phang, Trembesi, and BNI) showed a total of 292.08 tonnes/ha. Trembesi had the highest carbon stock, dominated by *Samanea saman* with 77.30 tonnes/ha AGB and 15.46 tonnes/ha BGB (total 120.10 tonnes/ha), followed by Putroe Phang (64.31 tonnes/ha AGB, 12.86 tonnes/ha BGB; total 99.91 tonnes/ha). Other species *Tamarindus indica*, *Pterocarpus indicus*, and *Delonix regia* contributed 0.39 – 21.15 tonnes/ha. These findings confirm *Samanea saman* as the dominant carbon-storing species, consistent with Santoso *et al.* (2021).

Contribution of Diameter to Total Carbon Stored in Urban Forests

The Fabaceae family species found in this urban forest exhibit variations in their carbon storage capacity. Research by Amin *et al.* (2014) suggested that differences in biomass and carbon reserves among tree species are also influenced by vegetation density. The denser a species' vegetation, the greater its biomass and carbon reserves (Table 3).

Analysis of total biomass and carbon storage in the urban forest revealed that *Samanea saman* had the highest values. Allometric equations indicated variations among species, partly due to

the relatively young age of the trees. Amin (2016) supports this, noting that young forests consist of actively growing trees with high CO₂ absorption, whereas mature forests primarily act as carbon reservoirs.

Carbon variation between plots is influenced by tree number, density, basal area, and stem diameter, as most carbon is stored in trunks (Irund *et al.* 2020). Carbon storage reflects biomass accumulation (Wang *et al.* 2021), and increasing plant biomass enhances carbon reserves, supporting climate mitigation strategies (Santoso *et al.* 2021). Sustainably managed urban forests, reforestation, and forest rehabilitation can significantly increase carbon sequestration and reduce atmospheric CO₂ (Poorter *et al.* 2021).

Relationship between Stem Diameter and Tree Carbon Stocks

A strong positive relationship between stem diameter and carbon stocks at PP, TR, and BNI is shown in Figure 3. At PP, the correlation coefficient ($r = 0.8207$) indicates that larger stem diameters generally correspond to higher carbon stocks, despite variations in age, species, or soil. TR with r value of 0.976, showed a near-perfect relationship, likely due to species

homogeneity or uniform conditions, making stem diameter a highly accurate predictor. Similarly, BNI showed a strong correlation ($r = 0.9689$), influenced by the dominance of large-diameter trees and basal area conditions. Overall, stem diameter is a reliable predictor of carbon stocks in urban forests; however, its accuracy may vary depending on ecological conditions and species differences. Therefore, adjustments to site-specific characteristics are necessary to obtain more precise estimates (McPherson *et al.* 2016).

The relationship between stem diameter and carbon stocks per tree showed a strong to very strong positive correlation in all locations (Table 4). The highest correlation was at TR ($r = 0.976$), followed by BNI ($r = 0.9689$), both indicating favorable ecosystem conditions. PP also showed a strong correlation ($r = 0.8207$), which may be influenced by external factors such as species composition and tree age variation. Environmental variables, including water availability, nutrients, and climate, further influence carbon accumulation (Saremi *et al.* 2014). These findings underscore the importance of integrating physiological measurements with stand-level inventories to better predict carbon dynamics in diverse forest ecosystems (Loguercio *et al.* 2024).

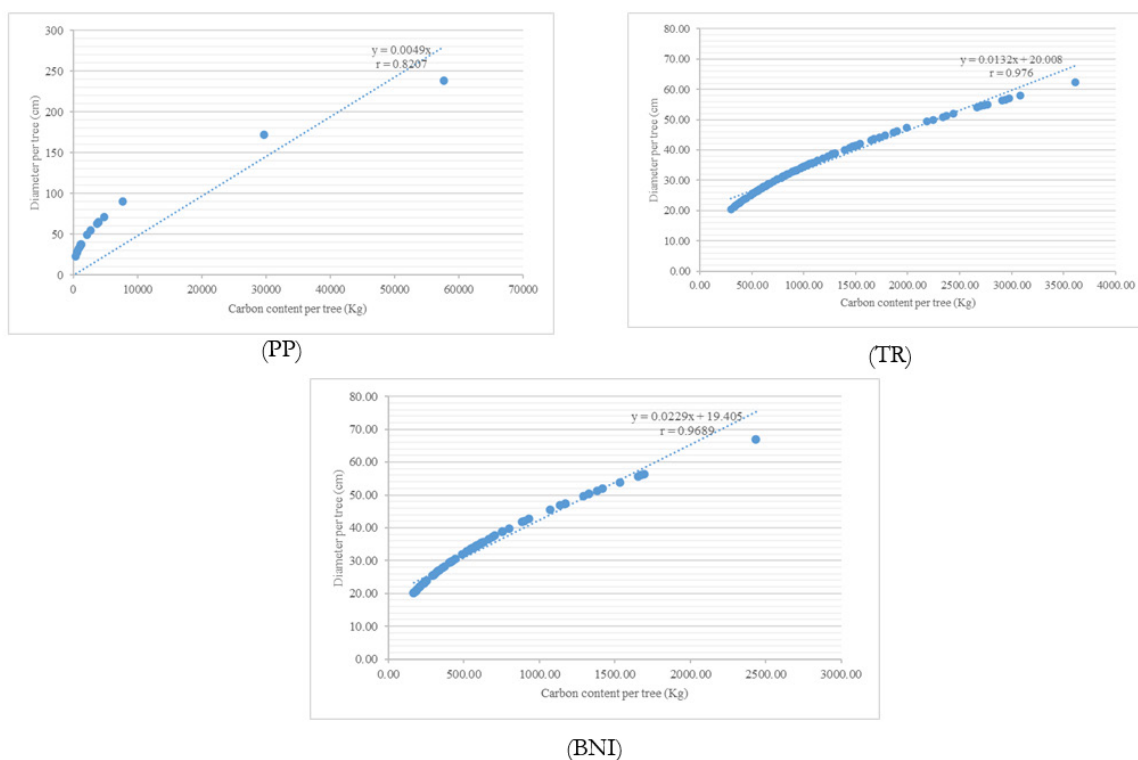


Figure 3 Relationship between stem diameter and tree carbon stocks

Table 4 Correlation coefficient (r) value between stem diameter and carbon stocks per tree at three urban forests in Banda Aceh

Location	Regression equation	r	Relationship category *
PP	$y = 0.0049x$	0.8207	Strong
TR	$y = 0.0132x + 20.008$	0.9760	Very Strong
BNI	$y = 0.0229x + 19.405$	0.9689	Very Strong

Notes: * = Categories based on general interpretation of correlation values: 0.70 – 0.89 = strong; ≥ 0.90 = very strong.

The correlation analysis graph indicates that the TR ($r = 0.9760$) and BNI ($r = 0.9689$) locations fall within the very strong relationship category. This suggests that stem diameter is a highly reliable predictor of variation in carbon stocks per tree at both locations. Meanwhile, the PP location ($r = 0.8207$) falls within the strong relationship category, but still below the very strong threshold ($r = 0.9$). Therefore, there are likely other factors that influence carbon stocks, such as species variation, tree age, and environmental conditions (Chave *et al.* 2014). In general, the closer the r value is to 1, the stronger the linear relationship between stem diameter and carbon stocks, indicating that carbon stocks can be predicted from stem diameter with a relatively high degree of accuracy. Thus, stem diameter can be used as a primary indicator in estimating carbon stocks (Basuki *et al.* 2009), especially at the TR and BNI locations, where the strength of the relationship is highest.

Vegetation Importance

This study identified 4 tree species and 197 individuals from the Fabaceae family. The presence of tree species found in each urban forest is presented in Table 5, showing that the four Fabaceae species were distributed across the three urban forests in Banda Aceh.

This finding is slightly lower than the results of a study conducted by Amin *et al.* (2014), who found five species, and Lubis *et al.* (2013), who reported nine species in Jakarta urban forests. The dominance of Fabaceae aligns with Irwan *et al.* (2021), who noted its prevalence across Sumatra, Kalimantan, Java, and Bali. Figure 4 presents the number of species and individuals per urban forest.

Fabaceae trees are widely planted in green open spaces due to their adaptability and ecological benefits. Ow *et al.* (2019) reported their broad tolerance to temperature, humidity, and soil conditions, supporting successful growth in Banda Aceh's urban forests. Irwan *et al.* (2021) further

noted the function of trees of the Fabaceae family as shade trees that reduce air pollution and supply oxygen. This function is crucial for sustaining urban carbon stocks, especially as the expansion of gray infrastructure often leads to tree loss, underscoring the need for effective protection and afforestation programs involving public participation (Lahoti *et al.* 2020).

Samanea saman (Rain tree) is the most abundant Fabaceae species, with 155 individuals across Putroe Phang, Trembesi, and BNI urban forests (Table 5). Its abundance is linked to its fast growth. Chaunan *et al.* (2019). This species can reach 25 m in height with trunk diameters of 30 – 40 cm. Field observations recorded that the average tree heights of *Samanea saman* reached 16 – 20 m with diameters of 40 – 60 cm in Trembesi urban forest, while in Putroe Phang, the average tree height of *Samanea saman* was 18 – 22 m with average tree diameter of 70 – 200 cm, which significantly contributes to carbon storage. Its CO₂ absorption capacity is reinforced by Dahlan (2010), who reported sequestration rates of 28.5 tonnes/ha annually (crown diameter 15 m).

Tamarindus indica (Tamarind) and *Pterocarpus indicus* (Narra) were found to be among the most abundant Fabaceae species in the three urban forests in Banda Aceh (Table 5). *Tamarindus indica* found in Putroe Phang, Trembesi, and BNI Urban Forests and was valued for carbon sequestration, timber, and fruit, with low maintenance requirements (Fajar & Nur 2017). *Pterocarpus indicus*, commonly found on roadsides and urban forests, tolerates environmental stress, absorbs CO₂ and air pollutants, and is considered a dominant shade tree with moderate carbon uptake (Gunawan *et al.* 2021).

Delonix regia (Flamboyant) has the fewest individuals in the three Banda Aceh Urban Forests, occurring only in Putroe Phang and BNI (Table 5). This species functions as a roadside shade tree for heavy metal absorption, making it suitable for urban forest planting (Febrianti 2019).

The Importance Value Index (IVI) value for each species from the Fabaceae family in three Banda Aceh urban forests ranged from 0 to 300 (Table 6).

Among species in the Fabaceae family, *Samanea saman* was found to have the highest Important Value Index across the three urban forests in Banda Aceh. This dominance may be attributed to reforestation programs involving planting activities

conducted by the Banda Aceh City Environment and Forestry Service. These programs likely resulted in *Samanea saman* having a larger basal area and greater root coverage compared to other species. This explanation is supported by the research result of Dharma and Zakaria (2022) which reported that *Samanea saman* had the highest IVI value among ten urban forests in Banda Aceh.

Table 5 Distribution of plant species in three urban forests in Banda Aceh

Name of species	PP	TR	BNI	Total of species
<i>Delonix regia</i>	1	0	3	4
<i>Pterocarpus indicus</i>	1	2	12	15
<i>Samanea saman</i>	4	107	44	155
<i>Tamarindus indica</i>	10	1	12	23
Total of species	4	3	4	4
Total of individual	16	110	71	197

Notes: PP = Putroe Phang; TR = Trembesi; BNI = BNI.

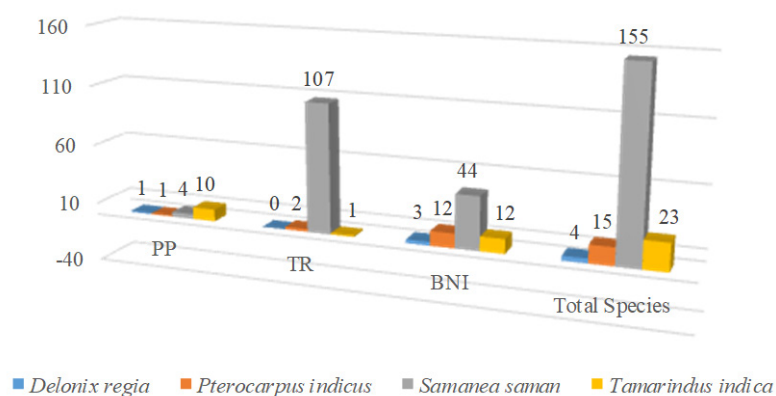


Figure 4 Number of species and individuals of the Fabaceae family in three urban forests in Banda Aceh

Table 6 Important value index of each species of Fabaceae family in three urban forests in Banda Aceh

No	Urban forest	Species	Total individual	RF (%)	RD (%)	RD0 (%)	IVI (%)
1.	Putroe Phang	<i>Samanea saman</i>	4	13.79	9.52	58.70	82.01
		<i>Tamarindus indica</i>	10	17.24	23.81	13.79	54.84
		<i>Pterocarpus indicus</i>	1	3.45	2.38	0.60	6.43
		<i>Delonix regia</i>	1	3.45	2.38	0.31	6.14
2.	Trembesi	<i>Samanea saman</i>	107	53.85	93.04	93.99	240.34
		<i>Pterocarpus indicus</i>	2	7.69	1.74	1.94	11.51
		<i>Tamarindus indica</i>	1	7.69	0.87	0.35	9.36
3.	BNI	<i>Samanea saman</i>	44	24.32	44.20	36.08	116.59
		<i>Pterocarpus indicus</i>	12	13.51	12.24	17.17	38.54
		<i>Tamarindus indica</i>	12	8.11	12.24	16.70	33.65
		<i>Delonix regia</i>	3	8.11	3.06	2.97	13.31

Notes: RF = Relative frequency; RD = Relative density; RD0 = Relative dominance; IVI = Important value index.

CONCLUSION

Four tree species and 197 individuals in the Fabaceae family were found in three urban forests in Banda Aceh. The total potential carbon stock value of trees belonging to the Fabaceae family found in those urban forest areas was 292.08 tonnes/ha. *Samanea saman* exhibited the highest biomass and carbon sequestration value.

ACKNOWLEDGMENTS

We extend our sincere gratitude to Universitas Syiah Kuala for financial support of research. We also thank all individuals and institutions who contributed to the successful completion of this research.

REFERENCES

- Abbas S, Wong MS, Wu J, Shahzad N, Irteza SM. 2020. Approaches of satellite remote sensing for the assessment of above-ground biomass across tropical forests: Pan-tropical to national scales. *Remote Sens* 12(20):3351. DOI: 10.3390/rs12203351
- Amin N. 2016. Carbon reserves in urban forest plants in Banda Aceh. In: *Proceedings of the National Seminar on Biotics* 4(1):71–80. DOI: 10.22373/pbio.v4i1.2534
- Amin N, Hasanuddin, Djufri. 2014. The potential of plant species in the Banda Aceh Urban Forest to reduce CO₂ emissions. *J EduBio Tropica* 2:187–250.
- Basuki TM, van Laake PE, Skidmore AK, Hussin YA. 2009. Allometric equations for estimating the above-ground biomass in tropical lowland Dipterocarp forests. *For Ecol Manag* 257(8):1684–1694. DOI: 10.1016/j.foreco.2009.01.027
- [BMKG] Meteorology, Climatology, and Geophysics Agency. 2022. Indonesia's extreme climate change. [Internet]. [Accessed 15 April 2022]. Available from <https://www.bmkg.go.id/iklim/?p=ekstrem-climate-change>
- Brown S. 1997. Estimating biomass and biomass change of tropical forests: A primer. FAO Forestry Paper. Vol 134. Rome (IT): Food and Agriculture Organization.
- [BSN] Indonesian National Standard. 2019. SNI 7724:2019 – Measurement and calculation of carbon stocks for forest carbon stock estimation. Jakarta (ID): Indonesian National Standard.
- Chaunan NN, Jadeja MB, Patel MS, Shah BN. 2019. Pharmacognostic studies on stems of *Samanea saman* (Jacq) Merr. *Pharma Sci Monit* 10:76–84. DOI: 10.1016/j.foreco.2009.01.027
- Chave J, Réjou-Méchain M, Búrquez A, Chidumayo E, Colgan MS, Delitti WBC, Vieilledent G. 2014. Improved allometric models to estimate the aboveground biomass of tropical trees. *Glob Change Biol* 20(10):3177–3190. DOI: 10.1111/gcb.12629
- Chen X, Luo M, Larjavaara M. 2023. Effects of climate and plant functional types on forest above-ground biomass accumulation. *Carbon Balance Manag* 18:5. DOI: 10.1186/s13021-023-00225-1
- Dahlan EN. 2010. Trembesi was once foreign, now it is no longer. Bogor (ID): IPB Press.
- Dharma W, Zakaria R. 2022. Vegetation analysis of 10 urban forest in the city of Banda Aceh, Indonesia. *Biodiversity* 23:4131–4137. DOI: 10.13057/biodiv/d230834
- Duveiller G, Hooker J, Cescatti A. 2018. The mark of vegetation change on Earth's surface energy balance. *Nat Commun* 9(1):679. DOI: 10.1038/s41467-017-02810-8
- Fajar AR, Nur BA. 2017. Estimation of carbon reserves by modeling the application of tamarind planting on green roads in Rembang Regency. In: *Proceeding Biology Education Conference*. Vol 14. p. 229–232.
- Forrester DI. 2021. Does individual-tree biomass growth increase continuously with tree size?. *For Ecol Manag* 118717:1–10. DOI: 10.1016/j.foreco.2020.118717
- Gielen B, Acosta M, Altimir N, Buchmann N, Cescatti A, Ceschia É, Wohlfahrt G. 2018. Ancillary vegetation measurements at ICOS ecosystem stations. *Int Agrophys* 32(4):645–664. DOI: 10.1515/intag-2017-0048
- Gunawan S, Karyati, Syafrudin M. 2021. Pollutant content on the leaves of Angana (*Pterocarpus indicus* Willd.) in Samarinda City. *Journal of Development Research* 3(2):46–54. DOI: 10.36087/jrp.v3i2.72
- Indrawan M, Primack RB, Supriatna J. 2012. Conservation biology. Jakarta (ID): Yayasan Obor Indonesia.
- Irundu D, Beddu MA, Najmawati. 2020. Potential biomass and carbon storage in green open spaces in Polewali City, West Sulawesi. *Journal of Forests and Society* 12:49–57. DOI: 10.24259/jhm.v12i1.9675
- Irwan MR, Widiyanti P, Irsyam ASD, Astuti RS. 2021. Diversity of conservation status and potential of the Fabaceae family in the Bogor Botanical Gardens collection. *Tropical Biosciences* 1:1–10. DOI: 10.32678/tropicalbiosci.v1i2.4310
- Istomo, Farida NE. 2017. Potential above-ground carbon storage of *Acacia nilotica* L. (Willd.) ex Del. stands in Baluran National Park, East Java. *Journal of Natural Resources and Environmental Management* 7(2):155–162. DOI: 10.29244/jpsl.7.2.155-162
- Jilo D, Birhane E, Tadesse T, Ubuy MH. 2025. Aboveground biomass models for common woody species of lowland forest in Borana woodland, Southern Ethiopia. *Forests* 16(5):823. DOI: 10.3390/f16050823
- Lahoti S, Lahoti A, Joshi RK, Saitô O. 2020. Vegetation structure, species composition, and carbon sink potential of urban green spaces in Nagpur City, India. *Land* 9(4):107. DOI: 10.3390/land9040107
- Loguerio GA, Simon A, Winter AN, Ivancich H, Reiter EJ, Caselli M, Walentowski H. 2024. Carbon density and sequestration in the temperate forests of northern Patagonia, Argentina. *Front For Glob Change* 7:1373187. DOI: 10.3389/ffgc.2024.1373187

- Lubis SH, Arifin HS, Samsuudin I. 2013. Analysis of tree carbon stocks in urban forest landscapes in DKI Jakarta. *Journal of Social and Economic Research on Forestry* 10(1):1–20. DOI: 10.20886/jpsek.2013.10.1.1-20
- McPherson EG, van Doorn NS, Peper PJ. 2016. Urban tree database and allometric equations. General Technical Report; PSW-GTR-253. Albany (US): USDA Forest Service.
- Mountford H, Waskow D, Gonzalez L, Gajjar C. 2021. COP 26: Key outcomes from the UN climate talks in Glasgow. Rockville (US): World Resources Institute.
- Mueller-Dombois D, Ellenberg H. 1974. Aims and methods of vegetation ecology. New York (US): John Wiley and Sons.
- Mulunch MG, Worku BB. 2022. Carbon storages and sequestration potentials in remnant forests of different patch sizes in northern Ethiopia: An implication for climate change mitigation. *Agric Food Secur* 11(57):1–24. DOI: 10.1186/s40066-022-00395-0
- Municipal Government of Banda Aceh. 2019. Masterplan Banda Aceh Smart City 2019-2029: Becoming an Islamic smart city that is attractive and competitive. Banda Aceh (ID): Municipal Government of Banda Aceh.
- Nowak DJ, Greenfield EJ, Hoehn RE, Lapoint E. 2013. Carbon storage and sequestration by trees in urban and community areas of the United States. *Environ Pollut* 178:229–236. DOI: 10.1016/j.envpol.2013.03.019
- Ow LF, Ghosh D, Yusof MLM. 2019. Growth of *Samanea saman*: Estimated cooling potential of this tree in an urban environment. *Urban For Urban Green* 41:264–271. DOI: 10.1016/j.ufug.2019.03.021
- Pipite A. 2022. Estimation of aboveground biomass (ABG) using allometric equation: case study of colo-i-suva forest park in Fiji. *Earth Environ Sci Res Rev* 5(3):137–147.
- Poorter L, Amissah L, Bongers F, Hordijk I, Kok J, Laurance SGW, Chazdon RL. 2021. Multidimensional tropical forest recovery. *Science* 374(6573):1370–1376. DOI: 10.1126/science.abh3629
- Poorter L, van der Sande MT, Thompson J, Arets EJMM, Alarcón A, Álvarez-Sánchez J, Peña-Claros M. 2015. Diversity enhances carbon storage in tropical forests. *Glob Ecol Biogeogr* 24(11):1314–1328. DOI: 10.1111/geb.12364
- Pragasana LA. 2015. Total carbon stock of tree vegetation and its relationship with altitudinal gradient from the Shervarayan Hills located in India. *J Earth Sci Clim Change* 6(4).
- Santoso N, Sutopo P, Pambudi GP, Danarta VF, Wibisono RA, Astuti TP, Wicaksono DB. 2021. Estimation of biomass and carbon sequestration in several areas of the Jakarta, Bekasi, and Bogor Urban Forest Parks. *Journal of Plantation Forest Research* 18(1):35–49. DOI: 10.20886/jpht.2021.18.1.35-49
- Saremi H, Kumar L, Stone C, Melville GJ, Turner R. 2014. Sub-compartment variation in tree height, stem diameter and stocking in a *Pinus radiata* D. Don plantation examined using airborne LiDAR data. *Remote Sens* 6(8):7592–7609. DOI: 10.3390/rs6087592
- Singh S, Kumar SN. 2014. A review: Introduction to genus *Delonix*. *World J Pharm Pharm Sci* 3(6):2045–2055.
- Soerianegara I, Indrawan A. 1988. Indonesian forest ecology. Bogor (ID): Forest Ecology Laboratory, Faculty of Forestry, Bogor Agricultural University.
- Stiling P. 2012. Ecology. New York (US): The McGraw-Hill Companies.
- Sukma Y. 2019. Phenotypic relationship of Fabaceae family members in the BNI Banda Aceh Urban Forest as a reference for higher plant botany courses. [Thesis]. Banda Aceh (ID): UIN Ar-Raniry.
- Sun T. 2023. The impact of global climate change policy on employment-environmental regulation in the context of just transition. *SHS Web of Conferences* 154:01017. DOI: 10.1051/shsconf/202315401017
- Sutthichaimethee P, Saraphirom P, Junsiri C. 2025. Long-term strategy for determining the potential of climate-smart agriculture to maximize efficiency under sustainability in Thailand. *Sustainability* 17(8):3635. DOI: 10.3390/su17083635
- Tagesson T, Schurgers G, Horion S, Ciais P, Tian F, Brandt M, Fensholt R. 2020. Recent divergence in the contributions of tropical and boreal forests to the terrestrial carbon sink. *Nat Ecol Evol* 4(2):202–209. DOI: 10.1038/s41559-019-1090-0
- Wang Y, Chang Q, Li X. 2021. Promoting sustainable carbon sequestration of plants in urban greenspace by planting design: a case study in parks of Beijing. *Urban For Urban Green* 64:127291. DOI: 10.1016/j.ufug.2021.127291
- Wang Z, Xu L, Shi Y, Ma Q, Wu Y, Lu Z, Zhang Q. 2021. Impact of land use change on vegetation carbon storage during rapid urbanization: A case study of Hangzhou, China. *Chinese Geogr Sci* 31(2):209–222. DOI: 10.1007/s11769-021-1183-y