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Carbon Stock Analysis of Family Fabaceae in the Forest Area of Surabaya State University as An Effort to Conserve the Environment

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ABSTRACT

Forest vegetation plays a crucial role in mitigating global climate change through carbon sequestration. The Universitas Negeri Surabaya campus forest has significant potential as a carbon sink, particularly through tree species belonging to the Fabaceae family. This study aimed to analyze carbon stocks in Fabaceae trees within the campus forest as an effort toward environmental conservation. Carbon stock estimation was carried out using a non-destructive approach through allometric equations, focusing only on above-ground biomass. The research was conducted in the campus forest area targeting Fabaceae species. Parameters measured included tree trunk diameter at 1.3 meters above ground level, secondary data on wood specific gravity, and leaf chlorophyll content. Data analysis was performed using the Pearson correlation test to determine the relationship between morphological and physiological characteristics of trees and their stored carbon stock. The results showed that the Unesa campus forest contained 4 species and 52 individual trees. The average carbon stock per tree was 213.96 kg C $tree^{-1}$ $year^{-1}$, and the total carbon stock in the observed area reached 992.79 kg/ha. Pearson correlation results indicated a positive relationship between morphological and physiological characteristics and carbon stock (Sig. 0.31). Based on these findings, Fabaceae species are recommended as effective contributors to environmental conservation strategies to reduce carbon emissions. These trees also support campus greening programs and align with the achievement of Sustainable Development Goals (SDGs).

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INTRODUCTION

The phenomenon of global climate change represents an urgent environmental challenge of global concern. Rapid human development and technological advancement have significantly accelerated the emission of greenhouse gases (GHGs), thereby altering the global climate system in unprecedented ways. Among the most impactful greenhouse gases, carbon dioxide (CO_2) plays a dominant role in the intensification of the greenhouse effect. According to the Intergovernmental Panel on Climate Change (IPCC, 2021), atmospheric CO_2 concentrations have increased dramatically since the pre-industrial era, leading to global warming and severe climatic disruptions (Nasir, 2024). These disruptions manifest in rising global average temperatures, increased frequency of extreme weather events, shifting precipitation patterns, and accelerated sea-level rise (Gyn, 2024). Globally, the contribution to CO_2 emissions is uneven, with major industrialized and developing countries dominating. Based on Climate Watch 2021 reports greenhouse gas (GHG) emissions, China accounts for approximately 26% of global emissions, followed by the United States (11%), India (6.9%), Russia (4%), and Brazil (3.1%). Indonesia occupies the sixth position, contributing around 3% of global emissions. This high-ranking places Indonesia among the major emitters, highlighting the urgency of implementing effective mitigation strategies to achieve national and international climate goals (Pierre et al., 2025).

In response to these challenges, mitigation has emerged as a critical component of climate change management. According to Indonesian Law No. 24/2007, mitigation encompasses comprehensive efforts aimed at reducing disaster risks, including those associated with climate-related hazards. One of the most effective mitigation strategies is enhancing carbon sequestration capacity within terrestrial ecosystems, particularly forests (Kintan A. & Weishaguna, 2023). Forest ecosystems serve as essential carbon sinks by absorbing atmospheric CO_2 through photosynthesis and storing it as biomass in different plant components such as stems, branches, leaves, and roots (Muslih et al., 2022).

The measurement of carbon stock, defined as the total quantity of carbon stored in vegetation and soil, provides an essential metric for assessing the contribution of forests to climate change mitigation (Subedi et al., 2010). Higher biomass content generally corresponds to a greater capacity for carbon sequestration, as approximately 40–50% of plant dry weight consists of carbon (Joshi & Garkoti, 2025). Thus, understanding biomass accumulation dynamics becomes fundamental in estimating carbon storage potential and formulating conservation strategies.

Recent studies underscore the importance of assessing carbon stock variations across ecosystems to identify effective climate mitigation strategies. Kumar et al. (2024) reported significant differences in carbon stocks across land-use systems, highlighting the role of vegetation composition and management practices. Brancalion et al. (2025) further emphasized that restoration activities, such as reforestation and the implementation of sustainable forestry practices, significantly enhance long-term carbon storage. However, most of these studies have focused on natural forests, peatlands, and large-scale conservation areas (Hairiah et al., 2011).

In contrast, urban green spaces and campus forests remain underexplored in carbon stock research, despite their critical role in mitigating the urban heat island effect and reducing carbon emissions (Nowak et al., 2006; Escobedo et al., 2011). This lack of empirical evidence represents a significant research gap, as urban ecosystems increasingly contribute to global sustainability goals due to rapid urbanization trends. Consequently, greater scientific attention must be directed toward quantifying carbon stocks within urban and peri-urban ecosystems, including campus forests, to support sustainable urban planning and climate resilience (Mustikaningrum & Rosida, 2023).

Surabaya City, a prominent metropolitan city in Indonesia, exemplifies an ecological approach in urban planning, as articulated in the RPJMD 2016-2021, which articulates the vision "*Surabaya is a Sentosa City with character and Global Competitiveness based on Ecology*". This ecological approach aspires to enhance environmental quality in the context of rapid urban development, a process frequently accompanied by environmental degradation, including reduced green space and augmented air and water pollution. Consequently, concerted efforts are necessary to preserve and enhance environmental quality by ensuring the allocation of sufficient green open space (RTH), constituting a pivotal component of urban planning strategies.

As delineated in the Surabaya City Spatial Plan, the quality of green open spaces in Surabaya City, both active and passive, remains a matter of ongoing concern. Efforts to enhance the provision, management, and improvement of green open space (RTH) are generally directed at optimizing the function, quality, and distribution of public RTH proportionally throughout Surabaya City (BPP Surabaya City). A critical component of this initiative is the development of urban forests.

An urban forest is defined as a region comprising densely growing trees in urban areas, including both state-owned and privately owned land, and designated as an urban forest by the relevant authority. According to Surabaya City Regional Regulation No. 15/2014 on Urban Forests, the minimum percentage of urban forest area is set at 10% (ten percent) of the total city area, equivalent to 3,300 hectares (three thousand three hundred hectares), to be achieved within a decade. However, the current urban forest in Surabaya has reached only 48.68 hectares, or approximately 0.01% of the provision mandated by the regional regulation. This indicates that Surabaya falls significantly short of the target and has yet to fully realize the ecological benefits that urban forests are intended to provide.

Urban forests have the potential to mitigate the Urban Heat Island (UHI) phenomenon, which occurs when urban areas experience higher temperatures than surrounding areas due to human activity and land-use change. Additionally, urban forests can contribute to reducing groundwater pollution, the risk of waterlogging, and tidal flooding due to the lack of water catchment areas. The UHI phenomenon is influenced by various factors, including the lack of green open spaces, hard surfaces such as asphalt, and carbon emissions. In Surabaya, there has been a 72.97% increase in carbon emissions over the past two decades, while hard surface areas have surged by 97.69%, largely due to the construction of toll roads and major roads. The combined increase in carbon emissions and hard surfaces, along with the stagnant area of green open space, has led to rising temperatures and substantial temperature variations between urban and rural regions (Aghnia & Umilia, 2018).

The impediments to the development of urban forests in Surabaya are manifold, including but not limited to a paucity of support from policymakers, inadequate funding, insufficient community participation, and a dearth of experts. Achieving the established objectives and realizing the ecological and social benefits of the urban forest is challenging without concerted efforts and substantial support from various stakeholders (Nurhasan & Damayanti, 2022). To this end, there is an ongoing need for enhanced sustainable urban planning efforts that adopt an ecological approach, with the objective of transforming Surabaya into a greener, healthier, and more livable city.

Surabaya State University's campus forest area offers a distinctive opportunity to integrate environmental conservation with education and research. This campus forest not only provides significant green space for climate change mitigation but also functions as a living laboratory for students and researchers to study ecosystems and their environmental interactions. However, the specific role of vegetation in campus forests in carbon storage has received limited research attention, despite evidence indicating that urban and semi-urban green areas play a crucial role as carbon sinks. Legumes (Fabaceae) are a diverse plant family with a wide distribution in tropical regions, including Indonesia. They offer numerous benefits to human life, such as food, landscape greening, animal feed, tannin production, and medicinal uses. However, the utilization of legumes has not been fully optimized (Hariri et al., 2021).

Fabaceae represents one of the most diverse flowering plant families worldwide, occupying a prominent position within the taxonomic classification system. It is a member of the Fabales order, a group distinguished by its association with pod-bearing plants. This tribe stands as the second largest after Asteraceae or Compositae and Orchidaceae, encompassing an impressive array of up to 800 genera and more than 23,000 species. The legume family encompasses a wide range of growth forms, including herbaceous plants, shrubs, woody vines (lianas), and a small proportion of aquatic plants (Hariri et al., 2021). Legumes play a significant role in global vegetation, with a prevalence in marginal environments due to their capacity to fix nitrogen from the atmosphere through root nodules (Assyifa et al., 2023). Recent studies, including those by Danarto & Setyorini (2019) and Karma et al. (2021) have highlighted the significant carbon sequestration and storage potential of plants belonging to the Fabaceae family. These plants possess a unique ability to fix nitrogen through symbiotic relationships with *Rhizobium* bacteria. This process enhances soil fertility, thereby promoting robust and healthy plant growth, which in turn increases carbon storage capacity in the form of biomass (Singh et al., 2024). However, the majority of these studies have focused on natural forests or conservation areas, overlooking the significance of vegetation in campus forest areas as a carbon storage medium. The Unesa campus forest contains several species from the Fabaceae family, including flamboyant trees (*Delonix regia*), tamarind (*Tamarindus indica* L.), Chinese petai (*Leucaena leucocephala*), and gamal (*Gliricidia sepium*).

According to Griscom et al. (2017), forest conservation and restoration are pivotal strategies in climate change mitigation, aligning with the objectives of multiple *Sustainable Development Goals* (SDGs) established by the United Nations (UN). Sustainable forest management contributes to the realization of SDG 13, "Climate Action," by promoting measures to reduce greenhouse gas emissions and mitigate climate change. In addition, effective forest management contributes to the realization of SDG 15, "Life on Land," which emphasizes the conservation, rehabilitation, and sustainable utilization of terrestrial ecosystems, including forests. Furthermore, conservation and responsible forest management support the achievement of SDG 12, "Responsible Consumption and Production," by ensuring that forest resources are managed sustainably and that pressure on natural forests is mitigated. Consequently, research findings in this domain can meaningfully contribute to the realization of the SDGs and the global agenda for sustainability and well-being.

Research on the capacity of flora to absorb and store carbon has been conducted by numerous experts. In Indonesia, studies on carbon stocks predominantly focus on natural forests, peatlands, and other conservation areas. However, the role of campus forests in this context has received limited attention. Consequently, this study aims to address this research gap by focusing specifically on the carbon stock analysis of plants from the Fabaceae family in the campus forest area of Universitas Negeri Surabaya. The specific objectives of this study are threefold: first, to describe the physical characteristics of plants from the Fabaceae family; second, to analyze the carbon stocks stored in plants from the Fabaceae family; and third, to analyze the relationship between the physical characteristics of plants from the Fabaceae family and the carbon stocks stored in these plants. This research will use comprehensive methods, including measurement of plant biomass and analysis of physical characteristics to determine carbon content.

MATERIALS AND METHODS

Time and Location

This research was conducted over a period of five months, commencing in August 2023 and concluding in October 2023, and again from August 2024 to September 2024. The research was conducted in the Forest Area of the Universitas Negeri Surabaya Campus, Lidah Wetan, Lakarsantri District, Surabaya, East Java, located at coordinates -7.300496258l3927 and 112.67130694220681. Sampling was carried out in the Forest Area of UNESA Lidah Wetan Campus (Figure 1), while the analysis of chlorophyll levels was conducted in the IsDB Laboratory, Faculty of Mathematics and Natural Sciences, Universitas Negeri Surabaya.

Procedure

The parameters observed in this study included the collection on the diameter at breast height (DBH) of Fabaceae family trees, approximately 1.3 metres above the ground, plant biomass, carbon stock analysis, morphological characteristics, including tree stature (tree height), stem condition (diameter, circumference, and specific gravity) and leaf traits (leaf area), and physiological characteristics in the form of leaf chlorophyll levels for further analysis of the relationship between these parameters and carbon stocks stored in Fabaceae family plants in the area.

Tools and materials

The tools used in this study include measuring tape, raffia, scissors, stationery, working paper for data recording, portable laser leaf area meter, UV-1800 UV-Vis type spectrophotometer, MTA-38405896 soil thermometer, DMB72B WiFi air quality monitor analyser CO2 detector PM 2.5 detector TVOC meter, PC/laptop, smartphone and soil tester 3 in 1 moisture tester (pH, humidity and light intensity). The materials used in this study are trees and leaves from plants of the Fabaceae family in the forest area of the Unesa campus. The materials needed to test the chlorophyll content are leaf samples and 95% alcohol.

Type and Design of Data Collection

This research is a quantitative study and can be classified as exploratory descriptive research, using observational methods to collect data. The method used in this research is non-destructive primary data collection (without harvesting). The research design was carried out by determining the carbon estimate without damaging the plants to measure the dry weight of the tree mass. This was then calculated using the allometric equation based on diameter at breast height (DBH), which is approximately 1.3 metres above the ground.

The measurement of morphological characteristics, the observation of plants as research objects and the measurement of environmental conditions of physicochemical factors were carried out using the puposive sampling technique. This technique was carried out by determining the sampling site in the forest area of the Unesa campus, divided into several observation points. Meanwhile, the analysis of chlorophyll content in plants and measurement of leaf surface area was carried out at the IsDB laboratory, Faculty of Mathematics and Natural Sciences, Surabaya State University.

Data Collection Technique

Primary and secondary data were collected in this study. The primary data collected in this study were tree diameter at breast height (DBH), leaf chlorophyll content of Fabaceae plants, and environmental condition data.

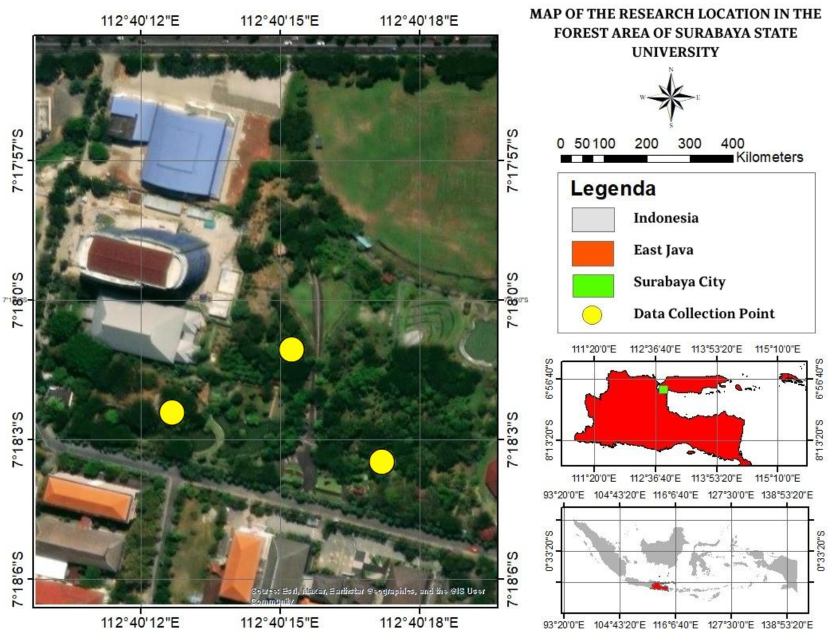

Figure 1. The research location
(Source: Google Earth, 2024)

Secondary data in this study consisted of wood specific gravity data obtained from global wood density databases (Chave et al. 2009). The first stage involved the introduction of tree species names obtained from direct findings in the field, followed by the identification of morphological characteristics of plants and identification based on these characteristics using identification keys, namely the Flora of Java book (Backer & Brink, 1963) and the Flora book (Steenis, 2006), along with the measurement of environmental conditions in terms of physicochemical factors).

The next step was to measure tree biomass using a non-destructive method, namely estimating tree volume without harvesting. Tree volume was estimated by measuring the diameter of the trunk at breast height (DBH) or approximately 1.3 m above the ground. Tree biomass was measured using the Kettering allometric equation (Kettering et al. 2001).

$$B = 0{,}11 \times \rho \times DBH^{2{,}62}$$

Note:

B : Tree/plant biomass (kg).

ρ : Specific weight of wood ($g.cm^{-3}$).

DBH : Diameter at breast height or 1.3 metres above ground (cm).

Once the plant biomass has been calculated, the carbon stock was calculated by multiplying the total tree biomass by a general carbon conversion factor of 0.46 (Hairiah et al., 2011).

The formula used was:

$$\text{Stok Karbon (kg)} = W \times 0{,}46$$

Note:

W : Total biomass (kg)

This carbon stock indicates how much carbon is stored in the tree biomass. The classification of high and low tree carbon stocks uses the classification of Dahlan (2008) with categories (units in kg C tree-year-1):

VL (Very Low) < 9.99

L (Low) 10 - 49.9

Md (Medium) 50-149

H (High) 150-500

VH (Very High) 500-1000

EH (Extra High) >1000

Afterward, clorophyll content was determined by weighing 1 g of leaves from each plant sample, cutting the leaves into small pieces, and grinding them in a porcelain mortar until smooth. The fine leaves were extracted by adding 100 ml of 95% alcohol and filtered to obtain the filtrate. If the filtrate obtained was less than 100 ml, 95 % alcohol was added until the volume was close to 100 ml. The chlorophyll content was measured using a spectrophotometer at wavelengths of 649 nm and 665 nm to determine the optical density (Pratiwi & Rachmadiarti, 2021).

Chlorophyll a :13.7 x (OD665) – 5.67 x (OD649)

Chlorophyll b :25.8 x (OD649) – 7.7 x (OD665)

Total Chlorophyll :20.0 x (OD649) + 6.1 x (OD665)

Data analysis

The data obtained, including tree morphological and physiological characteristics, biomass, and carbon stocks, were then analyzed using descriptive statistics and the Pearson correlation test to determine the relationship between tree morphological and physiological characteristics and carbon stocks in Fabaceae family trees in the Universitas Negeri Surabaya Campus Forest Area.

RESULTS AND DISCUSSION

Morphological Characterisation

Based on the survey and identification results, four species from the Fabaceae family, comprising a total of 52 individual trees, were identified in the campus forest area of Universitas Negeri Surabaya. These species include *Tamarindus indica* L., *Delonix regia*, *Gliricidia sepium*, and *Leucaena leucocephala*. The morphological characteristics of these species are summarized in Table 1.

The data reveal significant morphological variation among the species. *Tamarindus indica* L. exhibits the largest stature with the greatest trunk diameter and leaf area, while *Leucaena leucocephala* has the smallest measurements. Tree stature (encompassing height and trunk diameter) plays a crucial role in biomass accumulation and, consequently, carbon storage (Zhang et al., 2025). Similar findings were reported by Yuan et al., (2021), who emphasized that larger diameter trees contribute disproportionately to forest carbon stocks due to their higher wood density and extensive canopy structure (Putri & Dharmo, 2018).

Morphological traits such as trunk circumference and height are critical predictors of aboveground biomass because the stem serves as the primary carbon storage organ, mainly composed of lignin and cellulose, both rich in carbon (Rodrigues et al., 2023). The compound leaves of Fabaceae species enhance photosynthetic efficiency and support accelerated growth rates, thereby influencing biomass productivity (Mensah et al., 2023). This structural advantage explains the high carbon storage capacity observed in *Tamarindus indica* L., which combines large stature with broad leaf area and dense canopy coverage.

Physiological Characterisation

Physiological analysis focused on chlorophyll content, an important determinant of photosynthetic efficiency. The results of physiological characterisation in the form of chlorophyll content test of Fabaceae family trees, namely chlorophyll a, chlorophyll b, and total chlorophyll content (mg/l) presented in Table 2. These measurements describe the physiological characteristics of Fabaceae family trees in the campus forest area of Universitas Negeri Surabaya. The highest total chlorophyll content was found in *Tamarindus indica* L. tree species with total chlorophyll of 33.15 mg/l, while the lowest total chlorophyll content was found in Leucaena leucoceph*ala* tree species with total chlorophyll of 22.08 mg/l (Table 2).

According to Uthbah et al. (2017), forest biomass and carbon stocks are strongly influenced by plant physiological processes, particularly photosynthesis. The rate of photosynthesis in a stand is correlated with chlorophyll content, the number of stomata per unit leaf area, and the age of the stand. A larger leaf area enhances the ability of the stand to absorb carbon dioxide (CO_2). This suggests that physiological parameters and leaf structure play an important role in the efficiency of carbon sequestration in forest ecosystems (Fauziah, 2021).

Based on the results of chlorophyll levels in Fabaceae family trees in the Unesa campus forest area (Table 2), the average total chlorophyll in *Tamarindus indica* L. is higher than in Leucaena leucocephala. Chlorophyll plays an important role in regulating the efficiency of solar energy absorption to support biomass growth and carbon storage. In this case, species with high chlorophyll levels, such as *Tamarindus indica* L., have greater potential to contribute to carbon stocks, in line with research showing that chlorophyll levels are positively correlated with photosynthetic rates and biomass accumulation. Meanwhile, lower chlorophyll levels in *Leucaena leucocephala* may reflect adaptive responses to certain environmental stresses, such as low light intensity or unfavourable soil conditions.

Table 1. Morphological characteristics of Fabaceae family trees in universitas Negeri Surabaya campus forest area

Species Name	Mean Plant Height (cm^2) ± sd	Mean Stem Circumference (cm^2) ± sd	Mean Stem Diameter (cm^2) ± sd	Mean Leaf Area (cm^2) ± sd
Tamarindus indica L.	627 ± 200	92 ± 21	29 ± 7	98 ± 19
Delonix regia	577 ± 203	75 ± 21	24 ± 7	97 ± 22
Gliricidia sepium	485 ± 82	69 ± 4	22 ± 1	82 ± 29
Leucaena leucocephala	384 ± 98	42 ± 23	13 ± 7	71 ± 12

Table 2. Physiological characteristics of Fabaceae family trees in Universitas Negeri Surabaya campus forest area

Species Name	Chlorophyll a (mg/l) ± sd	Chlorophyll b (mg/l) ± sd	Total Chlorophyll (mg/l) ± sd
Tamarindus indica L.	19.46 ± 3.20	10.43 ± 3.59	30.04 ± 6.55
Delonix regia	12.87 ± 6.05	10.06 ± 3.20	23.03 ± 6.61
Gliricidia sepium	12.58 ± 2.84	8.38 ± 4.32	21.05 ± 2.73
Leucaena leucocephala	10.23 ± 3.00	10.07 ± 8.00	20.38 ± 5.62

Table 3. Biomass, carbon stock, and carbon stock value category of Fabaceae family trees in Universitas Negeri Surabaya Campus Forest Area

Species Name	Biomass per species ($kg.tree.^{-1}.year^{-1}$) ± sd	Carbon Stock ($kg\ C.tree^{-1}.year^{-1}$) ± sd	Category*
Tamarindus indica L.	1093.09 ± 696.22	502.82 ± 320.26	Very High
Delonix regia	233.16 ± 178.66	107.26 ± 78.32	Medium
Gliricidia sepium	204.07 ± 30.02	93.87 ± 48.51	Medium
Leucaena leucocephala	130.36 ± 175.86	59.96 ± 26.99	Medium

Note (*): Dahlan (2008) Classification of high and low carbon stock categories:
VL (Very Low) < 9.99
L (Low) 10 - 49.9
M (Medium) 50-149
H (High) 150-500
VH (Very High) 500-1000
EH (Extra High) >1000

Table 4. Pearson Correlation Test Results of Morphological Characteristics and Physiological Characteristics with Carbon Stocks Stored in Fabaceae Family Trees in Universitas Negeri Surabaya Campus Forest Area

Parameter	Pearson Correlation Coefficient*	Sign.
Height	0.299	0.031
Circumference	0.772	0.000
Diameter	0.772	0.000
Parameter	Pearson Correlation Coefficient*	Sign.
Leaf area	-.388	0.004
Klorofil content	0.773	0.003

Note:
Significance value <0.05 = correlated
Significance value > 0.05 = not correlated
(*) Degree of Relationship
Pearson Correlation Coefficient Value:
0 = No Correlation
0.20-0.40 = Weak Correlation
0.41-0.60 = Moderate Correlation
0.61-0.80 = Strong Correlation
0.81-1 = Perfect Correlation

Differences in chlorophyll levels are influenced by leaf area, environmental conditions such as light intensity, soil moisture, and the availability of nutrients around the tree. In terms of physiological characteristics, leaf chlorophyll levels reflect the ability of plants to absorb solar energy and convert it into chemical energy. Carbon dioxide plays a critical role in the process of photosynthesis in plants. In photosynthesis, plants use carbon dioxide and water to produce sugars and oxygen for food.

Carbon stock Estimation

The results showed that the biomass and carbon stock values of each tree species of the Fabaceae family in the campus forest area varied considerably , presented in Table 3.

The carbon stock of a plant can be determined by measuring the amount of carbon stored in the biomass of living plants. The measurement reflect the ability of a particular plant species to absorb and store CO_2 from the atmosphere, providing an indication of its contribution to reducing carbon emissions and mitigating climate change. The carbon stock stored in the trees of the Unesa campus forest, which covers an area of 4.46 hectares, is 992.79 kg/ha, with a total biomass of 2158.25 kg/ha. Based on the research results shown in Table 3, the *Tamarindus indica* L. is a tree that has the highest carbon stock compared to trees of other Fabaceae families growing in the Unesa campus forest area. A total of 27 tamarind trees are able to store carbon up to 503.49 kg C tree-^{1} year-^{1}.

The high carbon stock in *Tamarindus indica* L. aligns with its superior morphological traits, particularly trunk diameter and canopy size. Previous studies confirm that tree diameter at breast height (DBH) is the strongest predictor of carbon storage across forest ecosystems (Chave et al., 2014; Poorter et al., 2015). Large trees contribute disproportionately to carbon storage, even in fragmented or urban forest landscapes (Lutz et al., 2018).

The tamarind tree (*Tamarindus indica* L.) is a productive species with a carbon sequestration function. This condition is influenced by the environmental conditions around the tree, those located on the road dividers, has lush foliage and a large trunk diameter, enabling greater carbon absorption and storage in the form of biomass (Febrianti., 2023). This observation aligns with the Minister of Public Works' Regulation No: 05/PRT/M/2012, on guidelines for planting trees on the road network system, which recommends tamarind trees as medium-sized trees suitable for reducing pollutants , such as carbon dioxide (Chave et al., 2014).

The amount of carbon stored in a stand varies from plant to plant, which is influenced by species and specific gravity (wood density) (Isnaeni et al., 2019). Hartoyo et al. (2018) explained that carbon stocks in a vegetation represent the capacity of the vegetation to absorb and store carbon in the form of vegetation biomass. Consequently, both vegetation biomass and tree size are key factors determining the carbon storage capacity of a tree.

Relationship Between Morphological and Physiological Traits with Carbon Stock

The Pearson correlation analysis (Table 4) indicates strong positive correlations between carbon stock and stem circumference ($r = 0.772$, $p < 0.001$), stem diameter ($r = 0.772$, $p < 0.001$), and chlorophyll content ($r = 0.773$, $p = 0.003$). Conversely, leaf area showed a negative correlation ($r = -0.388$), possibly due to species-specific traits and shade-adapted leaf morphology.

Based on statistical tests carried out using the Pearson's test, the relationship between the two variables and carbon stocks has a positive correlation; higher value of morphological and physiological characteristics in Fabaceae family trees correspond to greater carbon stock in the Unesa Campus forest area (Table 4). Morphological characteristics have the greatest influence on the ability of plants to absorb and store carbon as upper surface biomass, especially stems (Castanho et al., 2020). This is due to the stem, which is the woody part and a storage site for food reserves derived from photosynthesis (Afra et al., 2024). Trees use photosynthesis to produce energy by absorbing carbon from the environment.

These findings corroborate previous studies by Poorter et al., (2015) and Joshi & Garkoti (2025), which demonstrated that tree size parameters, such as DBH and height, are the most reliable predictors of aboveground biomass. Additionally, the significant correlation between chlorophyll content and carbon storage confirms the link between physiological efficiency and carbon assimilation (Joshi & Garkoti, 2025).

Nedhisa et al. (2020) reported that 45-50% of plant biomass is composed of carbon. Plants, through the mechanism of photosynthesis, absorb CO^2 from the

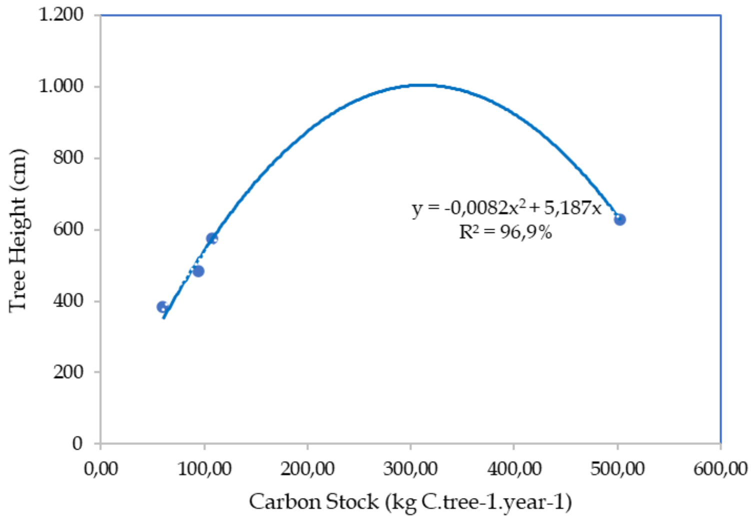

Figure 2. Relationship Between Tree Height and Carbon Stock

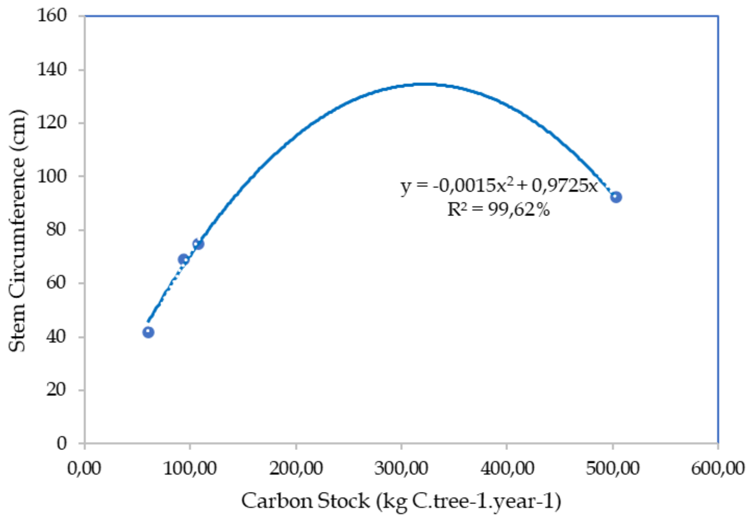

Figure 3. Relationship Between Stem Circumference and Carbon Stock

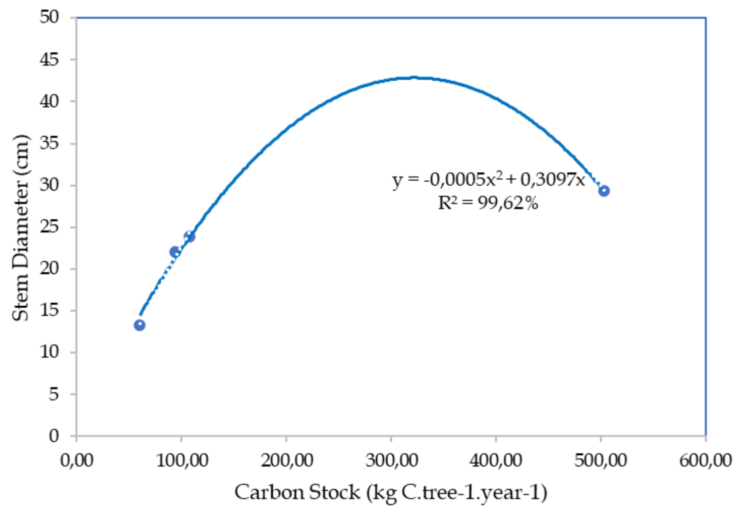

Figure 4. Relationship between stem diameter and carbon stock

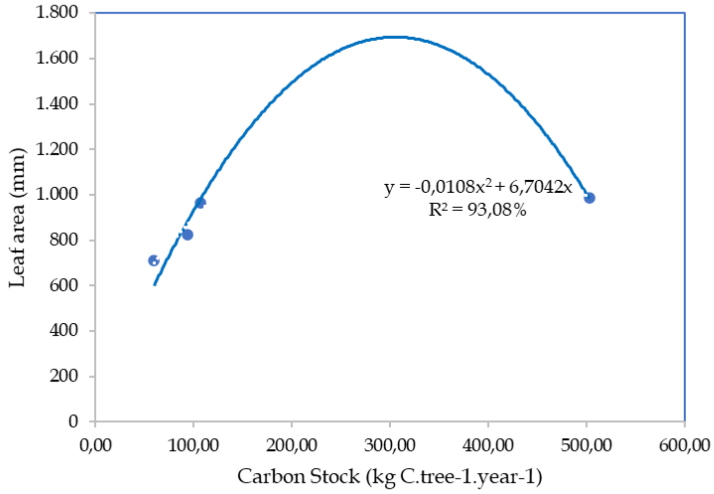

Figure 5. Relationship between leaf area and carbon stock

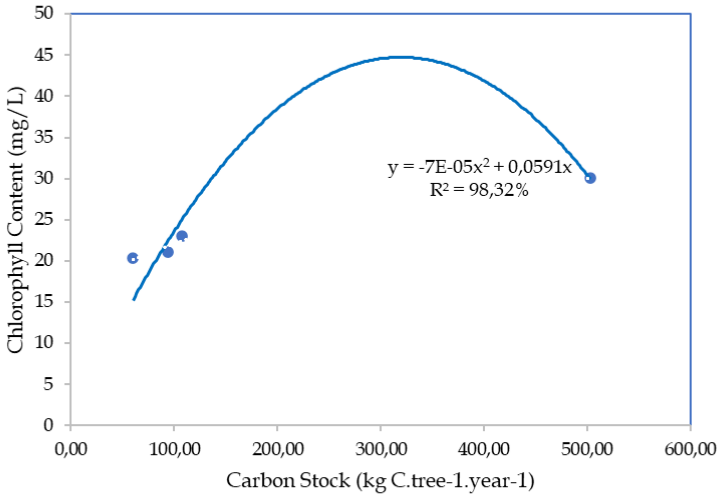

Figure 6. Relationship between chlorophyll content and carbon stock

air through their leaves, then convert it into organic carbon and the results are distributed and converted into biomass such as trunks, branches, leaves, roots and so on. Therefore, the higher the biomass value of a tree, the higher the carbon storage. According to (Dharma et al., 2025), the high carbon content in tree trunks is due to carbon, which is the main element in the composition of wood. Wood is composed of compounds, such as hemicellulose, cellulose, and lignin, with carbon being the predominant element. This component plays an important role in determining the ability of wood to store carbon (Pan et al., 2024). This is in line with the opinion of Manibuy et al. (2021), who demonstrated that tree biomass has a linear geometric relationship with tree diameter, wood specific gravity, and tree height.

The plant species found in the forest area of the Unesa campus are generally dominated by parboreal members of the Fabaceae family, characterized by robust stem structures, abundant foliage, tolerance to extreme environmental conditions, and rapid growth in open areas, making this family group the recommended plant group for planting (Weissgerber et al., 2024). In addition to the morphological characteristics of the plants, the high amount of carbon stored in the form of biomass is also influenced by several other factors, such as species diversity, wood density, environmental conditions, and tree age, and is highly dependent on the physiological process of the plants, particularly photosynthesis (Nulik & Gabb., 2013).

Other factors that affect tree biomass are environmental conditions, such as light intensity and temperature. Fauziah (2021) explined that sunlight plays an important role in photosynthesis and other physiological processes of plant, such as respiration, growth, development, stomatal regulation, germination and metabolism .

Therefore, the availability of light is the main factor that determines the level of productivity of a plant. Factors that can affect the size of a tree's diameter include the intensity of light absorbed by the tree. The density of the wood affects the amount of light that reaches the vegetation (Yu et al., 2023). Trees that absorb little sunlight tend to grow slowly, resulting in a small trunk diameter; on the other hand, light intensity can also affect cell enlargement and differentiation, which affects height growth, leaf size, leaf and stem structure (Nuraini et al., 2021).

According to Naz's (2022), soil pH also indirectly affects carbon stocks by influencing the availability of nutrients such as nitrogen (N) and potassium (K). Nitrogen supports the formation of chlorophyll, which plays an important role in the photosynthetic process, while potassium is involved in biochemical processes, physiology, stress resistance, ATP synthesis, and the production of enzymes important for photosynthesis (Darlina et al., 2023). This aligns with Eriawati et al., (2025), who highlighted the ability of plants in the Fabaceae family to fix nitrogen from the air and store it in the roots through symbiotic relationships with certain bacteria. This ability contributes to improve soil fertility and increased productivity in dry environments (Ahmad et al., 2016).

According to the results of the study, Fabaceae plants in the campus forest area exhibit a high capacity to absorb and store carbon, averaging 213.96 kg C tree-^{1} year-^{1}. This capacity represents a mechanism for reducing atmospheric CO_2 levels, through the process of photosynthesis, during which carbon dioxide is absorbed by the leaves. The four tree species of the Fabaceae family thus contribute substantially to mitigating carbon concentrations in the atmosphere.

This capacity supports the achievement of SDG 13 (*Climate Action*), which aims to address climate change by reducing greenhouse gas emissions and enhancing resilience to its impacts. In addition, the contribution of Fabaceae plants to carbon sequestration is closely linked to SDG 15 (*Life on Land*), which focuses on the conservation of terrestrial ecosystems, sustainable forest management, and restoration of degraded land. Integrating Fabaceae species in urban forest management aligns with global efforts for nature-based solutions and urban resilience strategies (Seddon et al., 2021). Therefore, the conservation of Fabaceae plants not only contributes to climate change mitigation, but also enhances ecosystem sustainability , improves environmental quality, and ensures the preservation of natural resources for future generations.

CONCLUSION

The morphological characteristics of Fabaceae family trees in the Universitas Negeri Surabaya campus forest area include an average tree height of 518 cm, an average trunk circumference of 70 cm, an average trunk diameter of 22 cm, and an average leaf area of 871 mm^2. Physiological characteristics of Fabaceae family trees in Surabaya State University campus forest area include total chlorophyll content with an average of 24 (mg/l). The ability of Fabaceae family trees in the Surabaya State University campus forest area to store carbon stocks varies, and the average carbon stock storage of Fabaceae family trees in the Surabaya State University campus forest area is 213.96 kg C tree-^{1} year-^{1}. The relationship between morphological characteristics (tree stature, stem condition, and leaf area) and physiological characteristics (leaf chlorophyll content) with carbon stocks in Fabaceae family trees is positively correlated, which means that the higher the value of both morphological characteristics and physiological characteristics, the higher the carbon stock stored in trees of the Fabaceae family in Universitas Negeri Surabaya campus forest area.

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