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CARBON STOCK AND CO_2 SEQUESTRATION POTENTIAL OF *Terminalia mantaly* AS A CONSERVATION EFFORT IN THE CAMPUS FOREST OF THE STATE UNIVERSITY OF SURABAYA

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ABSTRACT: Carbon stocks in campus forests play an important role in maintaining ecosystem balance and supporting climate change mitigation. This study aims to analyze the biomass, carbon stock, and carbon sequestration of *Terminalia mantaly*, along with the contributing factors that influence them. This research employed a non-destructive measurement with purposive sampling. The relationship among variables was analyzed using pearson correlation. The result showed that the highest biomass, carbon stock, and CO_2 sequestration values were found at station 2 with sequential sizes of 187.29 kg; 88.02 kg; 323.05 kg. The results of the correlation analysis indicate that carbon stock has a strong and significant positive correlation with diameter, biomass, and CO_2 uptake ($r = 0.94$, $r = 1$, and $r = 1$, respectively). Leaf area showed a strong but non-significant correlation ($r = 0.73$). Meanwhile, no significant correlations were found between tree height and leaf chlorophyll content and carbon stock ($r = 0.20$ and $r = 0.38$, respectively). These findings indicate that *Terminalia mantaly* has the potential to serve as a carbon sink and CO_2 sequester, particularly in the Surabaya State University Campus Forest.

Keywords: Biomass, Carbon, Diameter, Environmental Restoration.

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INTRODUCTION

The world's forests are one of the largest ecosystems and play a vital role in maintaining the global environmental balance. Forests serve as habitats for millions of plant and animal species on Earth. The role of the world's forests influences global climate change by affecting the Earth's surface temperature and altering the atmosphere through soil moisture patterns (Psistaki et al., 2024). Indonesia's forests play a crucial role in the global carbon cycle by absorbing atmospheric CO_2 and storing it in biomass, thereby contributing to ecosystem stability and climate regulation (Shafitri et al., 2018). However, deforestation continues to occur reducing forest area and carbon stronge capacity (Ramadhany et al., 2023). This situation is generally driven by land-use conversion for plantations, mining, settlements, infrastructure, and agriculture. Consequently, forest areas are

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shrinking, threatening the survival of various living organisms, and increasing carbon emissions that could potentially trigger global warming.

This rise in emissions can be attributed to greenhouse gases in the atmosphere and carbon dioxide (CO_2) (Rahmawati & Robertus, 2023). Climate change causes shifts in rainfall patterns, frequency, and weather distribution, and impacts the lives of living organisms (Heshmati, 2016). One important approach to mitigating these impacts is through forest conservation and management, as forests have significant potential for carbon sequestration. Through photosynthesis, plants absorb atmospheric CO_2 and store it as organic carbon in above- and below-ground biomass, contributing substantially to carbon storage in terrestrial ecosystems (Murphy, 2024). Urban forests can be a solution for reducing air pollution and absorbing carbon through tree biomass. In Indonesia, urban green spaces, including urban forests, have been developed in several cities such as Surabaya to support environmental sustainability (Syaputri & Suryawati, 2021).

One forest that plays a strategic role in Surabaya is the University of Surabaya (UNESA) Campus Forest. This forest makes a significant contribution to environmental sustainability, particularly in the city of Surabaya. The UNESA Campus Forest spans ± 759.333 m^2 and is located on the Lidah Wetan Campus. This area functions as an urban green space with potential for carbon sequestration through vegetation biomass. Various types of plants have been cultivated in the UNESA Campus Forest, ranging from citrus and mango trees to flowering trees. Identification results indicate the presence of more than 65 plant species in the UNESA Campus Forest, which contribute to absorbing and storing carbon as part of climate change mitigation efforts (Rachmadiarti, 2024). One plant species that plays a role in carbon storage is *Terminalia mantaly.* The main advantage of this plant is its high adaptability due to its rapid growth, which is why it is widely found in various regions, particularly in tropical areas. This plant plays a role in absorbing carbon dioxide, producing oxygen, and absorbing water during the rainy season through root absorption via osmosis. Additionally, it provides shade and improves climate conditions (Wakawa et al., 2022). Therefore, this plant is highly promising for further research, particularly regarding its role in carbon sequestration.

Previous research on carbon stocks has been conducted. A study by (Darlina et al., 2023) reported that there are 33 plant species acting as carbon reservoirs and carbon sinks in Maluku Park, Bandung, one of which is *Terminalia mantaly*, which showed an estimated carbon stock of 0.940 tons and an estimated carbon uptake of 3.448 tons. Meanwhile, a similar study was also conducted by Kurniawan et al. (2023) on carbon stocks found in the government office complex of Sleman Regency. The study identified 38 plant species, one of which was *Terminalia mantaly*, which contributed 3,036.97 kg of carbon stock. However, these studies focus solely on estimating carbon stocks without taking into account morphological and physiological factors such as chlorophyll content, leaf area, and environmental parameters that support plant growth. Information regarding research focused on *Terminalia mantaly* as a carbon sink and carbon reservoir at the species level remains limited, particularly in the Surabaya State University Campus Forest. Therefore, this study can help fill that gap and serve as a foundation for future researchers.

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Based on the background described above, this study aims to analyze the biomass, carbon stock, and carbon sequestration of *Terminalia mantaly*, along with the contributing factors that influence them. This study serves as a contribution to the environmental restoration of the Campus Forest, in alignment with the global Sustainable Development Goals (SDGs), particularly SDG 11 on sustainable development, SDG 13 on climate action, and SDG 15 on terrestrial ecosystems.

METHODS

Sampling Time and Location

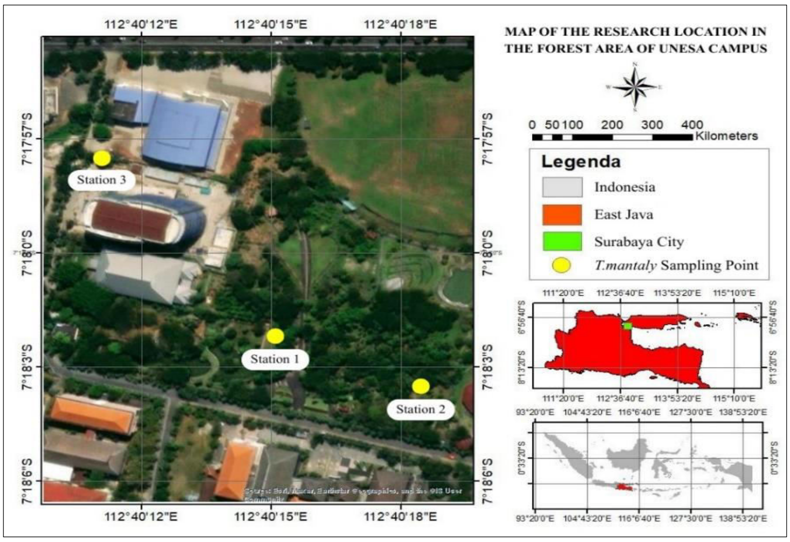


Figure 1. Research Location in Surabaya State University Campus Forest Lidah Wetan.

This research was conducted in the Campus Forest area of Surabaya State University, located on Jalan Kampus Unesa Lidah Wetan, Lakarsantri District, Surabaya, East Java. The coordinates are -7.30º South Latitude and 112.67º East Longitude. Sampling was conducted in the Campus Forest area of Unesa Lidah Wetan, and chlorophyll content analysis was conducted at the IsDB Laboratory, Faculty of Mathematics and Natural Sciences, Surabaya State University, from September 2024 to October 2024.

Tools and Materials

The tools used in this study were Erlenmeyer flasks, measuring cylinders, measuring tapes, mortars, pestles, funnels, filter paper, a soil thermometer, a soil tester, a lux meter, an air meter, a Mapada V-110D spectrophotometer, and an ADC AM350 Leaf Meter. The materials required for this study were leaf samples and 96% alcohol.

Data Capture Design

This study employed a purposive sampling method, which researchers use when they have specific considerations in sampling or when determining a sample for a specific purpose (Santina et al., 2021). Data were collected from three different stations. The first station was located furthest from the main road, the second station was at a moderate distance, and the third station was located closest to the main road.

Data Collection Technique

Tree Diameter and Height Measurement

The parameters used in the study included measuring tree height and diameter using a non-destructive method. Tree height measurements were performed using the Measure application, which utilizes augmented reality (AR) technology on smartphones. Tree circumference is measured at a height of 1.3 m above ground level and converted to diameter at breast height (DBH). The results of the tree circumference measurement can be used to determine the diameter based on (Royal Forestry Society, 2021):

$$\text{Diameter} = \text{Circumference} / \pi$$

Tree Biomass Measurement

Tree biomass was estimated using an allometric equation for tropical trees developed by (Ketterings et al., 2001) which uses the following equation:

$$BK = 0.11 \times \rho \times D^{2,62}$$

Description:
BK= Tree biomass (kg);
D = Tree Diameter at breast height (cm); and
ρ = Specific gravity of wood (gr/cm^3), The specific gravity of wood is obtained from Indonesian Wood Atlas or Global Wood Density Data.

Carbon Stock and CO_2 Sequestration Analysis

Carbon stock analysis uses a formula that involves biomass. Measurement of carbon stock estimation can use the following formula (SNI 7724, 2011):

$$C = Y \times 47\%$$

Description:
C = Carbon stock (kg); and
Y = Total biomass.

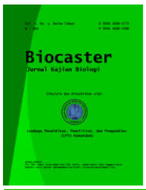
0.47 which is a conversion factor of international standards for estimating carbon or using the percent carbon value obtained from measurements in the laboratory. Next, to estimate CO_2 absorption, one can use the relative atomic mass of carbon (Fu et al., 2020), which can be determined using the following formula:

$$CO_2 = Cn \times 3,67$$

Description:
Cn = Amount of carbon in biomass; and
3,67 = Equivalent or conversion number of element C to CO_2.

Chlorophyll Analysis

Chlorophyll content testing utilizes a Mapada V-1100D spectrophotometer. A 0.1 gram leaf sample is taken, then crushed in a mortar and 1 ml of 96% alcohol solvent is added. The resulting extract is filtered using filter paper through a funnel to obtain a clear filtrate. The filtered solution is then placed in a cuvette, and its absorbance is measured using a spectrophotometer at wavelengths of 649 nm and 665 nm. The absorbance measurement results are then converted into mg/L using



the following Wintermans de Mots formula: 1) Chlorophyll Total (mg/L) = (20 x OD649 + 6,1 x OD645); 2) Chlorophyll a (mg/L) = (13,7 x A665) – (5,67 x A649); and 3) Chlorophyll b (mg/L) = (25,8 x A649) − (7,7 x A665). The data were then analyzed quantitatively on the chlorophyll content in the leaves at each station.

Leaf Area Measurement

Leaf area measurements are performed using an ADC AM350 leaf meter. The leaf to be measured is placed unfolded on the surface of the Leaf Area meter, then the scanner button is pressed and moved from top to bottom. The measurement results are automatically displayed on the instrument's screen in cm^2.

Environmental Parameter Measurement

Environmental parameter measurements involve various factors, including soil and air parameters. Soil parameters are measured using a soil tester to determine soil moisture and pH, and a thermometer to measure soil temperature. Additionally, air parameters are measured using a lux meter to determine light intensity, and an air meter to measure temperature, humidity, and CO_2 concentration in the air.

Data Analysis

Data from carbon stock, biomass, diameter, chlorophyll content, and leaf area were analyzed using descriptive statistical tests, namely the Pearson Correlation Test to determine the relationship between tree morphological and physiological characteristics such as carbon stock and biomass, diameter, CO_2 sequestration, height, chlorophyll content, and leaf area (Rohmah & Rachmadiarti, 2025).

RESULT AND DISCUSSION

Based on the research results, data on diameter, biomass, carbon stock, and CO_2 uptake at the three stations were obtained, as presented in Table 1. The research results presented in Table 1 show that the biomass, carbon stock, and CO_2 sequestration capacity of *Terminalia mantaly* vary across stations. These differences are related to the number and size of trees at each location. Station 1 has 15 trees with medium to large diameters, Station 2 has 17 trees with large diameters, while Station 3 has 18 trees that are generally small in diameter.

Tabel 1. Average and Standard Deviation of Height, Diameter, Biomass, Carbon Stock, and CO_2 Sequestration in *Terminalia mantaly* in the Unesa Campus Forest Area.

Station	Height (m)	Circumference (cm)	Diameter (cm)	Bimass (kg)	Carbon Stock (kg)	CO_2 Sequestration (kg)
1	13.1	47.05	14.98	148.53 ± 175.09	69.81 ± 82.29	256.19 ± 302.01
2	7.1	63.38	20.19	187.29 ± 98.52	88.02 ± 46.30	323.05 ± 169.94
3	9.5	33.67	10.72	40.36 ± 31.64	18.97 ± 14.87	69.63 ± 54.57
Total	29.7	144.1	45.89	376.18	176.8	648.87

Biomass, carbon stocks, and CO_2 uptake showed consistent variation across all stations, with the highest values recorded at Station 2, followed by Station 1, and the lowest at Station 3. Specifically, these values were as follows: biomass (187.29

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kg; 148.53 kg; and 40.36 kg), carbon stock (88.02 kg; 69.81 kg; and 18.97 kg), and CO_2 uptake (323.05 kg; 256.19 kg; and 69.63 kg). The biomass value of a plant can indicate the amount of stored carbon. The biomass at Station 2 was the highest compared to the other stations. The high biomass at that station may be influenced by the large tree diameter. Any increase in biomass content is accompanied by an increase in carbon content resulting from the absorption of CO_2 from the atmosphere, which is then stored as biomass distributed throughout the plant, thereby increasing the plant's diameter and height (Lodjo et al., 2023).

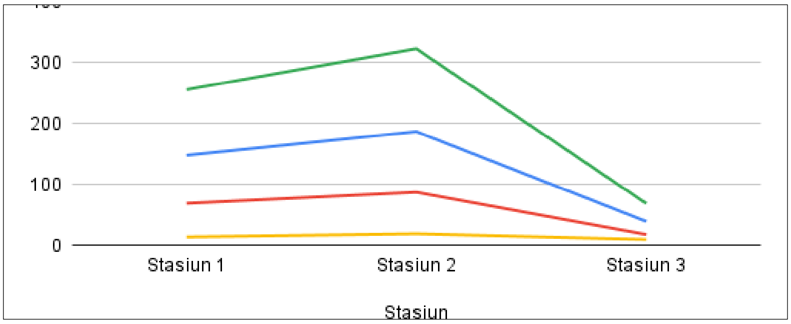

Figure 2. Graph Showing the Relationship between Biomass, Carbon Stock, and Diameter in *Terminalia mantaly* Trees.

Graphs of biomass, carbon stock, diameter, and CO_2 uptake of *Terminalia mantaly* trees at three observation stations show consistent patterns across these parameters. The highest values for biomass, carbon stock, diameter, and CO_2 uptake were recorded at Station 2, indicating the most optimal tree growth conditions compared to the other stations. The large trunk diameter at this station directly contributes to the high biomass, thereby increasing the tree's capacity to store carbon and absorb CO_2. In contrast, Station 1 exhibits moderate values across all parameters, suggesting suboptimal yet stable growth conditions, while Station 3 shows the lowest values, indicating limited growth performance and reduced carbon storage potential.

Figure 2 shows that diameter and biomass increase linearly with increasing carbon storage. Meanwhile, the highest CO_2 uptake was also observed at Station 2; this may be due to the fact that high biomass and carbon stock values can enhance CO_2 uptake capacity (Santoso, 2021). Some of the carbon absorbed by plants is used to support physiological processes, while the rest is stored as cellulose in leaves, twigs, branches, stems, and roots (Trissanti et al., 2022). Additionally, the longer the tree's growth period, the greater the biomass and carbon stock produced due to CO_2 uptake from the atmosphere through photosynthesis (Sardi et al., 2021).

Stored carbon stock values can be classified into several categories: high, moderate, and low. The carbon stock of *Terminalia mantaly* at Station 1 was 69.81 kg, and at Station 2 it was 88.02 kg. Based on Dahlan's classification, the results at Station 1 and Station 2 fall into the moderate carbon stock category. Meanwhile, at Station 3, a carbon stock value of 18.97 kg was obtained, which falls into the low category. However, compared to previous studies, the results of this study are significantly higher. In a previous study conducted by Haruna (Haruna, 2020), the results for biomass, carbon stock, and carbon sequestration were 0.07 kg, 0.03 kg, and 0.13 kg, respectively. Thus, based on these results, the values for biomass, carbon stock, and carbon sequestration in this study tend to be higher than those in the previous study.

Table 2. Correlation Results between Carbon Stock, Biomass, and Diameter of *Terminalia mantaly* in the Unesa Campus Forest Area.

Description	Pearson Correlation	Sig
Carbon Stock	1	0.00
Height	0.20	0.30
Diameter	0.94	0.00
Biomass	1	0.00
CO_2 Sequestration	1	0.00

The correlation results in Table 2 show that carbon stock has a very strong and significant correlation with biomass ($r = 1$; $p < 0.001$) and tree diameter ($r = 0.94$; $p < 0.001$). This results suggest that increases in biomass and diameter are directly associated with higher carbon stock. As tree biomass increases, the carbon content in the trees also rises, accompanied by carbon uptake. Biomass represents the amount of carbon stored within the plant body, a process known as carbon sequestration (C-sequestration) (Wulandari, 2020). Conversely, tree height has only a weak and insignificant correlation ($r = 0.20$; $p = 0.30$). Thus, carbon storage in *Terminalia mantaly* is more influenced by biomass and stem diameter than by tree height.

Table 3. Mean Results and Standard Deviations of Chlorophyll Tests on the Leaf Base, Middle Leaf, and Apical Leaf Sections of *Terminalia mantaly* in the Unesa Campus Forest Area.

Station	Leaf Section	Pigmen Type	Chlorophyll (mg/L)
Station 1	Leaf base	Chlorophyll A	25.57 ± 1.69
		Chlorophyll B	12.75 ± 0.96
		Total Chlorophyll	38.51 ± 1.00
	Middle leaf	Chlorophyll A	21.72 ± 3.87
		Chlorophyll B	10.80 ± 2.50
		Total Chlorophyll	37.06 ± 1.67
	Apical leaf	Chlorophyll A	20.09 ± 5.07
		Chlorophyll B	9.61 ± 3.40
		Total Chlorophyll	29.86 ± 8.00
Station 2	Leaf base	Chlorophyll A	27.54 ± 0.82
		Chlorophyll B	20.46 ± 4.42
		Total Chlorophyll	48.06 ± 4.98
	Middle leaf	Chlorophyll A	19.64 ± 8.28
		Chlorophyll B	18.13 ± 6.99
		Total Chlorophyll	37.91 ± 1.52
	Apical leaf	Chlorophyll A	19.21 ± 8.34
		Chlorophyll B	14.32 ± 2.14
		Total Chlorophyll	33.68 ± 6.64
Station 3	Leaf base	Chlorophyll A	24.99 ± 2.63
		Chlorophyll B	15.16 ± 4.56
		Total Chlorophyll	40.33 ± 7.21
	Middle leaf	Chlorophyll A	20,00 ± 2.39
		Chlorophyll B	10.52 ± 1.97
		Total Chlorophyll	30.67 ± 4.37

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Station	Leaf Section	Pigmen Type	Chlorophyll (mg/L)
	Apical leaf	Chlorophyll A	15.79 ± 3.47
		Chlorophyll B	7.77 ± 1.71
		Total Chlorophyll	23.68 ± 4.80

Based on Table 3, the highest chlorophyll a concentration in the basal leaf section was recorded at Station 2, at 27.54 mg/L. In the middle leaf section, the highest chlorophyll a concentration was found at Station 1, at 21.72 mg/L, while in the apical leaf section, the highest value was also found at Station 1, at 20.09 mg/L. The highest chlorophyll b concentration in the basal leaf section was recorded at Station 2 at 20.46 mg/L. In the middle leaf section, the highest chlorophyll b concentration was also found at Station 2 at 18.13 mg/L, while in the apical leaf section, the highest value was recorded at Station 2 at 14.32 mg/L.

Measurements of leaf chlorophyll content are used as a parameter to assess physiological characteristics. Chlorophyll levels can vary across different parts of the leaf due to several factors, such as the leaf's position or section; leaves at the base of the plant develop earlier and are older than those toward the tip. Chlorophyll plays a crucial role in absorbing blue and red light spectra during energy capture, transfer, and charge separation in photosynthetic reactions (Kolašinac et al., 2021). Chlorophyll a functions as a light-harvester and is the most efficient chlorophyll in absorbing light in the red and blue spectra, with peak absorption wavelengths of approximately 430–662 nm (Durrett & Welti, 2021). Chlorophyll b functions to absorb excess light from chlorophyll a and absorbs light in the blue-green spectrum with a peak absorption around 435 nm (Durrett & Welti, 2021). Meanwhile, total chlorophyll in photosynthesis functions as the primary pigment that captures light energy from the sun. Differences in chlorophyll content can be observed through variations in leaf color; the greener the leaf, the higher its chlorophyll content (Dharmadewi, 2020).

In addition, a decrease in the rate of photosynthesis also affects the high and low levels of chlorophyll content in leaves (Trissanti et al., 2022). There are differences in photosynthetic capacity among different leaf parts; the uppermost or terminal leaves have the poorest photosynthesis due to the incomplete development of photosynthetic organs, yet these terminal leaves play a role in elongation growth influenced by phototropism. Meanwhile, the middle leaves exhibit optimal photosynthetic capacity and are considered functionally active, while basal leaves are parts of the leaf with mature and fully developed photosynthetic apparatus, resulting in relatively high chlorophyll content (Zhang et al., 2020). This aligns with the data in Table 3, which shows that the basal leaf sections from each station have the highest chlorophyll content. Furthermore, as a plant grows, the rate of CO_2 uptake through photosynthesis exceeds that of respiration. Consequently, this helps reduce atmospheric CO_2 levels (Daud et al., 2021).

Table 4. Correlation Results between Carbon Stock and Leaf Chlorophyll Content in *Terminalia mantaly* in the Unesa Campus Forest Area.

Description	Pearson Corelation	Sig
Carbon Stock	1	0.05
Chlorophyll	0.38	0.05

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Table 4 shows that the Pearson correlation coefficient between carbon stock and leaf chlorophyll content is r = 0.38 with a significance value of p = 0.05, indicating a weak positive relationship. This indicates that an increase in chlorophyll content tends to be accompanied by an increase in carbon stock, although the relationship is not strong. It can be said that high chlorophyll levels have a weak correlation with carbon stocks.

This may be influenced by the fact that, in the process of photosynthesis, in addition to chlorophyll, there are also carotenoids that can optimize the photosynthetic process and are useful for carbon fixation and storage in plants (Maslova et al., 2021). Carotenoids also play a role in light absorption and photosynthetic rate by regulating carbon stocks (Kolašinac et al., 2021). This relationship maintains the stability of a healthy and productive ecosystem. These findings indicate that chlorophyll content contributes to carbon stock, but is not the primary factor, as it is still influenced by other factors.

Table 5. Average Results and Standard Deviations of Leaf Area at the Base, Middle, and Apical.

Station	Leaf base (Cm^2)	Middle Leaf (Cm^2)	Apical Leaf (Cm^2)
1	6.23 ± 0.75	5.20 ± 1.90	5.03 ± 0.50
2	7.47 ± 1.61	6.00 ± 0.50	5.60 ± 1.02
3	7.33 ± 2.75	5.70 ± 2.78	5.50 ± 1.19
Total	21.03	16.90	16.13

Based on the data presented in Table 5, the average leaf area measured at the base of each plant was the highest, at 21.03 cm². This was followed by the middle and the tip. These differences in leaf area may be influenced by the age, function, and photosynthetic capacity of each leaf section (Bielczynski et al., 2017). The basal part has larger leaves because the leaves in that region have reached full maturity, at which point cell division and expansion have ceased, resulting in the leaves reaching their maximum size. In contrast, the leaves at the apical region are still in the growth stage and have not yet undergone optimal cell expansion. The differences in leaf chlorophyll test results shown in Table 3 may be influenced by leaf surface area. According to Rahmadina (Rahmadina et al., 2022), there is a relationship between chlorophyll content and leaf area, such that as leaf area increases, so does the amount of chlorophyll produced. In this study, the leaves used for measurement were taken from the basal, middle, and apical parts of the plant. These differences in leaf location play a role in the leaf surface area results. *Terminalia mantaly* leaves are obovate or inverted egg-shaped.

Figure 3. The Base, Middle, and Tip of a *Terminalia mantaly* Leaf.

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As shown in Figure 3, the leaf area at the base of the leaf is larger than that of the middle and tip sections. This may be influenced by differences in age based on leaf position. Leaves located at the base are physiologically older than those toward the tip (Maleke et al., 2024). The larger leaf area is also influenced by greater sunlight reception. Light serves as an energy source in photosynthesis. An increase in leaf area allows for greater light absorption, enabling the photosynthesis process to occur more optimally (Seyedi et al., 2023). Sunlight exposure on leaves can influence their morphological growth, particularly regarding cell enlargement and differentiation (Zulkifli et al., 2022). Environmental changes can influence the formation of structures that, while morphologically similar, exhibit different variations in response to environmental stress (Ha Tran et al., 2024).

Table 6. Correlation between Carbon Stock and Leaf Area in *Terminalia mantaly* in the Unesa Campus Forest Area.

Description	Pearson Corelation	Sig
Carbon Stock	1	0.72
Leaf Area	0.73	0.72

Table 6 shows a strong positive relationship between carbon stock and leaf area in *Terminalia mantaly* in the Unesa Campus Forest area. A Pearson correlation coefficient of 0.73 indicates that an increase in leaf area tends to be followed by an increase in carbon stock, but the relationship is not consistent enough to be considered statistically reliable. The lack of significance implies that leaf area is not the primary factor influencing carbon stock in *Terminalia mantaly*. Leaf area is related to CO_2, an increase in leaf density can cause mesophyll cells to become compact and reduce the mesophyll surface area exposed to the intercellular air space, resulting in CO_2 diffusion resistance. Therefore, considering the leaf morphology of *Terminalia mantaly*, which has small leaves, it can be concluded that the leaves of *Terminalia mantaly* have the ability to reduce CO_2 emissions.

Table 7. Average Physicochemical Parameters and Standard Deviations for *Terminalia mantaly* in the Unesa Campus Forest Area.

Station	Air Parameters				Soil Parameters		
	Light Intensity (Lux)	Tempe-rature (C°)	Humidity (%)	CO_2 (ppm)	pH	Humidity (%)	Tempe-rature (C°)
1	9.860 ± 2556	30 ± 0	70.47 ± 0.51	428.47 ± 14.97	8 ± 0	41.60 ± 1.54	30 ± 0
2	9.078 ± 1652	32.06 ± 0.82	64.24 ± 3.86	497.53 ± 35.09	7.71 ± 1.46	30.59 ± 2.42	31.94 ± 1.39
3	12.651 ± 4050	31.61 ± 0.50	64.61 ± 2.19	538 ± 73.83	8 ± 0	32.22± 10.03	30.61 ± 0.50
Baku Mutu	5.500-20.000	25-35	30-35	<5.000	6-8	10-40	25-35

Source of quality standards: Kementrian Lingkungan Hidup dan Kehutanan.

Measurement of environmental parameters includes air and soil parameters. In air parameters such as Light Intensity, Temperature, Humidity, and CO_2, the average parameters obtained at light intensity in sequence are 9.860 lux; 9.078 lux; 12.651 lux, the average parameters at air temperature in sequence are 30ºC;

32.06ºC; 31.61ºC, the average humidity parameters in sequence are 70.47%; 64.24%; 64.61%, the average parameters at air CO_2 in sequence are 428.47 ppm; 497.53 ppm; 538 ppm. While the soil parameters include pH, humidity, and temperature. The average pH obtained in sequence at each station is 8; 7.71; 8, and the average soil moisture in sequence at each station is 41.60%; 30.59%; 32.22%, then the average soil temperature in sequence at each station is 30ºC; 31.94ºC; 30.61ºC.

Based on the analysis results, it can be concluded that the highest pH was recorded at stations 1 and 3, with a value of 8; this value still falls within the quality standard category. Soil pH can influence the availability of soil nutrients for plant growth. Based on the SNI 19-7030-2004 quality standard, nutrients are more easily absorbed by plants when the soil pH is in the range of 6.8–7.9 (Aeni et al., 2024). This occurs because a pH close to neutral provides nutrients at an optimal level and helps dissolve most nutrients in water (Kusuma & Yanti, 2022). Thus, the pH closest to the optimal pH was found at Station 2. Furthermore, the highest soil moisture content was found at Station 1 at 41.60%, a result classified as exceeding the quality standard. This is related to Station 1's location, which is far from the highway, making it shadier and more humid compared to the other stations.

Soil moisture affects root development, photosynthesis, and plant growth, and even contributes to plant wilting (Meilianto et al., 2022). Meanwhile, the highest soil temperature was recorded at Station 2 at 31.94 °C. Soil temperature is influenced by various factors, including climate, land slope, soil color, and geographic location. According to Soni et al. (2025), the optimal soil temperature range for most plant species is between 20 °C and 30 °C. Thus, it can be said that Station 2 is a relatively hot area compared to other stations, yet it remains within the optimal soil temperature range and meets quality standards.

Carbon stocks are formed through the process of photosynthesis carried out by plants, in which CO_2 is converted into carbon and subsequently stored within the plant body, such as in leaves, stems, branches, fruits, and flowers. Understanding these carbon stocks is key to maintaining a sustainable ecosystem balance. Supporting parameters, such as chlorophyll content tests on leaves, also help indicate the role of chlorophyll in photosynthesis, as well as the role of leaf area in determining the rate of photosynthesis and the amount of carbon stock in leaves. Environmental physicochemical parameters can also serve as environmental indicators supporting the growth of *Terminalia mantaly* in its capacity as a carbon-absorbing and carbon-storing plant.

Terminalia mantaly has a high air pollution tolerance index, making it suitable as a biosink and even as a bioindicator of air pollution (Obia et al., 2022). This aligns with the role of campus forests in environmental restoration and represents a crucial step in supporting the achievement of the Sustainable Development Goals (SDGs): Goal 11 (Sustainable Cities and Communities), Goal 13 (Climate Action), and No. 15 (Life on Land), where campus forests contribute to improving urban environmental quality, maintaining ecosystem balance, and supporting the sustainability of green open spaces in urban areas. The presence of campus forests also plays a role in climate change mitigation efforts through their ability to absorb and store carbon within biomass. Furthermore, information regarding the magnitude of stored carbon stocks can serve as a scientific basis for the sustainable management of campus forests, while simultaneously supporting biodiversity conservation and environmentally friendly land use.

CONCLUSION

Based on the research results, it can be concluded that the total biomass, carbon stock, and CO2 uptake by *Terminalia mantaly* in the Surabaya State University Campus Forest were highest at Station 2, at 376.18 kg, 176.8 kg, and 648.87 kg, respectively. Pearson's correlation analysis indicates that carbon stock has a strong correlation with diameter, biomass, and CO_2 uptake. Meanwhile, leaf area shows a strong but non-significant correlation, while tree height and leaf chlorophyll content exhibit neither a strong nor a significant correlation. These findings indicate that *Terminalia mantaly* has the potential to serve as a carbon sink and CO_2 sequester, particularly in the Surabaya State University Campus Forest.

SUGGESTIONS

Further evaluation of the allometric method for estimating biomass in *Terminalia mantaly* is necessary. If the study is to be continued, a destructive approach is recommended to obtain more accurate measurements of carbon stock stored in the trees.

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