

## Carbon Stock Estimation in Tanjung Plants (*Mimusops elengi* L.) in the Campus Forest of Surabaya State University

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**Abstract:** Forests have a role in the global carbon cycle by absorbing and storing carbon in the environment. One of the plants in the campus forest of Surabaya State University that can absorb carbon and store it in the form of biomass is the tanjung plant (*Mimusops elengi* L.). This study aims to estimate the carbon stock stored in tanjung plants (*Mimusops elengi* L.) in the campus forest of Surabaya State University which was carried out from September to December 2024. The research method uses a non-destructive method. The parameters measured in this study include stem diameter, circumference, height, chlorophyll content, leaf surface area and environmental parameters that support the growth of *Mimusops elengi*. The data collection technique was carried out by *purposive sampling*, at three stations with a total of 50 individuals. Statistical analysis of the data used the Pearson correlation test. *Mimusops elengi* was able to absorb carbon respectively by 106.03 kg; 43.96 kg and 31.89 kg. Having a biomass respectively, namely 225.08 kg/tree; 91.01 kg/tree and 67.87 kg/tree. The absorption values  $\text{CO}_2$  were 389.14 tons C/ha; 161.34 tons C/ha and 117.0 tons C/ha, respectively. The results of statistical tests on height, circumference and diameter had a positive correlation with carbon stock. Meanwhile, chlorophyll content and leaf surface area were negatively correlated with carbon stock. These results indicate that tanjung plants have significant potential in absorbing carbon in the campus forest of Surabaya State University, thus playing a role in reducing greenhouse gas emissions in the atmosphere.

**Keywords:** Biomass, campus forest, *Mimusops elengi*, climate change mitigation, carbon stock

### Introduction

Forests absorb carbon dioxide from the atmosphere through photosynthesis and then store it in biomass, dead organic matter, and soil. Other functions of forest ecosystems include providing water, producing oxygen, providing habitat for flora and fauna, and playing a role in mitigating climate change (Sultan *et al.*, 2020). According to the World Resources Institute (WRI), by 2023, the total loss of tropical primary forests worldwide is expected to reach around 3.7 million hectares, with nearly the same total in 2019 and 2021. All levels of forest loss result in carbon dioxide emissions of 2.4 gigatons, equivalent to half the annual fossil fuel emissions in the United States. Indonesia is known as one

of the countries with the largest tropical rainforests in the world, earning it the nickname "the lungs of the world." Indonesia has a forest area of 135 million hectares. However, this forest area is decreasing annually due to land conversion and unsustainable forest use. The high rate of forest degradation has made Indonesia one of the largest contributors to greenhouse gas emissions in the world (Rahmadhani *et al.*, 2019). According to a report from the Ministry of Environment and Forestry, deforestation in Indonesia decreased by 8.4% in 2021-2022 compared to 2020-2021. Indonesia's net deforestation in 2021-2022 was 104,000 hectares, lower than the 113.5 hectares recorded in 2020-2021. This represents the lowest deforestation rate in Indonesia. Meanwhile,

Indonesia's peak deforestation rate occurred between 1996 and 2000, reaching 3.5 million hectares per year. In 2023, the total natural forest loss in Indonesia reached 257,384 hectares, exceeding the 230,760 hectares recorded in 2022. West Kalimantan was the largest contributor to deforestation in Indonesia, with 35,162 hectares lost. Forest destruction in Indonesia can have serious impacts, such as reduced biodiversity, loss of animal habitats and declining quality of natural resources in Indonesia and can affect global climate change (Wahyuni & Suranto, 2021).

East Java's forests are the largest on the island of Java, covering  $\pm 738,156.93$  hectares. However, forest cover in East Java has been declining since 2019 due to deforestation, land conversion for agriculture, and development activities. It is estimated that between 150 and 400 hectares of forest in East Java will be deforested between 2022 and 2023. In 2018 and 2019, East Java lost 5,066 hectares of forest, a total of 5,804.7 hectares of community forest areas. Forest degradation is a serious challenge caused by land clearing, mining, illegal logging, and forest fires (Rachmah *et al.*, 2024). Meanwhile, Surabaya City has a forest area of 306.35 hectares. East Java Province, particularly Surabaya City, has made efforts to maintain ecological balance through reforestation and conservation programs, including the development of urban forests and green spaces within campuses.

The Lidah Wetan State University of Surabaya campus covers an area of 82 ha with a campus forest area of  $+759,333 \text{ m}^2$ . Several plant species have been found in the campus forest that have great potential in terms of carbon absorption, one of which is the tanjung plant (*Mimusops elengi* L.). Tanjung is a plant that is widely planted on the edges of city roads because it can function as a shade plant that can provide coolness in urban areas. The canopy area of tanjung plants varies depending on their age and environmental conditions. Generally, tanjung plants can reach a wide canopy between 5-15 meters. The canopy area affects the plant's capacity to absorb carbon and contributes to carbon storage in the ecosystem. Tanjung is an effective plant in absorbing dust, which is  $0.00094 \text{ g/cm}^2$  because tanjung plants have the characteristic of leaves that curve upwards

(Khair, 2020). Campus forests have a contribution to climate change, especially in the city of Surabaya which has quite high levels of pollution and carbon dioxide emissions.

There is a relationship between carbon stocks and the photosynthesis process in plants. Carbon dioxide is the initial product of photosynthesis. Carbon dioxide ( $\text{CO}_2$ ) in the atmosphere is absorbed by plants and converted into organic matter such as glucose, which serves as an energy source for plants. This carbon is then stored in plant biomass such as roots, stems, and leaves. The absolute carbon dioxide content in biomass is known as carbon reserves or stocks. The more optimal the photosynthesis process, the greater the carbon stocks stored in plants, thus supporting efforts to reduce carbon dioxide emissions and help mitigate climate change (Nuranisa *et al.*, 2020). In the study of carbon stocks of tanjung plants, measuring chlorophyll levels and leaf area is a crucial parameter. High chlorophyll levels indicate better photosynthetic efficiency, which means the plant has greater potential to absorb and store carbon. Leaf area plays an important role in the photosynthesis process, because the larger the leaf surface area, the more light the leaves can capture, which can support biomass production and carbon storage (Santrum *et al.*, 2021).

Research related to estimating carbon stocks in local vegetation as a climate change mitigation measure generally relies on allometric methods to calculate biomass and carbon stocks. Furthermore, carbon stock estimates can also be calculated using remote sensing technology, such as drones, by relying on vegetation indices as a reference in an area (Marzuki, 2021). Many studies on carbon stocks have been conducted, such as the study by Fadillah *et al.* (Fadillah *et al.*, 2023) which stated that the total carbon stock in Penggaron Forest, Unggaran City, was  $3,049,515.14 \text{ kgC}$  or  $3,049,515 \text{ kgC/ha}$ , with mahogany trees having the highest carbon absorption capacity with an average trunk diameter of  $46.921 \text{ cm}$ . A similar study by Sardi *et al.* (Sardi *et al.*, 2021) also stated that in the Mt. Tumpa HV Worang has 21 tree species with 88 individuals from 17 families with a total accumulation of tree carbon storage of  $838.35 \text{ tons/ha}$  and the *Alstonia scholaris* species which has the highest carbon storage value, namely  $389.35 \text{ tons/ha}$ . Research by Selfiany *et al.*,

(Selfiany *et al.* , 2023) in the Nanga Semangut Village Forest, Kapuas Hulu Regency stated that there are 14 tree species with a total of 368 individuals/ha which have a carbon storage of 109.44 tons C/ha or equivalent to 401.66 tons CO<sub>2</sub>/ha and the species with the largest carbon storage is the meranti type with 218 individuals with a carbon storage value of 61.57 tons C/ha or equivalent to 225.97 tons CO<sub>2</sub>/ha. Although many studies have been conducted on carbon stock estimation, but on specific plants, such as tanjung plants (*Mimusops elengi*) in Indonesia is still limited. There is research from Romadhon (Romadhon, 2023) which reported 12 individuals of tanjung plants (*Mimusops elengi* L.) on Jalan Demang Lebar Daun, Palembang City which had a carbon reserve value of 0.2679-0.8946 kg/tree.

Therefore, this study aims to estimate the carbon stock stored in tanjung plants in the campus forest of Surabaya State University, so that it can help mitigate climate change. This research can also support environmental conservation efforts in urban areas, especially in the campus forest of Surabaya State University which contributes to reducing carbon emissions and improving air quality. This research plays an important role in supporting the Sustainable Development Goals (SDGs), number 13 on climate change aspects and number 15 on terrestrial ecosystem conservation.

## Materials and Methods

The research was conducted in the forest area of the Surabaya State University campus, Lidah Wetan. Chlorophyll content testing and *leaf area measurements* of tanjung (*Mimusops elengi* L.) were conducted at the IsDB Biology Research Laboratory, Building C1, Faculty of Mathematics and Natural Sciences, Surabaya State University. The research period was four months, from September to December 2024.

## Research Instruments

This study used various tools and materials for sampling and chlorophyll analysis. The tools used included measuring tapes, *smartphone measuring apps*, *thermometers*, *soil testers*, *air quality control*, and *lux meters*. *leaf area meter*, analytical balance, Mapada V-110D Spectrophotometer meter, mortar and pestle. The materials used include tanjung plant leaves

(*Mimusops elengi* L.), 96% alcohol and filter paper.

## Sampling

The samples used were leaf samples of tanjung trees (*Mimusops elengi* L.) located in the campus forest of Surabaya State University Lidah Wetan. In this study, carbon stocks were measured in all 50 tanjung trees (*Mimusops elengi* L.) spread across the research area. The sampling technique was *purposive sampling*. Leaf samples were taken at 3 stations, station 1 close to the highway, station 2 medium from the highway and station 3 far from the highway. Samples at each station were taken as many as 3 trees, which on each tree, namely at the top, middle and base of the leaf which was done on the first branch because it was easy to reach.

## Tree Diameter and Height Measurement

The stem diameter of the tanjung tree (*Mimusops elengi* L.) was measured using a measuring tape, at a height of 1.3 meters from the ground, commonly known as *Diameter at Breast Height* (DBH). Tree height was measured using a measuring app on a *smartphone*. After obtaining the circumference of 50 tanjung trees (*Mimusops elengi* L.), the following formula was used to measure vegetation diameter:

$$D = \frac{K}{\pi}$$

Information:

D = Stem diameter (cm)

K = Circumference of the stem (cm)

$\pi$  = Ratio of circumference to diameter

## Measurement of Soil and Air Physical and Chemical Parameters

Measurement of soil and air physical and chemical parameters includes several stages. Soil temperature is measured using a *thermometer* placed on the tree trunk. Soil pH and moisture measurements are carried out using a *soil tester*, which is inserted into the soil at a depth of  $\pm 5$  cm from the soil surface to obtain accurate results. Measurements of temperature, humidity and CO<sub>2</sub> air are carried out at 3 points using an *Air quality control tool*, by placing the tool around the tanjung plant (*Mimusops elengi* L.) at a height of 1-2 meters from the ground surface. Light intensity measurements are carried out using a *lux meter*, which is placed around the tanjung

plant canopy during the day to measure the amount of light intensity received by the leaves.

### Leaf Area Measurement

Leaf area measurement of tanjung plant (*Mimusops elengi* L.) was carried out using an ADC AM350 leaf area meter to obtain accurate results. The leaf area meter works by digitally scanning each sample of tanjung plant leaves and measuring the leaf surface area in units of  $\text{cm}^2$ . Each sample of tanjung plant leaves must be carefully placed on the sensor or surface of the tool so that the leaves are not folded or their shape is disturbed, so that the tool can calculate the leaf area optimally.

### Tree biomass calculation

Tree biomass measurement uses a non-destructive method, which is a calculation method without damaging or felling trees using allometric equations. The formula for calculating aboveground biomass is based on the formula proposed by Ketterings (2001), which is as follows:

$$BK = 0.11 \times \rho \times D^{2.62}$$

Information:

BK = Tree biomass (kg/tree)

$\rho$  = Specific gravity of wood ( $\text{gr}/\text{cm}^3$ ); Weight type can refer to Indonesian Wood Atlas or Global Wood Density Data

D = Diameter of the tree at chest height (1.3 m)

### Calculation of carbon stock reserves

The calculation of carbon stock estimates uses a process of multiplying the biomass value by a conversion factor of 0.47 (IPCC 2008, 2006) with the following equation:

$$C = 0.47 \times BK$$

Information:

C = Tree carbon (kg)

BK = Tree biomass (kg/tree)

### Absorption measurement $\text{CO}_2$

According to Banuwa (Banuwa *et al.*, 2019), the following formula can be used to estimate the absorption value:  $\text{CO}_2$

$$\text{Absorption } \text{CO}_2 = \frac{\text{Mr } \text{CO}_2}{\text{Ar C}} \times \text{Karbon}$$

Information:

Carbon = Carbon content in biomass

$\text{Mr } \text{CO}_2$  = Molecular weight of the compound  $\text{CO}_2$  (44 g/mol)

Ar C = Relative molecular weight of carbon atom (12 g/mol)

### Chlorophyll analysis

Measurement of chlorophyll content in leaves was carried out using a Mapada V-110D Spectrophotometer. Tanjung leaves (*Mimusops elengi* L.) were weighed as much as 0.1 grams, then the leaf sample was ground using a mortar and pestle. Then make a leaf extract by mixing the leaf smear with 10 mL of 96% alcohol solution, then the solution was filtered with filter paper to obtain a sufficient volume of filtrate for further testing. The chlorophyll content contained in the leaf filtrate was measured using a spectrophotometer at wavelengths of 649 and 665 nm. Then the chlorophyll value was calculated using the Wintermans and De Mots formula as follows:

$$\text{Chlorophyll a} = 13.7 \times \text{OD } 665 - 5.76 \times \text{OD } 649 \text{ (mg/L)}$$

$$\text{Chlorophyll b} = 25.8 \times \text{OD } 649 - 7.7 \times \text{OD } 665 \text{ (mg/L)}$$

$$\text{Total chlorophyll} = 20 \times \text{OD } 649 + 6.1 \times \text{OD } 665 \text{ (mg/L)}$$

### Data Analysis

From the results of the carbon stock research in the leaves of tanjung plants (*Mimusops elengi*) using the Pearson correlation test which aims to identify a linear relationship between two variables that have a normal data distribution in carbon stock data against the parameters of circumference, height, diameter, chlorophyll content and leaf surface area.

## Results and Discussion

### Results of Calculation of Height, Circumference, Diameter, Biomass and Carbon Stock in *M. elengi*

The results of calculations on the height, circumference, stem diameter, biomass, and carbon stock of *M. elengi* were obtained from field measurements and calculations using allometric equations. The calculation data from three stations can be seen in Table 1.

### Chlorophyll Test Results of *M. elengi* Leaves

Results of chlorophyll tests on *M. elengi* leaves at the tip, middle, and base showed variations in values between leaf parts and

between research stations. These differences may be related to leaf maturity and environmental conditions. Chlorophyll content data can be seen in Table 2.

### Leaf Surface Area Measurement Results

The results of leaf surface area measurements at the base, middle, and shoot of *M. elengi* showed differences in size between leaf parts and between research stations. The leaf area measurement data are shown in Table 3.

### Pearson Correlation Test Results

The results of Pearson correlation analysis on stem diameter, height, circumference, leaf chlorophyll and leaf surface area (*leaf area*) with carbon stock in *M. elengi* showed the value

correlation coefficient and different levels of significance for each variable, which were conducted to determine the relationship between stem diameter, height, and circumference with carbon reserve estimates. The results of the correlation test are shown in Table 4.

### Results of Measurement of Physico-Chemical Parameters of Air and Soil

The results of measurements of the physicochemical parameters of the soil and air, including temperature, humidity, pH, light intensity, temperature, humidity, and CO<sup>2</sup> the location of *M. elengi growth*, showed varying values at the three stations. The environmental measurement data are shown in Table 5.

**Table 1.** Data on Height, Circumference, Stem Diameter, Biomass, Carbon Stock and CO<sub>2</sub> Absorption in *M. Elengi*

Statio n	Tall± SD (m)	Around ± SD (cm)	Stem Diameter± SD (cm)	Biomass ± SD (kg/tree)	Carbon Stock± SD (kg)	Absorption CO <sub>2</sub> ± SD (ton C/ha)
1	7.85 ± 1.51	58.21 ± 17.8	18.5 ± 5.46	225.08 ± 188.14	106.03 ± 88.89	389.14 ± 326.23
2	5.47 ± 1.51	42.4 ± 10.64	13.5 ± 3.39	91.01 ± 70.57	43.96 ± 32.31	161.34 ± 118.58
3	3.89 ± 1.28	34.32 ± 15.81	10.3 ± 5.46	67.87 ± 78.15	31.89 ± 36.73	117.0 ± 134.8

**Table 2.** Chlorophyll data on *M. elengi* leaves

Station	Part	Chlorophyll A± SD (mg/L)	Chlorophyll B± SD (mg/L)	Total Chlorophyll± SD (mg/L)
1	Base	23.29 ± 5.30	18.73 ± 2,66	34.69 ± 15,63
	Middle	12.43 ± 3.62	11.55 ± 9.76	21.12 ± 3.51
	Shoot	7.84 ± 4,08	6.06 ± 1.40	13.96 ± 5.18
2	Base	16.20 ± 8,54	14.42 ± 4,95	30.74 ± 12,91
	Middle	11.27 ± 1,36	9.45 ± 1,21	20.81 ± 2,33
	Shoot	7.39 ± 1.64	6.01 ± 7.34	11.63 ± 5.16
3	Base	13.91 ± 4,55	12.63 ± 3,81	26.64 ± 8,04
	Middle	10.84 ± 2,02	7.87 ± 5,03	18.79 ± 5,97
	Shoot	5.65 ± 1,02	2.30 ± 0,94	10.57 ± 5,57

**Table 3.** Leaf Area Measurement Data of *M. elengi*

Station	Base± SD ( cm <sup>2</sup> )	Middle± SD ( cm <sup>2</sup> )	Shoot± SD ( cm <sup>2</sup> )
1	73.3 ± 18.85	63.4 ± 11.31	55.6 ± 10.81
2	67.6 ± 8.64	61.3 ± 18.65	54.2 ± 7.07
3	66.8 ± 6.50	57.8 ± 10.19	51.2 ± 7.1

**Table 4.** Pearson Correlation Test Data for Diameter, Height, Tree Circumference, Chlorophyll Content and Leaf Surface Area in *M. Elengi* Against Carbon Stock

No.	Parameter	Pearson Correlation	Carbon Stock	Significance
1.	Diameter	1	0.934	0.000 < 0.05
2.	Tall	1	0.679	0.000 < 0.05
3	Around	1	0.718	0.000 < 0.05
4	Chlorophyll Content	1	0.275	0.166 > 0.05
5	Leaf Surface Area	1	0.278	0.146 > 0.05

**Table 5.** Air and Soil Physico-Chemical Parameter Data

Station	Physics And Chemistry of Air				Physics And Chemistry of Soil		
	Light intensity (luxury)	Temperature (°C)	Humidity (%)	CO <sub>2</sub> (°ppm)	pH	Humidity (%)	Temperature (°C)
1	4727.78 ±710.72	34.9 ±1.0	61.4 ±2.06	640.8 ±25.05	8 ± 0	24.4 ±5.1	33 ±0
2	4400.63 ±598.97	33.3 ±1.5	55.4 ±4.41	525.4 ±29.21	8 ±0	18.1 ±4.0	31.8 ±0.51
3	4362.50 ±560.54	33.0 ±1.2	55.2 ±2.05	513.3 ±6.15	8 ± 0	17.5 ±8.6	30.4 ±1
<b>Quality standards</b>	5000-20,000	25-35	50-88	350-1,000	6-7	10-30	20-35

## Discussion

### Height, Circumference, Stem Diameter, Biomass, Carbon Stock and CO<sub>2</sub> Absorption in *M. Elengi*

The results of the study in **Table 1** show that the biomass and carbon stock values at each station vary with a total of 50 *M. elengi* individuals. Station 1 has a biomass value of 225.08 kg/tree and a carbon stock of 106.03 kg with a total of 18 individual trees. Station 2 has a biomass value of 91.01 kg/tree and a carbon stock of 43.96 kg with a total of 16 individual trees. Station 3 has a biomass of 67.87 kg/tree and a carbon stock of 31.89 kg with a total of 16 individual trees. The absorption values CO<sub>2</sub> at the three stations also vary. Station 1 has an absorption value CO<sub>2</sub> of 389.14 tons C/ha, station 2 has an absorption value CO<sub>2</sub> of 161.34 tons C/ha, and station 3 is 117.0 tons C/ha. Based on **Table 1**, the total carbon content in *Mimusops elengi* is 60.63 kg which is classified as moderate because it is in the range of 50-149 (Dahlan, 2008). The carbon stock value describes the capacity of tanjung plants (*Mimusops elengi* L.) in absorbing and storing carbon, which is an important component in climate change mitigation efforts. The CO<sub>2</sub> highest biomass, carbon stock and absorption values are located at

station 1 and the lowest value is located at station 3. The high absorption value CO<sub>2</sub> is influenced by the magnitude of the biomass and carbon stock values at that station, the greater the biomass and carbon stock values, the greater the absorption value CO<sub>2</sub>. According to research (Bachmid et al., 2018) states that the absorption value CO<sub>2</sub> is directly proportional to the value of standing biomass and carbon stock values, which means that there is a positive relationship between biomass and carbon stock to absorption CO<sub>2</sub>. The high biomass and carbon stock values at station 1 are supported by the highest stem diameter at 18.5 cm compared to the other two stations. Stem diameter influences biomass and carbon storage. The higher the biomass, the greater the carbon storage at that station. Plant biomass increases because plants absorb atmospheric carbon dioxide through their leaves (Susanti, 2022). The carbon dioxide absorbed by plants is processed through photosynthesis to be converted into organic compounds, which can be used by plants for both upward (vertical) and lateral (horizontal) growth. Vertical growth influences stand height, which is influenced by the activity of the apical meristem at the tip of the stem and root, which continues to divide and produce new cells that later develop into plant parts. This upward growth can help plants obtain more light for

photosynthesis, thus supporting energy production and carbon storage. The horizontal growth of stands is caused by the activity of the lateral meristem which forms secondary vascular tissue and periderm tissue which results in an increase in the diameter size of the stand. So that the stem diameter can be used as an indicator in estimating biomass, carbon reserves and carbon absorption in stands (Hidayat *et al.*., 2020) . The diameter of the stem can also be influenced by the age of the individual stand, the stem diameter will increase with increasing age in the stand, stands that are older will have a larger diameter (Ahmed *et al.*., 2023) . In addition, the number of individuals in a stand can also affect the value of the carbon stock produced, the more individuals in a stand such as at station 1, the greater the carbon storage will be (Suprayitno *et al.*., 2024) . The high and low biomass can also be caused by the density of individuals in a stand. Low individual density can result in greater nutrient and sunlight intensity that can be absorbed by plants, so that it can increase the diameter optimally due to reduced competition in nutrient and sunlight absorption in individual stands (Karina & Nurdina, 2021) .

The biomass value in plants will continue to increase with growth, because biomass is the accumulation of photosynthesis results that will be distributed to leaves, twigs, stems and roots, thus causing an increase in stem diameter and plant height (Tsani & Muhsoni, 2022) . Plants that flower and bear fruit can have a higher photosynthesis process capability, so they are more optimal in absorbing carbon dioxide in the air. This process is supported by the greater energy requirements for flower and fruit growth, which can increase chlorophyll and the efficiency of sunlight absorption. The carbon stock value in plants can also be influenced by biotic and abiotic factors, such as nutrient content, soil type and optimal soil fertility levels, thus helping to increase biomass production. This shows that the value of carbon stocks above the ground in the form of biomass can also be influenced by carbon stored in the soil derived from organic materials. The presence of *tanjung* plants (*Mimusops elengi* L.) in the campus forest of Surabaya State University can support the achievement of Sustainable Development Goal (SDGs) number 13, namely on climate change mitigation. As a natural carbon absorber (*carbon*

*sink*), *Mimusops elengi* can play a role in reducing greenhouse gas concentrations in the campus environment.

### **Chlorophyll Test of *M. elengi* Leaves**

The results of the study in **Table 2** show that each station has different levels of chlorophyll a, chlorophyll b, and total chlorophyll. At the base, the highest chlorophyll value is station 1 with a chlorophyll a value of 23.29 mg/L, chlorophyll b of 18.73 mg/L, and total chlorophyll of 34.69 mg/L. Then, in the middle, the highest chlorophyll value is station 1 with a chlorophyll a value of 12.43 mg/L, chlorophyll b 11.55 mg/L, and total chlorophyll of 21.12 mg/L. Then, at the top, station 1 also has the highest value, namely chlorophyll a 7.84 mg/L, chlorophyll b 6.06 mg/L, and total chlorophyll of 13.9 mg/L. Therefore, it can be interpreted that of the three stations, the station with the highest chlorophyll content is at station 1, and the lowest chlorophyll content is at station 3. High chlorophyll levels can be associated with optimal photosynthesis, which can play a role in carbon accumulation in plant tissues. Differences in chlorophyll levels at each station can be influenced by the intensity of sunlight received by the leaves.

According to Widyawati *et al.*., (Widyawati *et al.*., 2023) , there is a relationship between light intensity on the leaves and their chlorophyll content, the higher the light intensity on the leaves, the higher the chlorophyll content in the leaves. There are differences in the amount of chlorophyll content at the base, middle, and top of *M. elengi* leaves. The part of the leaf that has the highest chlorophyll value is at the base and the lowest at the top, this is because the base of the leaf is the oldest part and the leaf top is the youngest part. The main factor that can affect the chlorophyll content in the leaves is the age of the leaves. The chlorophyll content at the top of *M. elengi* leaves has the lowest value compared to the middle and base. This is because the chlorophyll in young leaves located at the top is still in the form of protochlorophyll which has not fully formed into green chlorophyll. Chlorophyll itself will change color to green after the transformation of protochlorophyll (Khafid *et al.*., 2021) . The chlorophyll content in the middle and base of *M. elengi* leaves is known to have higher values than the leaf tips. This occurs because in both parts, chlorophyll has formed

optimally, along with the leaf maturation process. The closer to the base of the leaf, the higher the level of maturity and the maximum chlorophyll content. According to Dhimi *et al.*, (Dhimi et al., 2018), in mature leaves, the size and number of cells will increase, thus affecting the number of chloroplasts and causing higher pigment formation that helps in providing energy for the process of photosynthesis. Meanwhile, chloroplasts in young leaves are still limited, so the leaves will be pale in color. The amount of chlorophyll content can also be influenced by the surface area of the leaf. A large leaf surface area will result in more optimal light capture, so that the process of photosynthesis will run smoothly (Lu *et al.*, 2020). The chlorophyll content values at the three stations showed that the chlorophyll a content had a greater value than the chlorophyll b content. This is due to the role of chlorophyll a as the primary pigment involved in photosynthesis, absorbing light and converting it into chemical energy. Meanwhile, chlorophyll b acts as an antenna pigment, capturing light and transferring energy to chlorophyll a. Therefore, chlorophyll b is not directly involved in photosynthesis (Putri et al., 2022).

#### **Leaf Surface Area of *M. elengi***

The results of the measurement of the leaf area of *M. elengi* in **Table 3**. consist of 3 stations. On each tree, the base, middle and shoot were taken. At station 1, the base, middle and shoot had values of 73.3; 67.6 and 66.8, respectively cm<sup>2</sup>. Then at station 2 the base, middle and shoot had values of 63.4; 61.3 and 57.8, respectively cm<sup>2</sup>. Then at station 3 the base, middle and shoot had values of 55.6; 54.2 and 51.2, respectively cm<sup>2</sup>. It can be seen in **Table 3**. that the total average leaf area at the 3 stations with the highest value was at station 1 and the lowest was at station 3. The surface area of the leaf can affect the role of the leaf in the process of photosynthesis. The wider the surface area of the leaf, the leaf can absorb a greater capacity of sunlight, so that the process of photosynthesis can run optimally. Optimal photosynthesis can support biomass production by allowing plants to absorb more carbon dioxide from the atmosphere. Leaf area is an important indicator used in analyzing growth and physiological performance in plants (Andrian *et al.*, 2022).

The part of the *M. elengi* leaf with the largest area is at the base and the part with the smallest area is at the leaf apex. A factor that influences leaf surface area is leaf age. The base leaves are the oldest leaves and have a larger surface area compared to the middle leaves and apex leaves. This is because older leaves have gone through a longer growth phase, causing their cells to develop optimally and their chloroplasts to mature, thus supporting optimal chlorophyll accumulation for photosynthesis. The base leaves also have a thicker cuticle and more mature mesophyll tissue, thus supporting a larger surface area. The base of the leaf is the leaf that is shaded or protected from direct sunlight by the younger leaves above it, which causes a larger leaf area without experiencing stress due to excessive sunlight (Sanah & Rahmadina, 2024). As the plant ages, it will have more leaves and the leaf area will also increase because the plant continues to develop both in the roots, stems and leaves (Yang *et al.*, 2022). The surface area of the leaf can also be affected by environmental conditions such as humidity and temperature. Humidity in the air that is too low and temperatures that are too high can cause an excessive increase in evapotranspiration, so that the plant will lose a large amount of water. This causes cell pressure to decrease and the ability to absorb water and nutrients to be suboptimal, so that it can inhibit growth and expand the surface of the leaf (Wahyuningtyas *et al.*, 2022). Leaf surface area can also be influenced by plant nutrient uptake, particularly nitrogen. Nitrogen content in the soil plays a crucial role in supporting protein synthesis, which is used in leaf cell division and expansion. This affects leaf size and chlorophyll density (Lutfiah *et al.*, 2021).

#### **Physical and Chemical Parameters of Air and Soil**

The results of the study in **Table 5**. show the measurement of air physicochemical parameters including light intensity, temperature, humidity and CO<sub>2</sub>. While the soil physicochemical parameters include pH, humidity and temperature. It can be seen that at station 1, the light intensity is 4727.78 lux, air temperature 34.9 °C, air humidity 61.4%, CO<sub>2</sub> 640.8 °ppm, soil pH 8, soil humidity 24.4% and soil temperature 33 °C. Then at station 2, the light

intensity is 4400.63 lux, air temperature 33.3 °C, air humidity 55.4%, CO<sub>2</sub> 55.4 °ppm, pH 8, soil humidity 18.1% and soil temperature 31.8 °C. At station 3, the light intensity is 4362.50 lux, temperature 33 °C, humidity 61.4%, CO<sub>2</sub> 513.3 °ppm, soil pH 8, soil humidity 17.5% and soil temperature 30.4 °C. The sunlight intensity at station 1 had the highest value, consistent with the highest values for diameter, biomass, and carbon stock at station 1. The light intensity at each station was within the standard range for plant growth, which is 5,000-20,000 lux. Suboptimal light intensity can inhibit plant growth because it affects the ability of stomatal cells in the leaves to transport light. Characteristics of plants lacking sunlight during the growing period include pale leaves, long, and slender growth (Pramadana *et al.* , 2021) . Furthermore, sunlight can also affect the photosynthesis process in plants. Too low a light intensity can cause a decrease in the rate of photosynthesis due to reduced energy requirements. Meanwhile, too high a light intensity can also cause photoinhibition in plants, which can damage chloroplasts, thus disrupting the rate of photosynthesis. The more optimal the light intensity received by the leaves, the more photosynthesis will increase and biomass production will increase, which will affect carbon storage. This can also be explained by the increasing chlorophyll content and surface area of the leaves in response to optimal light intensity levels (Darmanti *et al.* , 2009) . The air temperature at each station is still within the standard quality range, namely 25-35 °C. Air temperature is inversely proportional to air humidity. Air temperatures that are too high can potentially damage chlorophyll in the leaves and reduce enzyme performance, so that photosynthesis efficiency will decrease, biomass production and carbon stock storage will also decrease. In addition, increasing temperatures can increase the respiration rate, decrease pH and close stomata (Azizah & Rachmadiarti, 2018) . The air humidity value at each station is still within the optimal range for plant growth, namely 50-88% (Miru *et al.* , 2024) . Air humidity is related to the photosynthesis process carried out by plants. Low air humidity can reduce the rate of photosynthesis in plants, due to the closure of stomata to reduce excessive water

evaporation, thus limiting the absorption of atmospheric carbon dioxide as a material for photosynthesis. This results in decreased biomass production in plants and the accumulation of carbon stocks (Farid *et al.* , 2023) . Optimal air humidity can support the process of photosynthesis in leaves, increasing biomass production and the accumulation of carbon stocks in plants. CO<sub>2</sub> At 3 stations, the values varied and were still within the optimal range for plant growth, namely 350-1000 °ppm. CO<sub>2</sub> The highest air concentration is at station 1 and the lowest is at station 3. The level of air concentration is at station 1 and the lowest is at station 3. CO<sub>2</sub> Air pollution can provide an indication of the extent to which *M. elengi* in the campus forest of Surabaya State University Lidah Wetan can absorb carbon dioxide in the atmosphere. The high carbon dioxide emissions (CO<sub>2</sub>) at station 1 indicate that the air quality at that station is deteriorating, which may be caused by motor vehicle emissions, among other things. This is consistent with the location of station 1, which is closer to the highway than the other stations. Increased carbon dioxide levels CO<sub>2</sub> Air humidity is related to increased chlorophyll content in leaves, which plays a role in optimizing light capture, thereby increasing the rate of photosynthesis in *M. elengi* at that station. This results in greater biomass production and increased carbon storage (Lestari & Martuti, 2024) . The soil pH value at each station is 8, indicating the soil tends to be alkaline and exceeds the optimal limit of 6-7 (Karamina *et al.* , 2018) . However, *tanjung* plants have adaptive roots so they can survive and grow well in soil conditions that tend to be alkaline. Optimal soil pH can play an important role in determining the availability of nutrients in the soil. Nutrients in the soil will decrease if the soil is at a low pH, and nutrients will increase when the pH rises to a neutral or optimal level (Mualif & Kusumawati, 2021) . Soil moisture at each station is still within the standard range for plant growth, which is 10-30%. The level of moisture in the soil depends on the type of soil. Optimal soil moisture can affect water absorption in roots, which plays a role in metabolic processes, photosynthesis, and biomass accumulation in plants. High soil moisture can cause the soil to become saturated with water, thereby reducing oxygen availability

around the roots, inhibiting root respiration and causing stress in plants. Meanwhile, low soil moisture can make it difficult for plants to absorb water, thus disrupting metabolic processes, photosynthesis, biomass production, and carbon storage (Karyati *et al.*, 2018). Soil temperatures at each station were still within the quality standard limits, namely 20-35 °C, which are considered appropriate to support physiological processes in plants. Optimal soil temperature can help balance photosynthesis and respiration in plants. Soil temperatures that are too high can cause the root respiration rate to increase and the carbon that is bound will be used more as energy than in the form of biomass. Thus, it can reduce carbon storage in plants (Cahyaningprastiwi *et al.*, 2021). Tanjung plants (*Mimusops elengi* L.) contribute to SDGs no. 15 concerning the preservation of terrestrial ecosystems. The preservation of this terrestrial ecosystem involves managing the campus forest at Surabaya State University, rehabilitating degraded land, and preserving biodiversity. Environmental physicochemical parameters can support terrestrial ecosystem preservation by providing optimal environmental conditions, which can influence carbon stock estimates in tanjung plants. Tanjung plants are well-adapted to environmental conditions and have a high tolerance for air pollution, making them suitable for planting in the campus forest at Surabaya State University (Purnama Sari *et al.*, 2021).

#### **Pearson Correlation Test of Diameter, Height, Tree Circumference, Chlorophyll Content and Leaf Surface Area in *M. Elengi* Against Carbon Stock**

The Pearson correlation test for stem height, circumference, and diameter on carbon stocks in **Table 4** shows a positive correlation with a significance value of  $<0.05$ , namely 0.000, indicating a strong correlation between stem height, circumference, and diameter on carbon stocks. The results of this statistical analysis can be interpreted as meaning that the greater the value of height, circumference, and diameter in plants, the more biomass production and carbon stock storage will also increase. The Pearson correlation value for diameter is 0.934, indicating a perfect correlation with carbon stocks. This is in accordance with the largest stem diameter located at station 1, so the resulting biomass and

carbon stock values can also be greater. Conversely, a smaller diameter will result in a smaller biomass value and a lower carbon stock value, as at station 3. The larger the stem diameter, the more tissue will be formed that can store carbon in the form of cellulose and lignin (Manibuy *et al.*, 2021). The high Pearson correlation value of 0.679 indicates a moderate correlation with carbon stocks. Taller plants generally have wider canopies, allowing them to capture more sunlight, which can be used in photosynthesis. The results of this photosynthesis are then converted into biomass. This can increase biomass production and increase carbon storage (Rahmawati & Chairul, 2022). The circumference correlation value is 0.718, indicating a moderate correlation with carbon stock. The larger the circumference of an individual, the greater its carbon storage. This is because a large biomass is influenced by a large circumference value, thus influencing more optimal carbon accumulation (Alviana *et al.*, 2023).

The Pearson correlation test of chlorophyll values with carbon stocks in **Table 4** shows a negative correlation, because the significance result is  $> 0.05$  at 0.146. The increase in chlorophyll content in leaves is not always directly proportional to the value of carbon stocks. This may be caused by the allocation of carbon produced from the plant's photosynthesis process being maximized not in the leaves but in the roots and stems which can increase carbon storage capacity in the long term and help when plants are in unfavorable environments. Flowering plants can divert energy and biomass to support flower formation and fruit production, which can reduce the contribution of leaves to carbon storage. Therefore, even though the high chlorophyll value is not directly proportional to the carbon stock produced (Uthbah *et al.*, 2017).

Pearson correlation test on the value of the leaf surface area of *M. elengi* with carbon stock in **Table 4**. negatively correlated with a significance result of  $> 0.05$  of 0.166. This is influenced by factors of changes in leaf thickness and the amount of mesophyll tissue in the leaves. Leaves that have optimal thickness and a stable amount of mesophyll tissue can increase light absorption and  $\text{CO}_2$ , thus causing the photosynthesis process to run optimally. Meanwhile, excessive leaf thickness and

unbalanced distribution of mesophyll tissue can inhibit light absorption and CO<sub>2</sub> in the leaves, so that it can reduce the rate of photosynthesis, reduced biomass production and carbon stock storage (Nuryana *et al.*, 2024).

## Conclusion

Based on this research, it shows that tanjung plants (*Mimosa elengi* L.) have significant potential and contribution in carbon storage in the campus forest of Surabaya State University Lidah Wetan. The highest carbon stock value is located at station 1 at 106.03 kg, with a biomass value of 225.08 kg/tree and an absorption value CO<sub>2</sub> of 389.14 tons/ha. This is influenced by the diameter, circumference, and height of the plant. The results of the Pearson correlation test show that diameter, circumference, and height are positively correlated with carbon stock values. The greater the value of these three parameters, the greater the biomass production and carbon storage. Meanwhile, chlorophyll and leaf surface area in tanjung plants are negatively correlated with carbon stock. In addition, physical and chemical parameters in the air and soil also support the growth of tanjung plants. This research contributes to SDGs number 13 and 15 which support climate change mitigation and conservation of terrestrial ecosystems.

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## Reference

- Ahmed, Y., Kurniawan, CA, Efendi, GR, Pribadi, R., Nainggolan, FA, & Samudra, MBGS (2023). Estimation of Mangrove Carbon Stocks Based on Differences in Mangrove Rehabilitation Planting Years (2005, 2008, 2011, 2014, and 2017) in the Pandansari Mangrove Ecotourism Area, Brebes Regency. *Marina Oceanography Bulletin*, 12 (1), 9–19. <https://Doi.Org/10.14710/Buloma.V12i1.40871>
- Alviana, D., Anggraini, R., Hidayati, JR, Karlina, I., Lestari, F., Apdillah, D., Syakti, AD, & Sihite, D. (2023). Estimation of Carbon Stocks in the Mangrove Ecosystem in Pengudang Village, Teluk Seborg District, Bintan Regency. *Journal of Tropical Marine Sciences*, 26 (3), 464–472. <https://Doi.Org/10.14710/Jkt.V26i3.18326>
- Andrian, R., Agustiansyah, A., Junaidi, A., & Lestari, DI (2022). Application for Measuring Plant Leaf Area Using Android-Based Digital Image Processing. *Jurnal Agrotropika*, 21 (2), 115. <https://Doi.Org/10.23960/Ja.V21i2.6096>
- Azizah, DN, & Rachmadiarti, F. (2018). Potential of the Water Lily (*Hymenocallis Speciosa*), Croton (*Codiaeum Variegatum*), and Bintaro (*Cerbera manghas*) as Lead (Pb) Absorbents in the Air. *Lentera Bio: Scientific Scale Biology*, 7 (3), 195–202. [http://ejournal.unesa.ac.id/index.php/lentera\\_bio](http://ejournal.unesa.ac.id/index.php/lentera_bio)
- Bachmid, F., Sondak, C., & Kusen, J. (2018). Estimation of Carbon Absorption in the Bahowo Mangrove Forest, Tongkaina Village, Bunaken District. *Journal of Coastal and Tropical Seas*, 6 (1), 8. <https://Doi.Org/10.35800/Jplt.6.1.2018.19463>
- Banuwa, I.S., Afriliyanti, R., Utomo, M., Yusnaini, S., Riniarti, M., Sanjaya, P., Suroso, E., & Hidayat, W. (2019). Short Communication: Estimation of the Above- and Below-Ground Carbon Stocks in the University of Lampung, Indonesia. *Biodiversitas*, 20 (3), 676–681. <https://Doi.Org/10.13057/Biodiv/D200309>
- Cahyaningprastiwi, SR, Karyati, & Sarminah, S. (2021). (Regulation of the Minister of Public Works and Daily Activities Which Can Be Caused By In East Kalimantan For Approximately Six (6) Months, Namely September Meter, Global Position System (Gps)). *Agrifor Journal*, 189–198.
- Dahlan, EN (2008). Amount of CO<sub>2</sub> Gas Emissions and Selection of Plant Types with Very High Resorption Capacity: Case Study in Bogor City. *Conservation Media*, 13 (2), 85–89.

- Darmanti, S., Nurchayati, Y., Hastuti, D., & Syaifuddin, M. (2009). Biomass Production of Plants Grown at Different Light Intensities. *Anatomy Physiology*, *Xvii* (1), 22–29. <https://doi.org/10.14710/baf.v17i1.2532>
- Dhami, N., Tissue, D.T., & Cazzonelli, CI (2018). Leaf-Age Dependent Response Of Carotenoid Accumulation To Elevated Co2 In Arabidopsis. *Archives Of Biochemistry And Biophysics*, 67–75. <https://doi.org/10.1016/j.abb.2018.03.034>
- Fadillah, MA, Bashit, N., Qoyimah, S., Susilo, H., & Apriyanti, D. (2023). Analysis of Vegetation Carbon Stock Estimation with Remote Sensing Using the Light Use Efficiency Method in Penggaron Forest, Ungaran City, Semarang Regency, Central Java Province. *Elipsoida: Journal of Geodesy and Geomatics*, 6 (1), 32–42. <https://doi.org/10.14710/Elipsoida.2023.18829>
- Farid, N., Sartijo, A., & Ulinuha, Z. (2023). The Effect of Media Humidity on the Growth and Evapotranspiration of Five Dendrobium Orchid Varieties. *Agromix*, 14 (1), 96–103. <https://doi.org/10.35891/Agx.V14i1.3014>
- Hidayat, W., Susatya, A., & Apriyantio, E. (2020). Growth of Nyamplung (*Callophyllum Innophyllum* L.) Plants in Organic Blocks from Palm Oil Fruit Fiber Waste with Fertilization in Coastal Land. *Naturalis: Journal of Natural Resources and Environmental Management Research*, 9 (2), 109–118. <https://doi.org/10.31186/naturalis.9.2.13512>
- Karamina, H., Fikrinda, W., & Murti, AT (2018). The Complexity of the Effect of Temperature and Soil Moisture on Soil pH Values in Crystal Guava (*Psidium Guajava* L.) Plantations in Bumiaji, Batu City. *Cultivation*, 16 (3), 430–434. <https://doi.org/10.24198/Kultivasi.V16i3.13225>
- Karina, SP, & Nurdina. (2021). Tree Carbon Biomass in the Iboih Mountains, Suka Karya District, Sabang City. *Proceedings of the National Biotic Seminar*, 9 (1).
- Karyati, K., Putri, RO, & Syafrudin, M. (2018). Soil Temperature and Moisture in Post-Mining Revegetation Land at PT Adimitra Baratama Nusantara, East Kalimantan Province. *Agrifor*, 17 (1), 103. <https://doi.org/10.31293/Af.V17i1.3280>
- Khafid, A., Suedy, SWA, & Nurchayati, Y. (2021). Chlorophyll and Carotenoid Content of Bay Leaves (*Syzigium Polyanthum* (Wight) Walp.) at Different Ages. *Anatomy and Physiology Bulletin*, 6 (1), 74–80. [Http://ejournal2.undip.ac.id](http://ejournal2.undip.ac.id)
- Khair, U. (2020). The Use of Tanjung Leaves (*Mimusops Elengi* L.) and Zinc (Zn) on Banda Aceh City Roads. *Ar-Raniry State Islamic University. Thesis*
- Lestari, NP, & Martuti, NKT (2024). Potential Carbon Stocks and Carbon Absorption in the Tinjomoyo City Forest Ecosystem, Semarang. *Life Science*, 13 (2), 119–133. <https://doi.org/10.15294/unnesjlfesci.v13.i2.592>
- Lu, G., Liebao, H., Shuxia, Y., & Yiwei, J. (2020). Chlorophyll Metabolism And Gene Expression In Response To Submergence Stress And Subsequent Recovery In Perennial Ryegrass Accessions Differing In Growth Habits. *Journal Of Plant Physiology*. <https://doi.org/10.1016/j.jplph.2020.153195>
- Lutfiah, I., Sulistyawati, & Pratiwi, SH (2021). The Effect of Nitrogen Dose on the Growth and Yield of Purple Eggplant (*Solanum Melongena* L. Var. Antaboga F1 Hybrid). *Jurnal Agroteknologi Merdeka Pasuruan*, 5 (1), 1–6. <https://jamp-jurnal.unmerpas.ac.id/index.php/jamppertanian/article/view/51/48>
- Manibuy, S., Nugroho, JD, & Sinery, AS (2021). Carbon Storage in the Bumi Saniari Urban Forest, Teluk Bintuni Regency. *Cassowary*, 4 (1), 1–9. <https://doi.org/10.30862/Cassowary.Cs.V5.I1.64>
- Marzuki. (2021). Thesis: Estimation of Biomass Carbon Stock in Mangrove Ecosystems Using Satellite Data on Nunukan Island, Nunukan Regency, North Kalimantan. *Hasanuddin University, Makassar. Thesis*, 1–57.
- MD Wahyuningtyas, Zubaidah, S., & Kulu, IP

- (2022). Growth and Yield of Kailan (Brassica Oleraceae Var Alboglabra LH Bailey) Upon Application of Liquid Organic Fertilizer from Fruit Peel Waste in Peat Soil. *Upr Research Journal* , 2 (1), 41–52.  
<https://doi.org/10.52850/Jptupr.V2i1.4895>
- Ministry of Environment and Forestry. 2023. Indonesia's deforestation rate fell by 8.4% in 2021-2022. Ministry of Environment and Forestry. <https://betahita.id/news/detail/10044/hari-hutan-sedunia-deforestasi-indonesia-2023-capai-257-ribu-ha.html?v=1711142623> (Accessed on October 3, 2024)
- Miru, R., Siahaya, L., & Aponno, HSE . (2024). Study of the Successful Growth of Canary Plants ( *Canarium Indicum* L.) Provenan Morela in the Seed Garden of Hatusua Village, Kairatu District, West Seram Regency. *Jurnal Sylva Scientiae* , 7 (4), 673.  
<https://doi.org/10.20527/Jss.V7i4.12650>
- Mualif, MS, & Kusumawati, A. (2021). The Effect of Soil Chemical Properties on Sugarcane (*Saccharum Officinarum* L.) Productivity. *Journal of Plantation Management (Jpp)* , 2 (2), 66–72.  
<https://doi.org/10.54387/Jpp.V1i1.5>
- Nuranisa, S., Sudiana, E., & Yani, E. (2020). Relationship between Age and Biomass, Carbon Dioxide Stock, and Duku Tree (*Lansium Parasiticum*) Stands in Kalikajar Village, Kaligondang District, Purbalingga Regency. *Bioeksakta: Unsoed Scientific Journal of Biology* , 2 (1), 146–151.  
<https://doi.org/10.20884/1.Bioe.2020.2.1.1866>
- Nuryana, MH, Darmanti, S., & Prihastanti, E. (2024). Anatomical Response of Adam and Eve Leaves ( *Rhoeo Discolor* ) and Red Shoots ( *Syzygium Oleaa* ) to CO2 Pollutants in Tembalang and Banyumanik Districts, Semarang City. *Journal of Environmental Science* , 22 (5), 1184–1193.  
<https://doi.org/10.14710/Jil.22.5.1184-1193>
- Pramadana, MH, Rivai, M., & Pirngadi, H. (2021). Solar Lighting Control System in Aquascape. *Jurnal Teknik ITS* , 10 (1), 15–21.  
<https://doi.org/10.12962/J23373539.V10i1.59809>
- Purnama Sari, BW, Sedijani, P., & Mertha, IG (2021). Traffic Density Affects Stomatal Character of Tanjung Plant ( *Mimusops Elengi* , L.) in Mataram City. *Journal of Tropical Biology* , 21 (1), 1–7.  
<https://doi.org/10.29303/Jbt.V21i1.2109>
- Putri, A.E., Ernawati, E., Priyambodo, P., Agustina, R., & Chrisnawati, L. (2022). Chlorophyll as an Indicator of Drought Tolerance Level of Upland Rice Sprouts of Local Lampung Variety, Lumbung Sewu Cantik. *Biota: Scientific Journal of Life Sciences* , 7 (November 2021), 142–150.  
<https://doi.org/10.24002/Biota.V7i2.5150>
- Rachmah, OZ, Bierhof, S., & Rizqi, MF (2024). Analysis of Law Enforcement Against Illegal Logging Perpetrators in Halimun Salak Forest, Banten. *Beleid* , 2 (1), 93.  
<https://doi.org/10.51825/Beleid.V2i1.25119>
- Rahmadhani, S., Yuwono, SB, Setiaan, A., Banuwa, IS (2019). Dust Absorption Effectiveness of Several Broadleaf Tree Species in the Median of Bandar Lampung City Roads. *Belantara Journal*, 2 (2), 134–141. <https://doi.org/10.29303/jbl.v2i2.181>
- Rahmawati, L., & Chairul, C. (2022). The Estimation of Ground Carbon Stock in the Tourist Forest Area of Ngalau Indah Payakumbuh. *Journal of Biology, Andalas University* , 10 (2), 78–84.  
<https://doi.org/10.25077/Jbioua.10.2.78-84.2022>
- Romadhon, MS (2023). In Absorbing Carbon as an Effort of Greenhouse Gas Mitigation in Palembang City. *Sriwijaya University. Thesis* .
- Sanah, R., & Rahmadina. (2024). Vegetative Growth Response of Soybean Plants ( *Glycine Max* L.) to Natural Shade Levels. *Bioedusains: Journal of Biology and Science Education* , 7 (No. 1), 37–45.  
<https://doi.org/10.31539/bioedusains.v7i1.9407>
- Santrum, MJ, Tokan, MK, & Imakulata, MM (2021). Estimation of Leaf Area Index and

- Net Photosynthesis of Mangrove Forest Canopies on Salupu Beach, West Kupang District, Kupang Regency. *Haumeni Journal of Education* , 1 (2), 38–43. <https://doi.org/10.35508/haumeni.v1i2.5402>
- Sardi, WDP, Kainde, RP, & Nurmawan, W. (2021). Carbon Stocks in Trees in the Gunung Tumpa HV Worang Grand Forest Park. *Cocos Journal* , 14 (3), 1–17. <https://doi.org/10.35791/cocos.v8i8.38736>
- Selfiany, WO, Mulyadi, & Sumarni, S. (2023). Carbon Potential in Tree Stands in Nanga Semangut Village Forest, Kapuas Hulu Regency. *Piper* , 19 (2), 145–152. <https://doi.org/10.51826/Piper.V19i2.915>
- Sultan, Hasanuddin, Latifah, H., & Awal, N. (2020). Donri ± Donri District, Soppeng Regency. *Bonita Forestry Research Journal* , 2 (1), 32–36. <https://doi.org/10.55285/bonita.v2i1.433>
- Suprayitno, S., Mustikaningrum, D., Kristiawan, K., Firlandiana, M., & Prasetyo, H. (2024). Estimation of Annual Plant Carbon Stocks in the Sunan Bonang University Campus Environment in Reducing the Impact of Global Warming in Tuban City. *Crop Production* , 12 (1), 45–55. <https://doi.org/10.21776/Ub.Protan.2024.012.01.06>
- Susanti, E. (2022). Estimation of Biomass and Carbon Storage in Trees in the Kuala Baru Coastal Protected Forest Area, Aceh Singkil. *Ar-Raniry State Islamic University, Banda Aceh. Thesis* , 1–66.
- Tsani, AAR, & Muhsoni, FF (2022). Estimation of Mangrove Carbon Stock in Taddan Village, Camplong District, Sampang Regency. *Journal of Archipelagic Marine Science* , 5 (1), 475–485. <https://doi.org/10.33387/Jikk.V5i1.4682>
- Uthbah, Z., Sudiana, E., & Yani, E. (2017). Analysis of Biomass and Carbon Stocks in Various Ages of Damar (Agathis Dammara (Lamb.) Rich.) Stands in East Banyumas Kph. *Scripta Biologica* , 4 (2), 119. <https://doi.org/10.20884/1.Sb.2017.4.2.404>
- Wahyuni, H., & Suranto, S. (2021). The Impact of Large-Scale Deforestation on Global Warming in Indonesia. *Jiip: Scientific Journal of Governmental Sciences* , 6 (1), 148–162. <https://doi.org/10.14710/Jiip.V6i1.10083>
- Widyawati, N., Herawati, MM, Kurnia, TD, Murdono, D., Simanjuntak, BH, & Setiawan, AW (2023). Chlorophyll Content, Growth, and Yield of Vertical Rice (*Oryza sativa* L.) Variety Situ Bagendit. *Vegetalika* , 12 (3), 256–271. <https://doi.org/10.22146/Veg.83196>
- Yang, H., Chai, Q., Yin, W., Hu, F., Qin, A., Fan, Z., Yu, A., Zhao, C., & Fan, H. (2022). Yield Photosynthesis And Leaf Anatomy Of Maize In Inter- And Mono-Cropping Systems At Varying Plant Densities. *Crop Journal* , 10 (3), 893–903. <https://doi.org/10.1016/J.Cj.2021.09.010>