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# Study on the Biomass and Soil Carbon Content of Mangrove Forest in Magyi Coastal Area, Ayeyarwady Region, Myanmar

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**Abstract**
The estimation of the biomass and soil carbon content was carried out in the mangrove forest of Magyi coastal area from November 2022 to September 2023. Three species of mangroves; *Rhizophora apiculata, Bruguiera gymnorhiza,* and *Ceriops tagal* were identified. In the present study, the highest value of aboveground biomass 953.24 g was recorded in plot 7 (transect III) however the lowest one was 17.15 g in plot 9 (transect II). The highest value of belowground biomass was 512.88 g in plot 1 (transect IV) but the lowest one was 2.36 g in plot 9 (transect II). The organic carbon content 172.51 kgm$^{-3}$ was found to be highest in plot 8 (transect III) however the lowest one was 50.04 kgm$^{-3}$ in plot 9 (transect II). The average aboveground, and belowground biomass and organic carbon content at transect III is more than in transects I, II, IV, and V. The highest average bulk density, 0.86 gcm$^{-3}$, was observed in plot 1 (transect III), however, the lowest one was 0.42 gcm$^{-3}$ in plot 3 (transect V).

**Keywords**
Aboveground biomass, belowground biomass, organic carbon, carbon content, bulk density

## 1. Introduction

Mangroves are keystone ecosystems providing numerous environmental services and critical ecological functions. These ecosystems are highly productive and rich in flora and fauna biodiversity. They are home to many aquatic species, and it is well known that most of the commercially important fin and shellfish species spend at least part of their life cycle in these ecosystems, which serve an important role in supporting coastal food webs and nutrient cycles in the adjacent coastal ecosystems (Vinod et al., 2018).

Blue carbon is the carbon stored in mangroves, salt tidal marshes, and seagrass meadows within the soil, the living biomass aboveground (leaves, branches, stems), the living biomass belowground (roots), and the non-living biomass (e.g., litter and dead wood).

Similar to the carbon stored in terrestrial ecosystems, blue carbon is sequestered in living plant biomass for relatively short time scales (years to decades). Unlike terrestrial ecosystems, carbon sequestered in coastal soils can be extensive and remain trapped for a very long period (centuries to millennia) (Howard et al. 2014).

The concentration of total carbon is the most vital parameter in describing the organic matter abundance and the inorganic carbon in soils, sediments, and vegetation (Kauffman et al., 2012). The distribution of organic matter in sediments occurs in almost all of the tropical, subtropical, terrestrial, and aquatic environments (Daniel et al., 2011).

The objectives of this study are to estimate the aboveground and belowground biomass and to measure the bulk density and carbon content of the mangrove forest in Magyi Coastal Area.

## 2. Materials and Methods

### *2.1. Study Area*

The present study was focused on biomass and soil carbon content of the Magyi mangrove area (Latitude 17°03' 30.85"N

Longitude 094° 27' 44.85"E to Latitude 17°04' 09.53"N Longitude 094° 27' 54.84") located in the Shwe Thaung Yan coastal area, Ayeyarwady Region, Myanmar from November 2022 to September 2023. Three species of mangrove plants (*Rhizophora apiculata, Bruguiera gymnorhiza,* and *Ceriops tagal*) have restored the study areas (Fig 1).

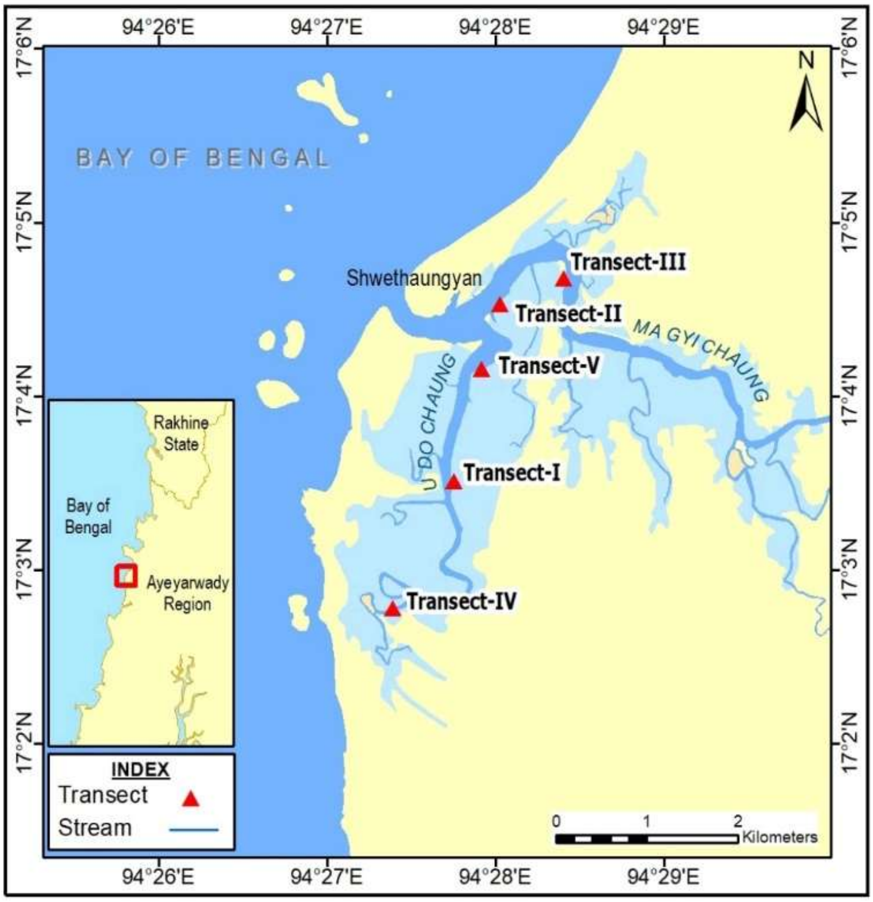


Fig. 1. Map showing the location of five transects in Magyi Coastal Area

### *2.2. Sampling Design*

In the present study, the line intercept transects method (LIT) was based on the Point Centered Quarter Method (PCQM) and then the random stratified sampling method was used. The locations of the sampling areas were marked by using GPS devices. Transect plots were set using measuring tape from the starting point and setting the center when it reached 15 m. Once it has reached the center of four compass directions (N, E, W, S) divide the sampling site into four quarters such as A, B, C, and D. The total length of each transect was 150 m and 10 plots. In each quarter, an adult mangrove plant which is the closest to this center point is chosen to measure. Distance from the center point to the tree was noted, as indices identification, height, and circumference were measured.

### *2.3. Soil Sample Collection and Processing*

The soil sample was collected by using a soil core sampler along the transect line. The soil samples were taken from three depths (30 cm, 60 cm, and 90 cm) within the plot using the soil core sampler and stored in a clean plastic bottle and mended with sticky tape to prevent oxidization and bacterial action. Totally 150 soil sample bottles were carried to the Laboratory of Marine Science Department, Pathein University for further analysis.

After collecting the soil sample, for the measurement of carbon content, 4.15 cm × 2.55 cm (diameter × length) was cut from soil samples and weighed using a digital balance to obtain the initial weight. The soil samples were placed in the crucial cup and dried at 80 ℃ by using the oven (DKN 400). The processing of drying and weighing was repeated to reach a constant weight. And then, the sample was baked again at 500℃ until it got its constant weight in the muffle furnace (Fig. 2).

### *2.4. Aboveground and Belowground Biomass*

The stem diameter and height of mangrove plants were measured. The stem diameter was measured above the first branch of the plants. Allometric equations for computing biomass of mangrove trees were only parameters of stem diameter and wood density. To determine the biomass of mangrove trees, existing allometric equations are applied. Accurate species identification is important as it allows the selection of the most appropriate allometric equation for each measured individual mangrove tree. This equation developed by Komiyama et al. (2005) for mangrove species in southeast Asia was used for the estimation of aboveground biomass (AGB) and belowground biomass (BGB).

$$W_{top} = 0.251 * \rho * (D)^{2.46} \quad (1)$$

$$W_R = 0.199*\rho^{0.899} *(D)^{2.2} \quad (2)$$

where; $W_{top}$ is the aboveground biomass, $W_R$ is the belowground biomass, ρ is the wood density of the respective species and $D$ is the diameter at breast height (DBH). The wood density values are the average wood density for each species (based on studies from Southeast Asia) derived from the World Agroforestry Database Chave et al. (2009).


Fig. 2. Soil sample collection processing: A) Soil sub-sampling, B) Stored in a clean plastic bottle, C) Full sample, D) Weighing subsample, E) Drying with oven and F) Muffle furnace

### *2.5. The Basis (Loss on Ignition (LOI) Method for Soil Sample*

Determining of weight percent of organic carbon content in soil samples using LOI based on sequential heating of the samples in a muffle furnace. After oven, drying of the soil to constantly weight organic matter is combusted in a first step to ash and carbon dioxide at a corresponding temperature.

The organic carbon content was determined with the following procedure in the laboratory.

1. Full soil sample was weighed, and then, half of the samples were cut for sub-sample.
2. The sub-sample was dried in the oven at 80°C for about 3 hours to 8 hours to get to the constant dry weight.
3. After that, the dry sub-samples were put into the muffle furnace with a temperature of about 500°C, it takes about 3 hours to 4 hours to get constant weight.
4. Calculate the organic carbon content of the soil sample.

The LOI is calculated by using the following equation: Howard et al. (2014).

$$\%LOI = \text{Dry mass before combustion-dry mass after combustion} / \text{Dry mass before combustion} \times 100 \quad (3)$$

### *2.6. Estimation of Bulk Density*

For the estimation of bulk density, the soil samples were placed in the crucial cup dried at 80 °C and weighed. The bulk density was calculated as the ratio of the dry mass of the soil sample to its volume according to Cadiz et al. (2020).

$$\text{Dry bulk density } (gcm^3) = \text{Mass of dry soil } (g) / \text{Original volume sampled } (cm^3) \quad (4)$$

### *2.7. The Classification of Mangrove Plants*

Phylum: Magnoliophyta
- Class: Magnoliospida
  - Order: Rhizophorales
    - Family: Rhizophoraceae
      - Genus: *Rhizophora*
        - Species: 1. *Rhizophora apiculata* (Fig. 3A)
      - Genus: *Bruguiera*
        - Species: 2. *Bruguiera gymnorhiza* (Fig. 3B)
      - Genus: *Ceriops*
        - Species: 3. *Ceriops tagal* (Fig. 3C)

The relationship between % LOI and $\%C_{org}$ for mangroves is

$$\%C_{org} = 0.415 \times \%LOI + 2.89 \quad (5)$$

## 3. Results and Discussion

### *3.1. Biomass of Mangrove*

In transect I, the highest value of aboveground biomass was 765.59 g in plot 1 however the lowest one was 25.59 g in plot 5. The highest value of belowground biomass was 442.69 g in plot 1 but the lowest one was 17.58 g in plot 4. In transect II, the highest value of aboveground biomass was 805.05 g in plot 5 however the lowest one was 17.15 g in plot 9. The highest value of belowground biomass was 430.54 g in plot 5 but the lowest one was 2.36 g in plot 9. In transect III, the highest value of aboveground biomass was 953.24 g in plot 7 however the lowest one was 269.92 g in plot 2. The highest value of belowground biomass was 499.59 g in plot 5 but the lowest one was 156.1 g in plot 2. In transect IV, the highest value of aboveground biomass was 868.68 g in plot 1 however the lowest one was 49.06 g in plot 9. The highest value of belowground biomass was 512.88 g in plot 1 but the lowest one was 83.57 g in plot 9. In transect V, the highest value of aboveground biomass was 596.84 g in plot 8 however the lowest one was 38.09 g in plot 9. The highest value of belowground biomass was 316.92 g in plot 8 but the lowest one was 25.23 g in plot 9 (Table 1).


Fig. 3. Habit of mangrove species: A) *Rhizophora apiculate*, B) *Bruguiera gymnorhiza* and C) *Ceriops tagal*

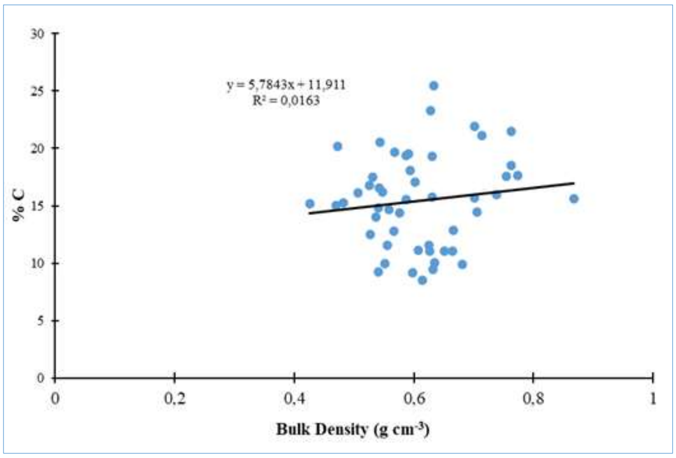


Fig. 4. Relationship of soil bulk density and %C in transects Mangyi mangrove forest

### *3.2. Comparison of Average Aboveground and Belowground Biomass of Transect I, II, III, IV and V*

The results of average aboveground biomass in transects I, II, III, IV and V were 226.04 g, 383.19 g, 569.80 g, 420.31 g, and 247.28 g. The highest average aboveground biomass was 569.80 g in transect III, however, the lowest one was 226.04 g in transect I.

The average belowground biomass in transects I, II, III, IV and V was 128.06 g, 201.30 g, 297.01 g, 256.70 g, and 136.23 g. The highest average belowground biomass was 297.01 g in transect III but the lowest one was 128.06 g in transect I (Table 1 and Fig. 5).

### *3.3. Estimation of Organic Matter (% C) for Transect I, II, III, IV and V*

In transect I, the highest value of organic matter was 25.24% in plot 5 however the lowest one was 12.82% in plot 9. In transect II, the highest value of organic matter was 19.39% in plot 1 however the lowest one was 9.15% in plot 8. In transect III, the highest value of organic matter was 21.93% in plot 4 however the lowest one was 11.58% in plot 10.

In transect IV, the highest value of organic matter was 17.05% in plot 1 however the lowest one was 8.55% in plot 3. In transect V, the highest value of organic matter was 20.18% in plot 4 however the lowest one was 14.35% in plot 1 (Table 2 and Fig. 6).

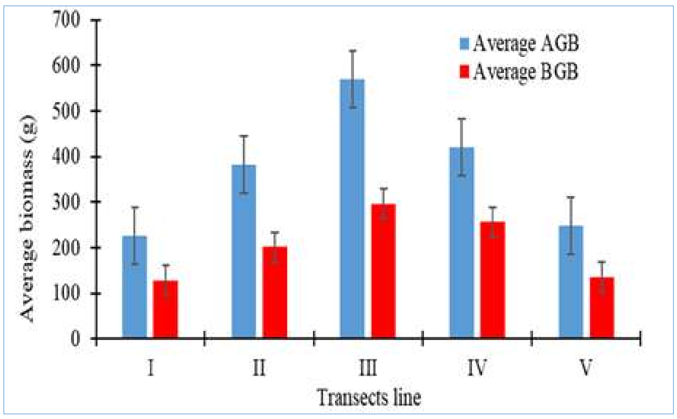


Fig. 5. Comparison of average aboveground and belowground biomass of transects I, II, III, IV and V

### 3.4. Comparison of Average Organic Matter (% C) of Transect I, II, III, IV and V

The results of average organic matter (% C) in transects I, II, III, IV, and V were 18.79%, 11.60%, 17.99%, 12.82%, and 15.98%. The highest average organic matter (% C) was 18.79% in transect I but the lowest one was 11.60 %in transect II (Table 2 and Fig. 6).

### 3.5. Estimation of Organic Carbon Content for Transect I, II, III, IV and V

The result of soil carbon content in transect I, the highest soil carbon content was 161.23 $kgm^{-3}$ in plot 5, however, the lowest one was 64.39 $kgm^{-3}$ in plot 9. In transect II, the highest soil carbon content was 111.99 $kgm^{-3}$ in plot 1 and the lowest soil carbon content was 50.04 $kgm^{-3}$ in plot 9.

In transect IV, the highest soil carbon content was 102.65 $kgm^{-3}$ in plot 1 and the lowest soil carbon content was 51.45 $kgm^{-3}$ in plot 3. In transect V, the highest soil carbon content was 92.95 $kgm^{-3}$ in plot 10 and the lowest soil carbon content was 63.73 $kgm^{-3}$ in plot 3. Comparison of average organic carbon content in transects I, II, III, IV, and V were 117.41±28.12 $kgm^{-3}$, 68.6±17.16 $kgm^{-3}$, 126.04±29.98 $kgm^{-3}$, 78.16±19.84 $kgm^{-3}$, and 79.65±9.93 $kgm^{-3}$. The highest average organic carbon was in transect III however the lowest one was in transect II (Table 3 and Fig. 7).

Table 1. Aboveground and belowground biomass (g) of transects I, II, III, IV and V

| Plot | Transect I | | Transect II | | Transect III | | Transect IV | | Transect V | |
|---|---|---|---|---|---|---|---|---|---|---|
| | ABG | BGB | ABG | BGB | ABG | BGB | ABG | BGB | ABG | BGB |
| Plot 1 | 765.59 | 442.69 | 704.66 | 356.10 | 939.20 | 456.00 | 868.68 | 512.88 | 211.36 | 121.20 |
| Plot 2 | 77.23 | 48.11 | 688.48 | 340.60 | 269.92 | 156.10 | 271.52 | 211.75 | 177.88 | 101.65 |
| Plot 3 | 162.34 | 91.71 | 82.26 | 50.49 | 548.82 | 300.29 | 369.39 | 158.36 | 277.42 | 156.99 |
| Plot 4 | 26.17 | 17.58 | 527.39 | 292.33 | 284.46 | 165.59 | 499.86 | 280.28 | 417.91 | 219.37 |
| Plot 5 | 25.59 | 18.09 | 805.05 | 430.54 | 952.38 | 499.59 | 212.36 | 125.03 | 151.39 | 85.02 |
| Plot 6 | 77.28 | 47.15 | 272.61 | 157.13 | 468.44 | 174.54 | 481.34 | 293.25 | 57.22 | 163.18 |
| Plot 7 | 432.63 | 229.47 | 87.36 | 49.92 | 953.24 | 481.60 | 548.23 | 309.35 | 305.10 | 35.25 |
| Plot 8 | 76.22 | 45.36 | 582.78 | 293.48 | 286.00 | 160.74 | 704.42 | 474.65 | 596.84 | 316.92 |
| Plot 9 | 400.32 | 217.35 | 17.15 | 2.36 | 289.59 | 166.91 | 49.06 | 83.57 | 38.09 | 25.23 |
| Plot 10 | 217.07 | 123.10 | 64.25 | 40.12 | 705.95 | 408.70 | 198.30 | 117.90 | 239.66 | 137.55 |
| Average | 226.04 | 128.06 | 383.19 | 201.30 | 569.80 | 297.01 | 420.31 | 256.70 | 247.28 | 136.23 |

Table 2. Estimation of organic matter (% C) for transects I, II, III, IV and V

| Plot | Organic matter (%C) | | | | |
|---|---|---|---|---|---|
| | Transect I | Transect II | Transect III | Transect IV | Transect V |
| Plot 1 | 15.66 | 19.39 | 15.63 | 17.05 | 14.35 |
| Plot 2 | 18.05 | 11.05 | 19.63 | 11.09 | 14.82 |
| Plot 3 | 16.58 | 9.42 | 15.57 | 8.55 | 15.21 |
| Plot 4 | 20.52 | 11.05 | 21.93 | 15.75 | 20.18 |
| Plot 5 | 25.44 | 10.04 | 19.33 | 14.48 | 15.26 |
| Plot 6 | 19.54 | 11.58 | 15.99 | 9.89 | 15.00 |
| Plot 7 | 17.55 | 11.08 | 17.63 | 16.16 | 16.11 |
| Plot 8 | 23.29 | 9.15 | 21.48 | 12.85 | 14.65 |
| Plot 9 | 12.82 | 9.27 | 21.13 | 12.5 | 16.76 |
| Plot 10 | 18.50 | 13.98 | 11.58 | 9.93 | 17.48 |
| Average | 18.79 ±3.65 | 11.60 ±3.08 | 17.99 ±3.31 | 12.82 ±2.95 | 15.98 ±1.77 |

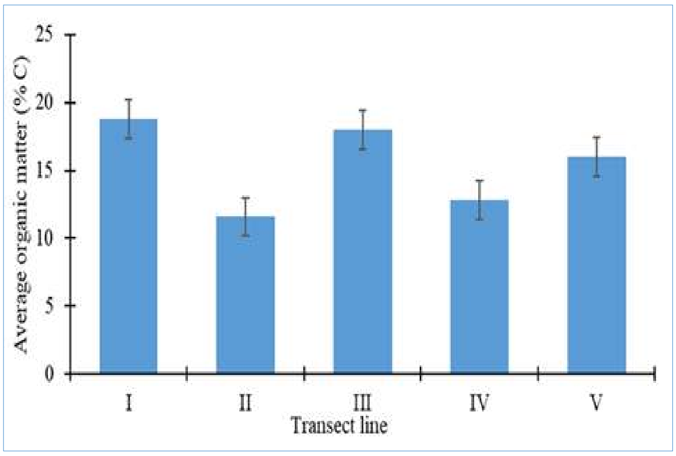


Fig. 6. Comparison of average organic matter (%C) of transects in Magyi coastal area

### 3.6. Bulk Density Estimation for Transect I, II, III, IV and V

In transect I, the highest bulk density was 0.76 $gcm^{-3}$ in plot 10. However, the lowest one was 0.54 $gcm^{-3}$ in plot 3 and 4. In transect II, the highest bulk density was 0.66 $gcm^{-3}$ in plot 2. However, the lowest one was 0.53 $gcm^{-3}$ in plot 10. In transect III, the highest bulk density was 0.86 $gcm^{-3}$ in plot 1, however, the lowest one was 0.56 $gcm^{-3}$ in plot 2. In transect IV, the highest bulk density was 0.7 $gcm^{-3}$ in plot 5, however, the lowest one was 0.52 $gcm^{-3}$ in plot 9. In transect V, the highest bulk density was 0.57 $gcm^{-3}$ in plot 1 but the lowest one was 0.42 $gcm^{-3}$ in plot 3. The highest average bulk density was 0.69±0.04 $gcm^{-3}$ in transect III however the lowest one was 0.59±0.05 $gcm^{-3}$ in transect II (Table 4 and Fig. 8).

### 3.7. Relationship of Soil Bulk Density and %C in Transects

The result showed that positive correlation between soil bulk density and %C content with an 'r' value of 0.13 in transects

Magyi mangrove forest (Fig 4). The biomass varied significantly with spatial locations. The highest biomass can be attributed to the dense stem density of transect III, followed by IV, II, V, and I in the present result (Table 1).

Table 3. Organic Carbon Content in transects I, II, III, IV and V

| Plot | Organic carbon (kg/m$^3$) | | | | |
|---|---|---|---|---|---|
| | Transect I | Transect II | Transect III | Transect IV | Transect V |
| Plot 1 | 108.78 | 111.99 | 132.98 | 102.65 | 77.71 |
| Plot 2 | 107.33 | 69.81 | 111.50 | 67.17 | 78.84 |
| Plot 3 | 88.45 | 58.91 | 89.48 | 51.45 | 63.73 |
| Plot 4 | 115.84 | 71.63 | 153.69 | 100.26 | 95.03 |
| Plot 5 | 161.23 | 63.65 | 120.35 | 101.89 | 74.24 |
| Plot 6 | 113.68 | 62.83 | 117.84 | 66.28 | 68.74 |
| Plot 7 | 132.79 | 67.90 | 136.37 | 87.81 | 81.09 |
| Plot 8 | 144.49 | 53.93 | 172.51 | 85.33 | 76.82 |
| Plot 9 | 64.39 | 50.04 | 151.70 | 65.24 | 87.30 |
| Plot 10 | 137.12 | 75.31 | 73.99 | 53.52 | 92.95 |
| Average | 117.41±28.12 | 68.6±17.16 | 126.04±29.98 | 78.16±19.84 | 79.65±9.93 |

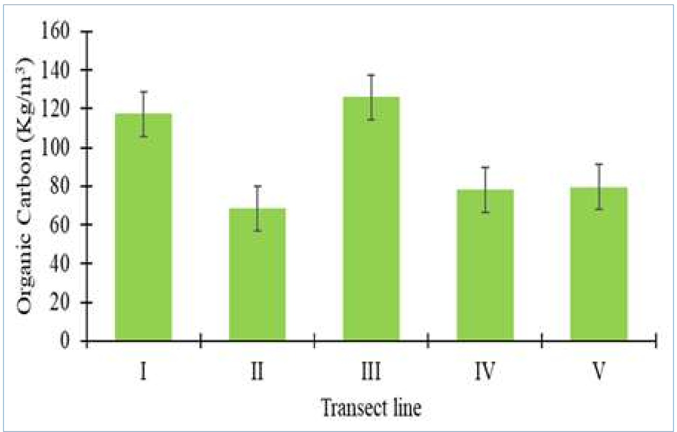


Fig. 7. Comparison of average organic carbon content in transects I, II, III, IV and V

Transects II, III, and V represented the mouth part of the tidal creek whereas the middle part was in transects I and IV. In transect, I, only two species of *Bruguiera gymnorhiza* and *Ceriops tagal* were found. However, *Rhizophora apiculata, Bruguiera gymnorhiza*, and *Ceriops tagal* were recorded in transect II, III, IV, and V (Fig. 1). Comparison of the five transects, the average aboveground and belowground biomass in transect III had the highest amount of biomass, followed by transect IV, transect II, transect V, and transect I (Table 1 and Fig 5).

Alimedia et al. (2014) described the higher biomass observed in plots with high density of adult trees. This result was the same as to present result. Savari et al. (2020) described the most biomass in station 3 as situated in the low intertidal zone from the Gulf of Oman. This result was similar to the present study. The finding of the present study was similar to the report of Harishma et al. (2020) in which the biomass values indicated a very high variability across different patches in different zones.

Table 4. Bulk density estimation for transects I, II, III, IV and V

| Transect | Bulk density (g/cm$^3$) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Plot 1 | Plot 2 | Plot 3 | Plot 4 | Plot 5 | Plot 6 | Plot 7 | Plot 8 | Plot 9 | Plot 10 | Average |
| I | 0.70 | 0.59 | 0.54 | 0.54 | 0.63 | 0.59 | 0.75 | 0.62 | 0.56 | 0.76 | 0.63±0.08 |
| II | 0.58 | 0.66 | 0.63 | 0.65 | 0.63 | 0.55 | 0.62 | 0.59 | 0.54 | 0.53 | 0.59±0.05 |
| III | 0.86 | 0.56 | 0.58 | 0.70 | 0.63 | 0.73 | 0.77 | 0.76 | 0.71 | 0.62 | 0.69±0.04 |
| IV | 0.60 | 0.60 | 0.61 | 0.63 | 0.70 | 0.68 | 0.54 | 0.66 | 0.52 | 0.55 | 0.61±0.06 |
| V | 0.57 | 0.54 | 0.42 | 0.47 | 0.48 | 0.47 | 0.51 | 0.55 | 0.52 | 0.53 | 0.60±0.05 |

The biomass varied significantly with spatial locations. The highest biomass can be attributed to the dense stem density of transect III, followed by IV, II, V, and I in the present result (Table 1). Transects II, III, and V represented the mouthpart of the tidal creek whereas the middle part was in transects I and IV. In transect, I, only two species of *Bruguiera gymnorhiza* and *Ceriops tagal* were found. However, *Rhizophora apiculata, Bruguiera gymnorhiza*, and *Ceriops tagal* were recorded in transect II, III, IV, and V (Fig 1). Comparison of the five transects, the average aboveground and belowground biomass in transect III had the highest amount of biomass, followed by transect IV, transect II, transect V, and transect I (Table 1 and Fig 5). Alimedia et al. (2014) described the higher biomass observed in plots with high density of adult trees. This result was the same as the present result. Savari et al. (2020) described the most biomass in station 3 as situated in the low intertidal zone from the Gulf of Oman. This result was similar to the present study. The finding of the present study was similar to the report of Harishma et al. (2020) in which the biomass values indicated a very high variability across different patches in different zones.

Comparing the average carbon content of five transects, transect III was more than other transects (Table 3 and Fig 7) because it is located at the mouth of the river, non-timber forest products have soil conservation, protecting coastal areas from cyclones and storms and providing livelihoods to local people. Meng et al. (2021) described the positive relationship between above- and below-ground carbon stocks in mangrove forests. This result was similar to the present study. In the present study, the highest bulk density was 0.86 $gcm^{-3}$ in plot 3, transect I but in transect II the lowest one was 0.42 $gcm^{-3}$ in plot 3 (Table 4 and Fig 8).

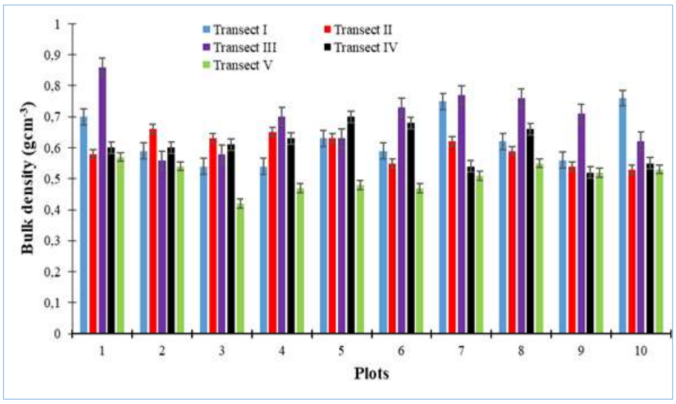


Fig. 8. Bulk density estimation for transects I, II, III, IV, and V

Lin (2022) reported that the value of total average soil bulk density was 1.13 $gcm^{-3}$ from Sepala mangrove, Bilu island, Mon coastal area, and Pricillia et al. (2021) described 1.10 $gcm^{-3}$ from Nusa Lembongan, Bali, Indonesia. These results were more than the present result (0.63 $gcm^{-3}$). Sasmito et al. (2020) described 0.3 - 0.9 $gcm^{-3}$ from Binturni Bay; 0.90 $gcm^{-3}$ in northern Vietnam (Tinh et al., 2020); 0.69 $gcm^{-3}$ in Segara Anakan (Kusumaningtyasa et al., 2019) and these results were nearly similar to the present result. Harishma et al. (2020) described that the bulk density and organic carbon storage in the mangrove systems were found to be inversely correlated however, it was a positive relationship in the present study. Effective action on climate change will require a combination of emissions reduction and carbon sequestration, protecting, enhancing, and restoring natural carbon sinks have become political priorities (Sanderman et al., 2018).

## 4. Conclusion

From the estimation of the biomass and soil carbon content of the mangrove forest Magyi, Shwe Thaung Yan coastal area, the highest aboveground, and belowground biomass and organic carbon content were recorded in transect III. In general, the mangrove forest of transect III can be concluded as good condition in the study sites. Bulk density was positively related to organic matter (%C) in transects. Biomass was also positively related to organic carbon content ($gcm^{-3}$). The soil carbon content was found to be depending on the soil type, pH, and salinity. The information on the organic carbon accumulation in the mangrove soil can be supported by climatic mitigation activities.

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