AN ASSESSMENT OF PHOTOSYNTHETIC BIOMASS RELATED TO THE MANGROVE SPECIES FROM THE SHWE THAUNG YAN COASTAL AREA

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DECLARATION

This is to certify that the material contained in this research is the work of the author except where otherwise acknowledged and has not been accepted for the award of any other degree in diploma.

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ABSTRACT

An assessment of the Photosynthetic Biomass related to the mangrove species from the Shwe Thaung Yan coastal areas in order to determine the oxygen restoration rate of the plants has been carried out. **Earth Restoration Method for Value Setting of Photosynthetic Biomass** was used in the present study. The method was based on the measurement of aboveground biomass data including tree height, stem diameter, canopy size, leaf size, and leaf weight of selected mangrove species. The determination had been carried out in two different types of mangrove areas - restored mangrove areas and natural mangrove areas so as to compare the amount of Photosynthetic Biomass. The results derived from the measurement of aboveground biomass data shows the highest accumulation of photosynthetic biomass component was observed in *Bruguiera gymnorhiza* for both restored (725.20 g) and natural mangroves (610 g). *Ceriops tagal* represented the lowest accumulation (477.50 g) for restored mangrove in contrast with *Rhizophora apiculata* (272.22 g) which shows the lowest accumulation for natural mangrove. All of the selected species have a positive correlation of photosynthetic biomass with age. Besides, the relationship between oxygen production and water production with the age of selected individual species also shows a positive relationship. The exponential increase of restored mangrove was observed after the age of 3 years while natural mangrove was observed after the height class of 5-6 ft.

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CHAPTER 1

INTRODUCTION

Photosynthesis is a process by which green plants use solar energy to convert carbon dioxide and water into energy in the form of carbohydrates. These energy-rich organic substances become a source of potential energy for the plant to make all the other complex compounds that it needs to live, grow and reproduce. Excess glucose is stored in the leaves, stems, and roots of the plant. The stored glucose provides food for higher organisms that eat the plants. This process is vital to the survival of ecosystems for two reasons. First, photosynthesis provides the energy that is used by all other organisms to survive. Second, photosynthesis removes carbon dioxide from the atmosphere, replacing it with life-sustaining oxygen.

In the photosynthesis process, light energy, water, carbon dioxide, and chlorophyll play as basic reactants. On the other hand, this process produces three key products – carbohydrates, oxygen, and water. Hence, photosynthesis can be summarized by the following equation -

$$12\ H_2O\ +\ 6\ CO_2 \xrightarrow[\text{Chlorophyll}]{\text{Sunlight}} C_6H_{12}O_6\ +\ 6\ O_2\ +\ 6\ H_2O$$

The energy of all living things on earth comes from the sun. It is the original energy source for all ecosystems. This light energy is captured by green plants using chloroplasts, which contain a green pigment called chlorophyll, to convert it into energy through the process of photosynthesis. Chlorophyll is the major class of photosynthetic pigments found in plants.

While light is essential to photosynthesis, not all wavelengths are equally effective in stimulating the process. Light can be effective only to the degree that the chlorophyll can absorb it and put it work. Chlorophyll absorbs the light of particular wavelengths (Alvin Nason and Philip Goldstein, 1969). Red light is the most effective in stimulating photosynthesis and blue light is the next (Engelmann, 1880). If the light is reflected without being captured, it can not act as a source of energy. Green is the only color in the spectrum of light that chlorophyll does not absorb and it is reflected off of the plant, resulting in the green color characteristic of the leaves. Although chlorophyll is always seen as green, there are other pigments that leaves can possess.

Photosynthesis occurred in two steps – the photo phase and the synthesis phase (Blackman, 1905). Both of these phases take place in chloroplasts: light-dependent reactions in the thylakoid and light-independent reactions in the stroma. The first step of photosynthesis, the photo phase requires light and also known as a light-dependent reaction. The photosynthetic pigments allow plants to absorb sunlight, which is needed to start the process. This light splits water molecules into oxygen and hydrogen ions. The oxygen is released into the atmosphere during the photo phase of photosynthesis (Hill, 1937). The remaining hydrogen atoms are sequentially transferred to the next step where glucose is created.

The next step of photosynthesis is the light-independent reaction or synthesis phase (formerly known as a dark reaction) and it does not require light. It is also known as Calvin Cycle and uses transferred hydrogen from the first stage of photosynthesis and carbon from carbon dioxide from the atmosphere to synthesize glucose. The protons from split water and “leftover” O_2 from carbon dioxide react to reform water.

Biomass is simply defined as the total mass of living matter within a given unit of environmental area. Additionally, it is carbon-based and comprises a complex mixture of organic matter such as carbohydrates, fat, and protein along with small amounts of minerals (Brown Sandra, 1997). The life support system of the planet is monitored by such a critical and valuable material namely photosynthetic biomass. Photosynthetic biomass is a type of aboveground biomass where photosynthesis processes take place, conspicuously emphasized on the leave of plants. It also performs the act of primary production, the initial step in the manifestation of life by enhancing carbon sequestration, carbohydrate production, oxygen production, and water transformation. And it increases in mass through the absorption of solar energy while releasing oxygen and water vapor into the atmosphere. Oxygen is a primary material for the sustainability of life. The total amount of atmospheric oxygen is maintained at about 21% volume by the photosynthesis of plants and the phytoplankton of the oceans. The released oxygen is therefore an indication of photosynthesis (Senanayake, R., 1998).

At a water release rate of 100:1, where over 100 molecules of water are released for each molecule of carbon dioxide absorbed by the leaf (Jones, 1973). This quantity of evaporative water not only influences local cooling events greatly but also contributes to the distribution of heat in the atmosphere. The ‘cleaning’ effect on water, releasing groundwater that has been freed of the chemical pollutants that it was once burdened with. The presence of water vapor in the atmosphere can have a direct effect on oxygen concentration in a local area through a process of dilution or displacing other components of air. Leaves are the ideal organs to carry out these functions effectively and also provide another critical element in water cycling (Senanayake, R., 1998).

Mangroves are woody plants that grow at the interface between land and sea in tropical and sub-tropical latitudes. The occurrence of mangroves is largely limited to the regions between 30°N and 30°S of the equator. According to the Global Forest Resources Assessment (FRA) 2020, the area of mangroves in the world is estimated at 14.8 million ha. The estimation of forest cover assessment 2015 states that about 44% of the country's total land area is still covered with natural forests and also describes Myanmar has mangrove area of approximately 4712.4 km^2 (Global Forest Resources Assessment 2020, Country Report, Myanmar).

Mangrove forests are among the most productive ecosystems. The mangal provides tremendous ecosystem services, for example, regulating climate, water purification, and coastal protection. Mangrove forests also stand for recreation, educational opportunities, spiritual and religious contributions, etc. as a non-material benefit from this ecosystem. The forest products and food are also given as provisioning services. The necessary elements for the production of other ecosystem services are supported by supporting services. For example, they support breeding, nursery, and feeding ground for coastal fisheries and production of biomass and life monitoring gaseous oxygen through the process of photosynthesis.

Mangroves show characteristic C3 photosynthesis. Like other plants, photosynthetic rates are strongly affected by environmental conditions such as temperature, light intensity, and carbon dioxide concentration. But mangroves have one more controlling factor of photosynthesis, salinity. Fluctuating soil salinities lead to significantly lower intercellular CO_2 concentration and reduced photosynthesis in scrub forests of south Florida (Lin, G. and Sternberg, L. D. S. L., 1992). The stunted mangroves in these habitats have much lower canopies, more main stems, and smaller leaves than mangroves in fringe forests that experience less salinity variability. Temperature-induced changes in the relative rates of photosynthesis and respiration, in turn, influence overall growth rates. Strong sunlight can also reduce mangrove photosynthesis through the inhibition of Photosystem II (Cheeseman, 1991). Even though the presence of mangrove is in high sunlight tropical environments, their photosynthetic rate saturate at relative low light levels (Kathiresan, K. and Bingham, B. L., 2001).

The world has lost an estimated area of 420 million ha of forest between 1990 and 2020, although the rate slowed over the period. In Asia, deforestation occurred mostly in South and Southeast Asia (1.96 million ha per year). Myanmar was expressed as rank 7 in the list of top ten countries for average net loss of forest area, 2010 - 2020.The annual net change of forest area in Myanmar for the period of 2010-2020 is 289,700 ha/yr (0.96%) (Global Forest Resources Assessment (FRA) 2020). Even though mangrove ecosystems have tremendous value for coastal communities and associated species, they are being drastically degraded by human activities at an alarming rate. Myanmar host a large number of mangrove but most of them are being drastically degraded. This is due to the overexploitation of mangrove forests for energy sources such as charcoal and firewood and conversion into large-scale areas, especially for farming. Myanmar mangroves are reported as some of the most degraded or destroyed mangrove systems in the Indo-Pacific in which prawn and fish ponds are constructed since about 2000 (FAO, The world's mangrove 1980-2005, 2007). Mangrove forests in Myanmar are primarily exploited to supply firewood and charcoal for local. Nearly 35,000 tons of charcoal and 40,000 tons of firewood are annually exported to Yangon from deltaic forest reserves (Than Htay and Saw Han, 1984).

Mangrove vegetation has been restored naturally by the seeds recruitment of animals and water dispersal. However, this rate is not enough to compensate for the degraded areas and the simple solution is to conduct protected mangrove areas or restored mangrove areas. In Myanmar, three protected mangrove areas extend over 12,500 hectares namely Letkokkon (400 ha), Kadonlay Kyun (100 ha), and Meinmahla Kyun (12,000 ha). Besides, Pathein University Mangrove Park (also known as Thor Heyerdahl Climate Park) with an area of 1800 acres was established in June 2015. This is the first mangrove park project in Myanmar and that park is now well established as an important research center with the first mangrove gene bank in the country (WIF, 2015). The recognition and evaluation of photosynthetic biomass must become a primary driver of the restoration process. There are still need to develop the sustainable mangrove restoration site to restore this degraded ecosystem.

An assessment of the photosynthetic biomass related to the species of mangrove was carried out along the Shwe Thaung Yan coastal area. The main objectives of the present study are (a) to assess the photosynthetic biomass in the early stage of three mangrove species - *Bruguier gymnorhiza*, *Ceriops tagal*, and *Rhizophora apiculata* (b) to assess the relationship of photosynthetic biomass with oxygen and water production rate to the atmosphere by the mangrove.

CHAPTER 2

LITERATURE REVIEWS

Nothing was known about photosynthesis until the 17th century when the earliest experiment is initiated by the Belgium scientist, Van Helmont. He performed a simple experiment about the weight gain of the plant. He concluded that plants build their body structure out of ordinary water. The fact that gases also play a part in the lives of plants was not suspected until the time when Joseph Priestley (1772) had discovered that green plants give off oxygen. A few years later, in 1779, Jan Ingen-Housz showed plants could liberate oxygen if they were exposed to sunlight and only the green part of the plant could do this. In 1819, the green coloring matter was named chlorophyll. In 1804, Nicolaus de Saussure made an experiment involving plants and oxygen and he showed that – when they exposed to light, green plants consumed carbon dioxide and gave off oxygen at the same time, the total carbon content of plants could be increased only by carbon dioxide was available, water must play a part in the process too. Theodor Wilhelm Engelmann (1880) investigated that red light was the most effective in stimulating photosynthesis and blue light was second.

Frederick Frost Blackman (1905) demonstrated that photosynthesis occurred in two steps – the photo phase and the synthesis phase. Robin Hill (1937) commenced the initial discoveries of the photo phase and he had drawn two logical conclusions that oxygen is released during the photo phase of photosynthesis and it must come from water (since the experiment was performed in the absence of carbon dioxide). This conclusion is confirmed by the crucial test of a biologist team at the University of California, in 1941. Melvin Ellis Calvin (from 1946 through 1957) founded the essential features of the synthesis phase of photosynthesis and he demonstrated that this process uses hydrogen from the photo phase to build carbohydrates by combining it with carbon dioxide (Alvin Nason and Philip Goldstein, 1969). He won the Nobel prize in chemistry in 1961 after identifying this process.

Most of the relevant references and literature are available from Biology: Introduction to life by Alvin Nason and Philip Goldstein. This book describes the historical background of photosynthesis and also mentions the process of making food in green plants, especially in Unit 5: How Many – Celled Plants Carry On Their Lives.

Many works on the study of mangrove plants have been investigated in Myanmar since many years ago. Many works on the study of mangrove plants of Myanmar have been investigated in Myanmar since many years ago. The earliest works were initiated by Aung Myint and Kyaw Soe (1981) studied the mangrove plants of the Kandone-ka-ni, Main-ma-hla from the Ayeyarwaddy Region in Myanmar. A total of 20 species of true mangrove plants and 27 species of associate were reported. Than Htay and Saw Han (1984) described generally the mangrove forests of Myanmar. They mentioned the growing stock, regeneration yield, method of exploitation, and commercial aspects of mangrove.

Ranil Senanayake (1998) reveals the important function and role of photosynthesis biomass in the life support system in Realizing the Value of Photosynthetic Biomass: The Role of Analog Forestry.The Biology of Mangroves and Mangrove Ecosystems: ADVANCES IN MARINE BIOLOGY VOLUME - 40 (2001) by Kathiresan K. and Bingham B. L. state the broad information about the mangrove ecosystem.

A thesis submitted by Wint Yee Paing (2010) also studied the on the mangrove (Family: Rhizophoraceae) of Magyi Coastal Area. Nan Htwe Htwe Maung (2011) also studied the zonation pattern of mangroves in Magyi tidal creek, Shwe Thaung Yan, Rakhine Coast. Htoo Lwin Aung (2016) studied on the species composition, zonation, and succession of the mangrove community along the Magyi coastal area, Shwe Thaung Yan Sub-Township, based on the mangrove formation of Magyi tidal and U-To tidal creek. Nay San Lin (2018) studied on the species composition and vegetative structure of mangrove forest in Haing Gyi and Nga Yoke Kaung coastal area. There is also rarely available literature concerning the relationship between photosynthetic biomass and mangrove species. In 2019, Earth Restoration PVT LTD conducted the value setting photosynthetic biomass in the early growth stage of mangrove species as a proxy for contributing molecular oxygen and clean water to the atmosphere.

The present study, assessment of photosynthetic biomass related to the mangrove species based on the mangrove formation of the Shwe Thaung Yan coastal area, had been carried out and discussed with those precious references and literature that were mentioned above.

CHAPTER 3

MATERIALS AND METHODS

3.1. Description of the Study Area

The present study was undertaken in restored mangrove areas and natural mangrove areas along the Shwe Thaung Yan coastal area from January to July, 2020. Data collection for the assessment of photosynthetic biomass related to the mangrove species of restored mangrove areas was carried out in different mangrove restoration sites – 2019, 2018, 2017, 2016, and 2015 representing the age of 1, 2, 3, 4, and 5 years. The geographical locations of the restoration sites were – Lat 17.16605000°N and 094.47529833°E for 2019 Restoration Site, Lat 17.15785500°N and 094.51517000°E for 2018 Restoration Site, Lat 17.08106645°N and 094.47019033°E for 2017 Restoration Site, Lat 17.05557000°N and 094.46193000°E for 2016 Restoration Site and Lat 17.07576117°N and 94.46734878°E for 2015 Restoration Site.

Another sampling was also carried out in the natural mangrove forest of Magyi with the height class of 1-2 ft, 3-4 ft, and 5-6 ft. The geographical location of natural mangrove area was Lat 17.06997833° N and Long 094.46332000° E. This study was mainly focused on the data collection of three mangrove species - *Bruguiera gymnorhiza, Ceriops tagal, and Rhizophora apiculata.* These species were commonly used species in the restoration site of those areas.

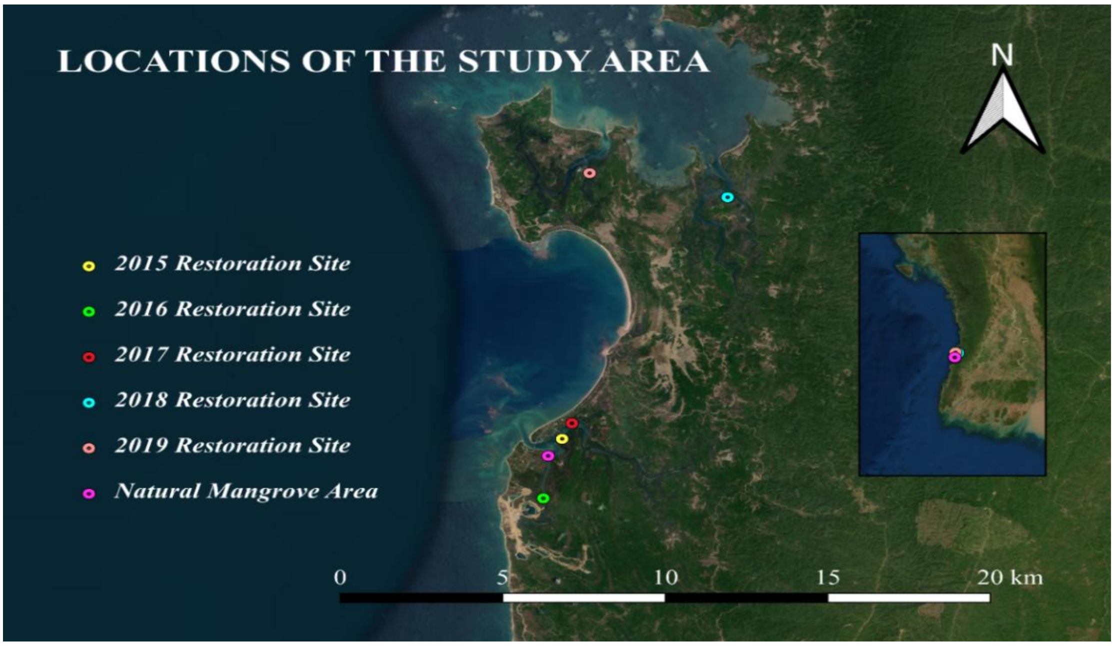


Figure 1. Map showing the locations of the study area, Shwe Thaung Yan Coastal Area, Ayeyarwaddy Region

3.2. Sampling Procedure

Earth restoration method for Value Setting of Photosynthetic Biomass was used in the present study. This method was based on the measurement of aboveground biomass data including - tree height, stem diameter, canopy size (length and width), leave size (length and width), and leave weight. As for the stem diameter, it was measured above the first branch of the plants. Leave weight was calculated by collecting all of the leave from one branch and weighed to multiply with the total number of branches of that plant. From each year or each height class, 10 individuals (a total of 30 individuals) were measured for each selected individual species. The apparatuses that were used in the fieldwork are - measuring tape, vernier caliper, electronic compact scale, and SW Map (mobile mapping app).

3.3. Converting PB Weight into Photosynthetic Efficiency

According to the photosynthetic biomass value was measured the oxygen production, 1g of PB gives 0.4 g of oxygen (Schuurmans *et al.*, 2015). Therefore, the mass of oxygen produced in g (m) = PB * 0.4, and density D = m/V, where m is the mass and V is the volume. Thereby, V = m/D and density of oxygen = 1.429 Kg m $^{-3}$ Where 1m $^{-3}$= 1 L $^{-1}$). Thereby, the volume, V (O_2 production in L) = m (PB * 0.4 grams of oxygen)/D (1.429) (Tagawa *et al.*, 2001). Therefore,

$$\text{V (oxygen production in L)} = \frac{\text{m (PB (g)} \times \text{0.4 g of oxygen)}}{\text{D (1.429 Kg m}^{-3}\text{)}}$$

When considering water production, l g of PB gives 100g of Water (Lam *et al.*, 2008). Mass of water produced in g (m) = PB (g) * 100, and Density D = m/V, where m is the mass and V is the volume. Thereby, V = m/D. Also, the density of Water = 1000 Kg m $^{-3}$ (Robakowski *et al*, 2018). Therefore,

$$\text{V (water production in L)} = \frac{\text{m (PB (g)} \times \text{100 g of water)}}{\text{D (1000 Kg m}^{-3}\text{)}}$$

CHAPTER 4

RESULTS

4.1. Taxonomic classification of the selected species

Phylum: Magnoliophyta

Class: Magnoliospida

Order: Rhizophorales

Family: Rhizophoraceae

Genus: *Bruguiera*

Species: *Bruguiera gymnorhiza* (L.) Lamk, 1797-1798

Burmese name: Byu-oat-saung

Figure 2. Habit of *Bruguiera gymnorhiza*

Description: Tree, height 5-15 m, evergreen, erect, much diffused spreading branches, knee roots prominent, develops short prop root rather than long stilt root. Leaves simple, large, opposite, thick and leathery, glossy green on the upper surface and reddish below, elliptic in shape with short pointed apex. Flower large, single, axillary, solitary, and red in color. Fruit cigar-shaped, stout, dark green to purple-tinted hypocotyl, green, surface smooth, blunt apically, slightly angular.

Phylum: Magnoliophyta

Class: Magnoliospida

Order: Rhizophorales

Family: Rhizophoraceae

Genus: *Ceriops*

Species: *Ceriops tagal* (C. B. Robo, 1908)

Burmese name: Ma-da-ma-gyi

Figure 3. Habit of *Ceriops tagal*

Description: Small to medium tree, buttress root on the trunk base, bark silvery grey to orangish-brown. Leaves opposite, yellowish-green in color, obovate, apex rounded, often flat but slightly rolled back from the margin in some cases. The flowers are white and borne singly in leaf axils, each has a long stalk and a short calyx tube. Fruit green to yellowish-brown, surface warty ridded and grooved, pointed apically.

Phylum: Magnoliophyta

Class: Magnoliospida

Order: Rhizophorales

Family: Rhizophoraceae

Genus: *Rhizophora*

Species: *Rhizophora apiculata* (Blume, 1827)

Burmese name: Byu-chay-tauk-ywet-chon

Figure 4. Habit of *Rhizophora apiculata*

Description: Medium to large size tree, erect, branches spreading profusely, bark brownish to whitish brown or grey. Roots conspicuous, stilt roots extending from the stem and sometimes it has aerial roots from the branches, slightly corky, woody. Leaves opposite, narrowly elliptical, apex apiculate, dark green. Flower yellowish-green, axillary, linear petal arranged in a cross-shaped pattern. Fruit cylindrical, green, relatively smooth, gradually tapering toward the end.

4.2. Photosynthetic Efficiency of Restored Mangrove

The list of the recorded average aboveground biomass data and list of PB weight, oxygen production, and water production of selected individual species of restored mangrove are as follows –

Table 1. Average aboveground biomass data (tree height, stem diameter, canopy size, leaf size, and leaf weight) of *Bruguiera gymnorhiza*

Years	Tree height (m)	Stem diameter (cm)	Canopy size		Leaf size		Leaf weight (g)
			Height (m)	Width (m)	Length (cm)	Width (cm)	
1	0.59	1.26	0.24	0.40	9.28	3.63	59.69
2	0.81	1.40	0.39	0.60	12.26	4.96	179.70
3	1.20	1.72	0.53	0.66	12.88	5.22	445.49
4	1.29	1.82	0.57	0.66	12.07	4.55	634.01
5	1.35	1.96	0.60	0.67	14.04	5.4	725.20

Table 2. Average PB Weight, Oxygen Production, and Water Production of *Bruguiera gymnorhiza*

Years	PB weight (g)	Oxygen production (L)	Water production (L)
1	59.69	16.71	5.97
2	179.70	50.30	17.97
3	445.49	124.70	44.55
4	634.01	177.47	63.40
5	725.20	202.10	72.52

Table 3. Average aboveground biomass data (tree height, stem diameter, canopy size, leaf size, and leaf weight) of *Ceriops tagal*

Years	Tree height (m)	Stem diameter (cm)	Canopy size		Leaf size		Leaf weight (g)
			Height (m)	Width (m)	Length (cm)	Width (cm)	
1	0.65	0.65	0.22	0.36	8.11	4.75	43.55
2	0.81	1.10	0.44	0.45	9.57	5.11	111.75
3	0.85	1.38	0.45	0.48	9.50	5.10	274.46
4	0.94	1.47	0.48	0.50	10.04	5.49	414.50
5	1.02	1.81	0.58	0.62	9.72	4.65	477.50

Table 4. Average PB Weight, Oxygen Production, and Water Production of *Ceriops tagal*

Years	PB weight (g)	Oxygen production (L)	Water production (L)
1	43.55	12.19	4.36
2	111.75	31.28	11.18
3	274.46	76.83	27.45
4	414.50	116.03	41.45
5	477.50	133.66	47.75

Table 5. Average aboveground biomass data (tree height, stem diameter, canopy size, leaf size, and leaf weight) of *Rhizophora apiculata*

Years	Tree height (m)	Stem diameter (cm)	Canopy size		Leaf size		Leaf weight (g)
			Height (m)	Width (m)	Length (cm)	Width (cm)	
1	0.99	1.13	0.30	0.62	11.15	3.96	51.75
2	1	1.44	0.42	0.71	12.58	4.74	149.09
3	1.11	1.66	0.44	0.80	12.35	4.51	397.16
4	1.23	1.74	0.59	0.96	11.95	4.48	450.16
5	1.46	2.69	0.71	0.97	12.88	4.21	659.10

Table 6. Average PB Weight, Oxygen Production, and Water Production of *Rhizophora apiculata*

Years	PB weight (g)	Oxygen production (L)	Water production (L)
1	51.75	14.49	5.18
2	149.09	41.73	14.91
3	397.16	111.17	39.72
4	450.16	126.01	45.02
5	659.10	184.49	65.91

Table 7. Comparison of average Photosynthetic Biomass Weight (g) between the selected species of restored mangrove

Years	Species		
	Bruguiera gymnorhiza	*Ceriops tagal*	*Rhizophora apiculata*
1	59.69	43.55	51.75
2	179.70	111.75	149.09
3	445.49	274.46	397.16
4	634.01	414.50	450.16
5	725.20	477.50	659.10

95% Confidence Interval of average Photosynthetic Biomass of with the age (Years) of *Bruguiera gymnorhiza*

(1) 95% Confidence Interval for average Photosynthetic Biomass of 1 year plants is between 44.2994 g and 75.0805 g where population mean (μ) = 59.69 and standard deviation (s) = 21.5145.

(2) 95% Confidence Interval for average Photosynthetic Biomass of 2 years plants is between 119.1972 g and 240.2028 g where μ = 179.70, s = 84.5771.

(3) 95% Confidence Interval for average Photosynthetic Biomass of 3 years plants is between 339.7673 g and 551.2127 g where μ = 445.49, s = 147.7902.

(4) 95% Confidence Interval for average Photosynthetic Biomass of 4 years plants is between 509.1297 g and 758.8903 g where μ = 634.01, s = 174.5706.

(5) 95% Confidence Interval for average Photosynthetic Biomass of 5 years plants is between 584.3371 g and 866.0629 g where μ = 725.20, s = 196.9128.

95% Confidence Interval of average Photosynthetic Biomass Weight (g) with the age (Years) of *Ceriops tagal*

(1) 95% Confidence Interval for average Photosynthetic Biomass of 1 year plants is between 29.8024 g and 57.2975 g where μ = 43.55, s = 19.2177.

(2) 95% Confidence Interval for average Photosynthetic Biomass of 2 years plants is between 80.1807 g and 143.3193 g where μ = 111.75, s = 44.1307.

(3) 95% Confidence Interval for average Photosynthetic Biomass of 3 years plants is between 211.4019 g and 337.5181 g where μ = 274.46, s = 88.1419.

(4) 95% Confidence Interval for average Photosynthetic Biomass of 4 years plants is between 302.0100 g and 526.9899 g where μ = 414.50, s = 157.2501.

(5) 95% Confidence Interval for average Photosynthetic Biomass of 5 years plants is between 378.7760 g and 576.2240 g where μ = 477.50, s = 138.0066.

95% Confidence Interval of average Photosynthetic Biomass Weight (g) with the age (Years) of *Rhizophora apiculata*

(1) 95% Confidence Interval for average Photosynthetic Biomass of 1 year plants is between 41.0934 g and 62.4065 g where μ = 51.75, s = 14.8967.

(2) 95% Confidence Interval for average Photosynthetic Biomass of 2 years plants is between 114.9927 g and 183.1872 g where μ = 149.09, s = 47.6647.

(3) 95% Confidence Interval for average Photosynthetic Biomass of 3 years plants is between 270.8513 g and 523.4686 g where μ = 397.16, s = 176.5673.

(4) 95% Confidence Interval for average Photosynthetic Biomass of 4 years plants is between 326.6295 g and 573.6904 g where μ = 450.16, s = 172.6836.

(5) 95% Confidence Interval for average Photosynthetic Biomass of 5 years plants is between 521.1263 g and 797.0736 g where μ = 659.10, s = 192.8738.

Table 8. Comparison of average Oxygen Production (L) between the selected species of restored mangrove

Years	Species		
	Bruguiera gymnorhiza	*Ceriops tagal*	*Rhizophora apiculata*
1	16.71	12.19	14.49
2	50.30	31.28	41.73
3	124.70	76.83	111.17
4	177.47	116.03	126.01
5	202.10	133.66	184.49

95% Confidence Interval of average Oxygen Production (L) with the age (Years) of *Bruguiera gymnorhiza*

(1) 95% Confidence Interval for average Oxygen Production of 1 year plants is between 12.4001 L and 21.0162 L where $\mu = 16.71$, $s = 6.0222$.

(2) 95% Confidence Interval for average Oxygen Production of 2 years plants is between 33.3652 L and 67.2366 L where $\mu = 50.30$, $s = 23.6744$.

(3) 95% Confidence Interval for average Oxygen Production of 3 years plants is between 95.1063 L and 154.2933 L where $\mu = 124.70$, $s = 41.3688$.

(4) 95% Confidence Interval for average Oxygen Production of 4 years plants is between 142.5136 L and 212.4256 L where $\mu = 177.47$, $s = 48.8651$.

(5) 95% Confidence Interval for average Oxygen Production of 5 years plants is between 163.5653 L and 242.4249 L where $\mu = 202.10$, $s = 55.1190$.

95% Confidence Interval of average Oxygen Production (L) with the age (Years) of *Ceriops tagal*

(1) 95% Confidence Interval for average Oxygen Production of 1 year plants is between 8.34219 L and 16.0385 L where μ = 12.19, s = 5.3793.

(2) 95% Confidence Interval for average Oxygen Production of 2 years plants is between 22.4439 L and 40.1174 L where μ = 31.28, s = 12.3529.

(3) 95% Confidence Interval for average Oxygen Production of 3 years plants is between 59.1748 L and 94.4767 L where μ = 76.83, s = 24.6743.

(4) 95% Confidence Interval for average Oxygen Production of 4 years plants is between 84.5374 L and 147.5129 L where μ = 116.03, s = 44.0168.

(5) 95% Confidence Interval for average Oxygen Production of 5 years plants is between 106.0254 L and 161.2943 L where μ = 133.66, s = 38.6302.

95% Confidence limit of Oxygen Production (L) with the age (Years) of *Rhizophora apiculata*

(1) 95% Confidence Interval for average Oxygen Production of 1 year plants is between 11.5027 L and 17.4685 L where μ = 14.49, s = 4.1698.

(2) 95% Confidence Interval for average Oxygen Production of 2 years plants is between 32.1883 L and 51.2770 L where μ = 41.73, s = 13.3421.

(3) 95% Confidence Interval for average Oxygen Production of 3 years plants is between 75.8156 L and 146.5272 L where μ = 111.17, s = 49.4240.

(4) 95% Confidence Interval for average Oxygen Production of 4 years plants is between 91.4288 L and 160.5851 L where μ = 126.01, s = 48.3369.

(5) 95% Confidence Interval for average Oxygen Production of 5 years plants is between 145.8716 L and 223.1136 L where μ = 184.49, s = 53.9884.

Table 9. Comparison of average Water Production (L) between the selected species of restored mangrove

Years	Species		
	Bruguiera gymnorhiza	*Ceriops tagal*	*Rhizophora apiculata*
1	5.97	4.36	5.18
2	17.97	11.18	14.91
3	44.55	27.45	39.72
4	63.40	41.45	45.02
5	72.52	47.75	65.91

95% Confidence limit of Water Production (L) with the age (Years) of Bruguiera gymnorhiza

(1) 95% Confidence Interval for average Water Production of 1 year plants is between 4.4299 L and 7.5080 L where $\mu = 5.97$, $s = 2.1514$.

(2) 95% Confidence Interval for average Water Production of 2 years plants is between 11.9197 L and 24.0202 L where $\mu = 17.97$, $s = 8.4577$.

(3) 95% Confidence Interval for average Water Production of 3 years plants is between 33.9767 L and 55.1212 L where $\mu = 44.55$, $s = 14.7790$.

(4) 95% Confidence Interval for average Water Production of 4 years plants is between 50.9129 L and 75.8890 L where $\mu = 63.40$, $s = 17.4570$.

(5) 95% Confidence Interval for average Water Production of 5 years plants is between 58.4337 L and 86.6062 L where $\mu = 72.52$, $s = 19.6912$.

95% Confidence limit of Water Production (L) with the age (Years) of *Ceriops tagal*

(1) 95% Confidence Interval for average Water Production of 1 year plants is between 2.9802 L and 5.7297 L where $\mu = 4.36$, $s = 1.9217$.

(2) 95% Confidence Interval for average Water Production of 2 years plants is between 8.0180 L and 14.3319 L where $\mu = 11.18$, $s = 4.4130$.

(3) 95% Confidence Interval for average Water Production of 3 years plants is between 21.1402 L and 33.7518 L where $\mu = 27.45$, $s = 8.8149$.

(4) 95% Confidence Interval for average Water Production of 4 years plants is between 30.2010 L and 52.6989 L where $\mu = 41.45$, $s = 15.7250$.

(5) 95% Confidence Interval for average Water Production of 5 years plants is between 37.8776 L and 57.6224 L where $\mu = 47.75$, $s = 13.8006$.

95% Confidence limit of Water Production (L) with the age (Years) of *Rhizophora apiculata*

(1) 95% Confidence Interval for average Water Production of 1 year plants is between 4.1093 L and 5.7297 L where $\mu = 5.18$, $s = 1.4896$.

(2) 95% Confidence Interval for average Water Production of 2 years plants is between 11.4992 L and 18.3187 L where $\mu = 14.91$, $s = 4.7664$.

(3) 95% Confidence Interval for average Water Production of 3 years plants is between 27.0851 L and 52.3468 L where $\mu = 39.72$, $s = 17.6567$.

(4) 95% Confidence Interval for average Water Production of 4 years plants is between 32.6629 L and 57.3690 L where $\mu = 45.02$, $s = 17.2683$.

(5) 95% Confidence Interval for average Water Production of 5 years plants is between 52.1126 L and 79.7073 L where $\mu = 65.91$, $s = 19.2873$.

4.2.1. Relationship between Photosynthetic Biomass and the age of restored mangrove

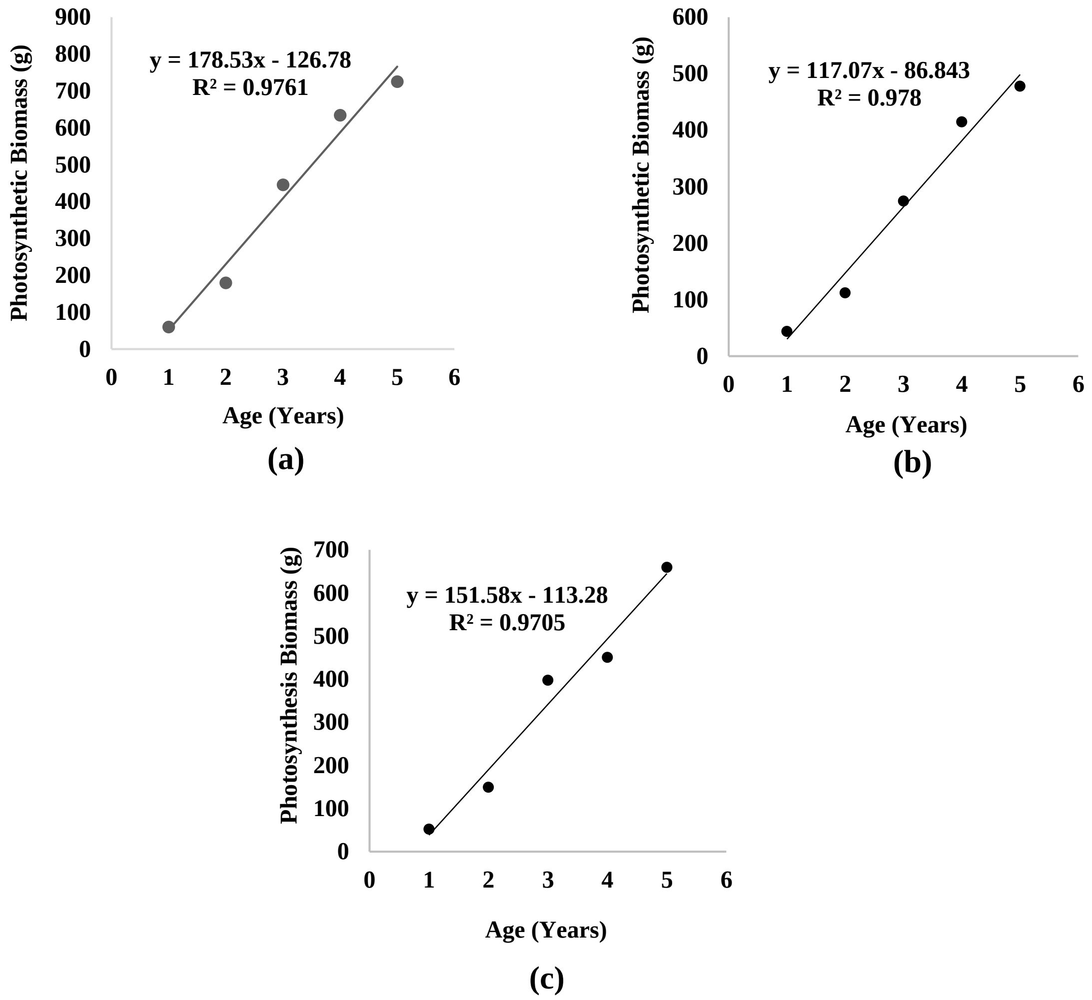
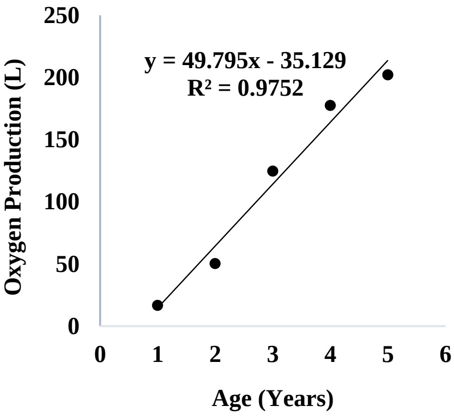


Figure 5. Relationship between Photosynthetic Biomass and the age of restored mangrove (a. *Bruguiera gymnorhiza*, b. *Ceriops tagal*, c. *Rhizophora apiculata*)

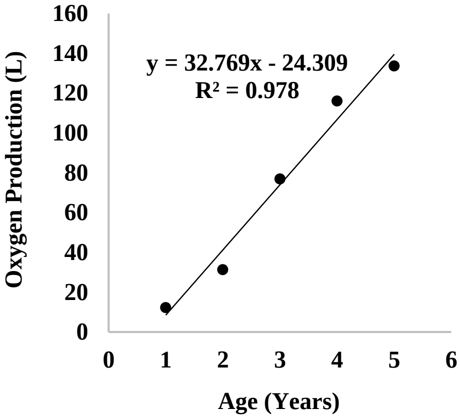
Table 10. Regression Factors between the Photosynthetic Biomass component of the selected species and selected factors of age

Species	R^2	Equation	Slope (b)
Bruguiera gymnorhiza	0.9761	y = 178.53x - 126.78	178.53
Ceriops tagal	0.9780	y = 117.07x - 86.843	117.07
Rhizophora apiculata	0.9705	y = 151.58x - 113.28	151.58

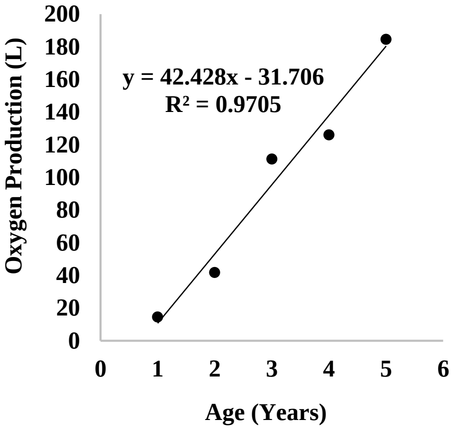
4.2.2. Relationship between oxygen production and the age of restored mangrove



(a)



(b)



(c)

Figure 6. Relationship between Oxygen Production and the age of restored mangrove (a. *Bruguiera gymnorhiza*, b. *Ceriops tagal*, c. *Rhizophora apiculata*)

Table 11. Regression Factors between the Oxygen Production of the selected species and selected factors of age

Species	R^2	Equation	Slope (b)
Bruguiera gymnorhiza	0.9752	y = 49.795x - 35.129	49.795
Ceriops tagal	0.9780	y = 32.769x - 24.309	32.769
Rhizophora apiculata	0.9705	y = 42.428x - 31.706	42.428

4.2.3. Relationship between water production and the age of restored mangrove

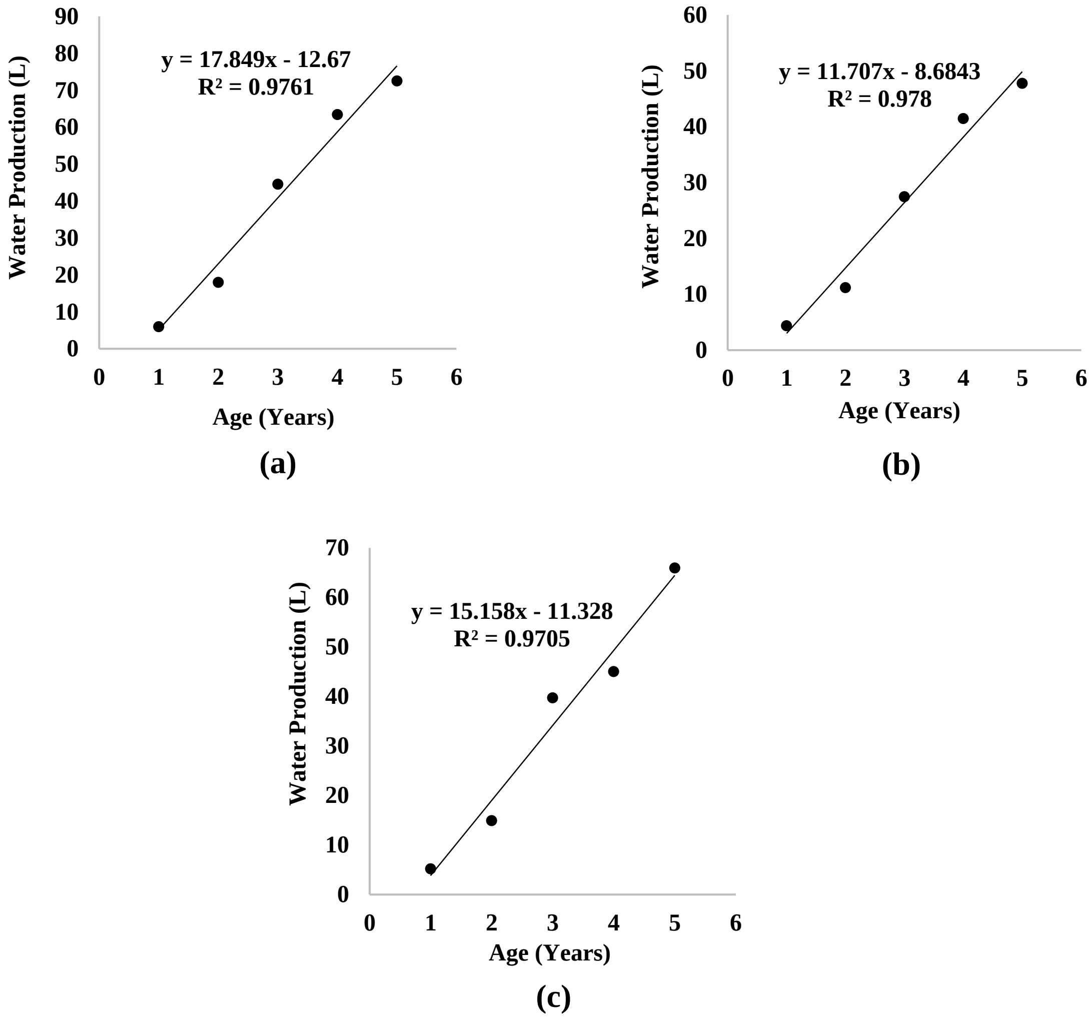


Figure 7. Relationship between Water Production and the age of restored mangrove (a. *Bruguiera gymnorhiza*, b. *Ceriops tagal*, c. *Rhizophora apiculata*)

Table 12. Regression Factors between the Water Production of the selected species and selected factors of age

Species	R^2	Equation	Slope (b)
Bruguiera gymnorhiza	0.9761	y = 17.849x - 12.670	17.849
Ceriops tagal	0.9780	y = 11.707x - 8.6843	11.707
Rhizophora apiculata	0.9705	y = 15.158x - 11.328	15.158

4.3. Photosynthetic Efficiency of Natural Mangrove

The list of the recorded average aboveground biomass data and list of PB weight, oxygen production, and water production of selected individual species of natural mangrove are as follows –

Table 13. Average aboveground biomass data (tree height, stem diameter, canopy size, leaf size, and leaf weight) of *Bruguiera gymnorhiza*

Height class	Tree height (m)	Stem diameter (cm)	Canopy size		Leaf size		Leaf weight (g)
			Height (m)	Width (m)	Length (cm)	Width (cm)	
1-2 ft	0.52	0.35	0.14	0.22	8.56	3.49	12.32
3-4 ft	1.07	1.39	0.37	0.58	11.96	5.15	237.75
5-6 ft	1.67	1.97	0.61	0.81	11.31	4.85	610

Table 14. Average PB Weight, Oxygen Production, and Water Production of *Bruguiera gymnorhiza*

Height class	PB weight (g)	Oxygen production (L)	Water production (L)
1-2 ft	12.32	3.45	1.23
3-4 ft	237.75	66.55	23.77
5-6 ft	610	170.75	61

Table 15. Average aboveground biomass data (tree height, stem diameter, canopy size, leaf size, and leaf weight) of *Ceriops tagal*

Height class	Tree height (m)	Stem diameter (cm)	Canopy size		Leaf size		Leaf weight (g)
			Height (m)	Width (m)	Length (cm)	Width (cm)	
1-2 ft	0.41	0.29	0.12	0.13	6.54	3.73	11.76
3-4 ft	1.06	1.48	0.47	0.61	8.61	4.59	221.01
5-6 ft	1.60	2.28	0.80	0.80	7.97	4.35	507.28

Table 16. Average PB Weight, Oxygen Production, and Water Production of *Ceriops tagal*

Height class	PB weight (g)	Oxygen production (L)	Water production (L)
1-2 ft	11.76	3.29	1.176
3-4 ft	221.01	61.86	22.10
5-6 ft	507.28	141.10	50.73

Table 17. Average aboveground biomass data (tree height, stem diameter, canopy size, leaf size, and leaf weight) of *Rhizophora apiculata*

Height class	Tree height (m)	Stem diameter (cm)	Canopy size		Leaf size		Leaf weight (g)
			Height (m)	Width (m)	Length (cm)	Width (cm)	
1-2 ft	0.51	0.35	0.12	0.17	8.003	3.35	12.83
3-4 ft	0.99	0.83	0.20	0.42	10.35	4.16	76.05
5-6 ft	1.64	1.855	0.65	0.74	12.55	4.615	272.22

Table 18. Average PB Weight, Oxygen Production, and Water Production of *Rhizophora apiculata*

Height class	PB weight (g)	Oxygen production (L)	Water production (L)
1-2 ft	12.83	3.59	1.28
3-4 ft	76.05	21.29	7.61
5-6 ft	272.22	76.20	27.22

Table 19. Comparison of Photosynthetic Biomass Weight (g) between selected species of natural mangrove

Height Class (ft)	Species		
	Bruguiera gymnorhiza	*Ceriops tagal*	*Rhizophora apiculata*
1 - 2	12.32	11.76	12.83
3 - 4	237.75	221.01	76.05
5 - 6	610	507.28	272.22

95% Confidence limit of Photosynthetic Biomass Weight (g) with the height of *Bruguiera gymnorhiza*

(1) 95% Confidence Interval for average Photosynthetic Biomass of 1-2 ft plants is between 9.5804 g and 15.0595 g where $\mu = 12.32$, $s = 3.8296$.

(2) 95% Confidence Interval for average Photosynthetic Biomass of 3–4 ft plants is between 54.1860 g and 421.3119 g where $\mu = 237.75$, $s = 256.6033$.

(3) 95% Confidence Interval for average Photosynthetic Biomass of 5-6 ft plants is between 349.7063 g and 870.2937 g where $\mu = 610$, $s = 363.8655$.

95% Confidence limit of Photosynthetic Biomass Weight (g) with the height of *Ceriops tagal*

(1) 95% Confidence Interval for average Photosynthetic Biomass of 1-2 ft plants is between 1.6452 g and 21.8747 g where $\mu = 11.76$, $s = 14.1394$.

(2) 95% Confidence Interval for average Photosynthetic Biomass of 3-4 ft plants is between 116.0392 g and 325.9808 g where $\mu = 221.01$, $s = 146.7390$.

(3) 95% Confidence Interval for average Photosynthetic Biomass of 5-6 ft plants is between 329.0961 g and 685.4639 g where $\mu = 507.28$, $s = 249.0839$.

95% Confidence limit of Photosynthetic Biomass Weight (g) with the height of *Rhizophora apiculata*

(1) 95% Confidence Interval for average Photosynthetic Biomass of 1-2 ft plants is between 2.5138 g and 23.1461 g where $\mu = 12.83$, $s = 14.4209$.

(2) 95% Confidence Interval for average Photosynthetic Biomass of 3-4 ft plants is between 40.9407 g and 111.1593 g where $\mu = 76.05$, $s = 49.0794$.

(3) 95% Confidence Interval for average Photosynthetic Biomass of 5-6 ft plants is between 181.6582 g and 362.7818 g where $\mu = 272.22$, $s = 126.5967$.

Table 20. Comparison of Oxygen Production (L) between selected species of natural mangrove

Height Class (ft)	Species		
	Bruguiera gymnorhiza	*Ceriops tagal*	*Rhizophora apiculata*
1 - 2	3.45	3.29	3.59
3 - 4	66.55	61.86	21.29
5 - 6	170.75	141.10	76.20

95% Confidence limit of Oxygen Production (L) with the height of *Bruguiera gymnorhiza*

(1) 95% Confidence Interval for average Oxygen Production of 1-2 ft plants is between 2.6817 L and 4.2154 L where $\mu = 3.45$, $s = 1.0719$.

(2) 95% Confidence Interval for average Oxygen Production of 3-4 ft plants is between 15.1675 L and 117.9319 L where $\mu = 66.55$, $s = 71.8273$.

(3) 95% Confidence Interval for average Oxygen Production of 5-6 ft plants is between 97.8884 L and 243.6092 L where $\mu = 170.75$, $s = 101.8517$.

95% Confidence limit of Oxygen Production (L) with the height of *Ceriops tagal*

(1) 95% Confidence Interval for average Oxygen Production of 1-2 ft plants is between 0.4605 L and 6.1230 L where $\mu = 3.29$, $s = 3.9578$.

(2) 95% Confidence Interval for average Oxygen Production of 3-4 ft plants is between 32.4812 L and 91.2472 L where $\mu = 61.86$, $s = 41.0746$.

(3) 95% Confidence Interval for average Oxygen Production of 5-6 ft plants is between 92.1192 L and 191.8723 L where $\mu = 141.10$, $s = 69.7225$.

95% Confidence limit of Oxygen Production (L) with the height of *Rhizophora apiculata*

(1) 95% Confidence Interval for average Oxygen Production of 1-2 ft plants is between 0.7036 L and 6.4789 L where $\mu = 3.59$, $s = 4.0366$.

(2) 95% Confidence Interval for average Oxygen Production of 3-4 ft plants is between 11.4599 L and 31.1152 L where $\mu = 21.29$, $s = 13.7381$.

(3) 95% Confidence Interval for average Oxygen Production of 5-6 ft plants is between 50.8490 L and 101.5484 L where $\mu = 76.20$, $s = 35.4364$.

Table 21. Comparison of Water Production (L) between selected species of natural mangrove

Height Class (ft)	Species		
	Bruguiera gymnorhiza	*Ceriops tagal*	*Rhizophora apiculata*
1 - 2	1.23	1.18	1.28
3 - 4	23.77	22.10	7.61
5 - 6	61	50.73	27.22

95% Confidence limit of Water Production (L) with the height of *Bruguiera gymnotrhiza*

(1) 95% Confidence Interval for average Water Production of 1-2 ft plants is between 0.9580 L and 1.5059 L where $\mu = 1.23$, $s = 0.3829$.

(2) 95% Confidence Interval for average Water Production of 3-4 ft plants is between 5.4186 L and 42.1312 L where $\mu = 23.77$, $s = 25.6603$.

(3) 95% Confidence Interval for average Water Production of 5-6 ft plants is between 39.9706 L and 87.0293 L where $\mu = 61$, $s = 36.3865$.

95% Confidence limit of Water Production (L) with the height of *Ceriops tagal*

(1) 95% Confidence Interval for average Water Production of 1-2 ft plants is between 0.1645 L and 2.1874 L where $\mu = 1.18$, $s = 1.4139$.

(2) 95% Confidence Interval for average Water Production of 3-4 ft plants is between 11.6039 L and 32.5980 L where $\mu = 22.10$, $s = 14.6739$.

(3) 95% Confidence Interval for average Water Production of 5-6 ft plants is between 32.9096 L and 68.5463 L where $\mu = 50.73$, $s = 24.9083$.

95% Confidence limit of Water Production (L) with the height of *Rhizophora apiculata*

(1) 95% Confidence Interval for average Water Production of 1-2 ft plants is between 0.2513 L and 2.3146 L where $\mu = 1.28$, $s = 1.4420$.

(2) 95% Confidence Interval for average Water Production of 3-4 ft plants is between 4.0940 L and 11.1159 L where $\mu = 7.61$, $s = 4.9079$.

(3) 95% Confidence Interval for average Water Production of 5-6 ft plants is between 18.1658 L and 36.2781 L where $\mu = 27.22$, $s = 12.6596$.

4.3.1 Relationship between photosynthetic biomass and the height of natural mangrove

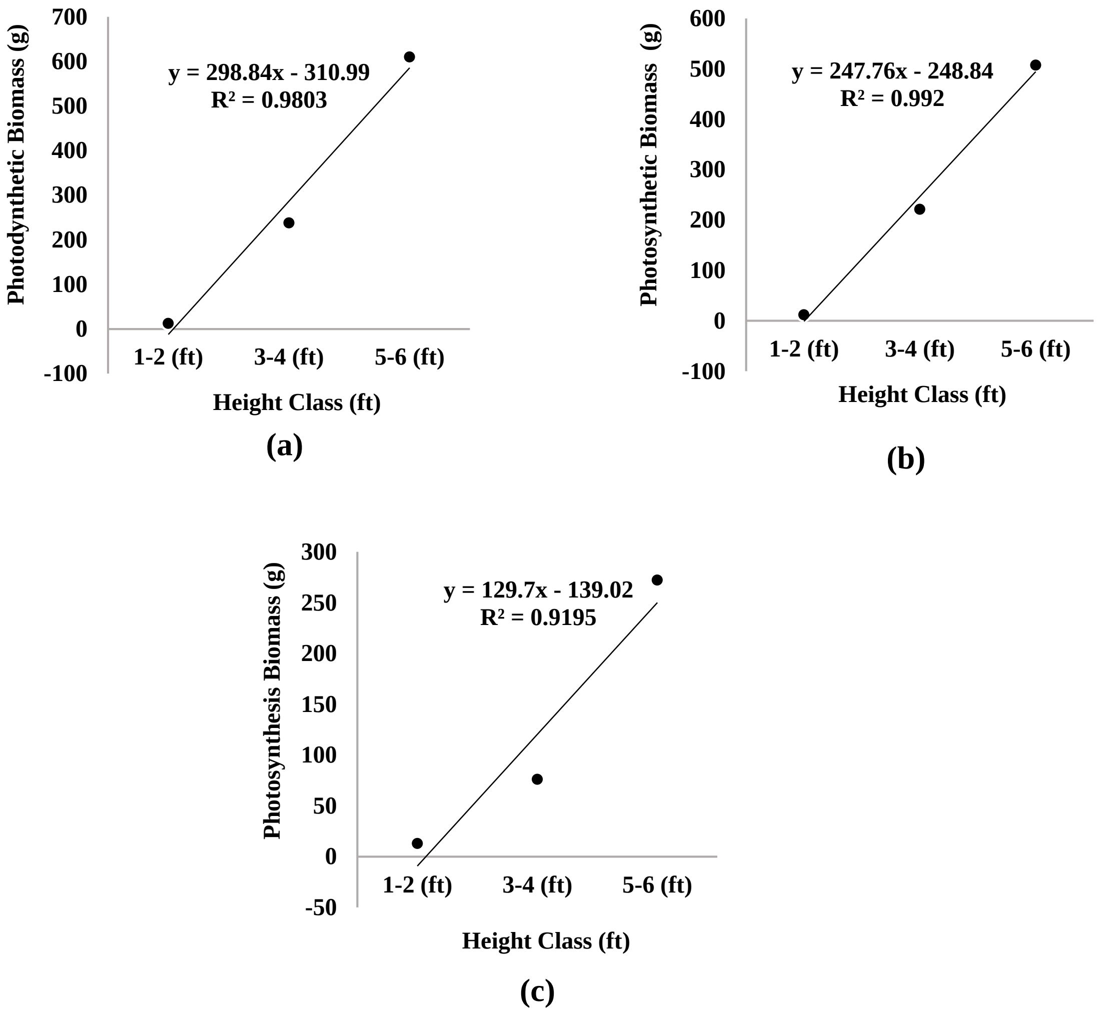


Figure 8. Relationship between Photosynthetic Biomass and the height of natural mangrove **(**a**.** *Bruguiera gymnorhiza*, b. *Ceriops tagal*, c. *Rhizophora apiculata*)

Table 22. Regression Factors between the Photosynthetic Biomass component of the selected species and selected factors of height

Species	**R^2**	**Equation**	**Slope (b)**
Bruguiera gymnorhiza	0.9803	y = 298.84x – 310.99	298.84
Ceriops tagal	0.9920	y = 247.76x – 248.84	247.76
Rhizophora apiculata	0.9195	y = 129.70x – 139.02	129.70

4.3.2. Relationship between oxygen production and the height of natural mangrove

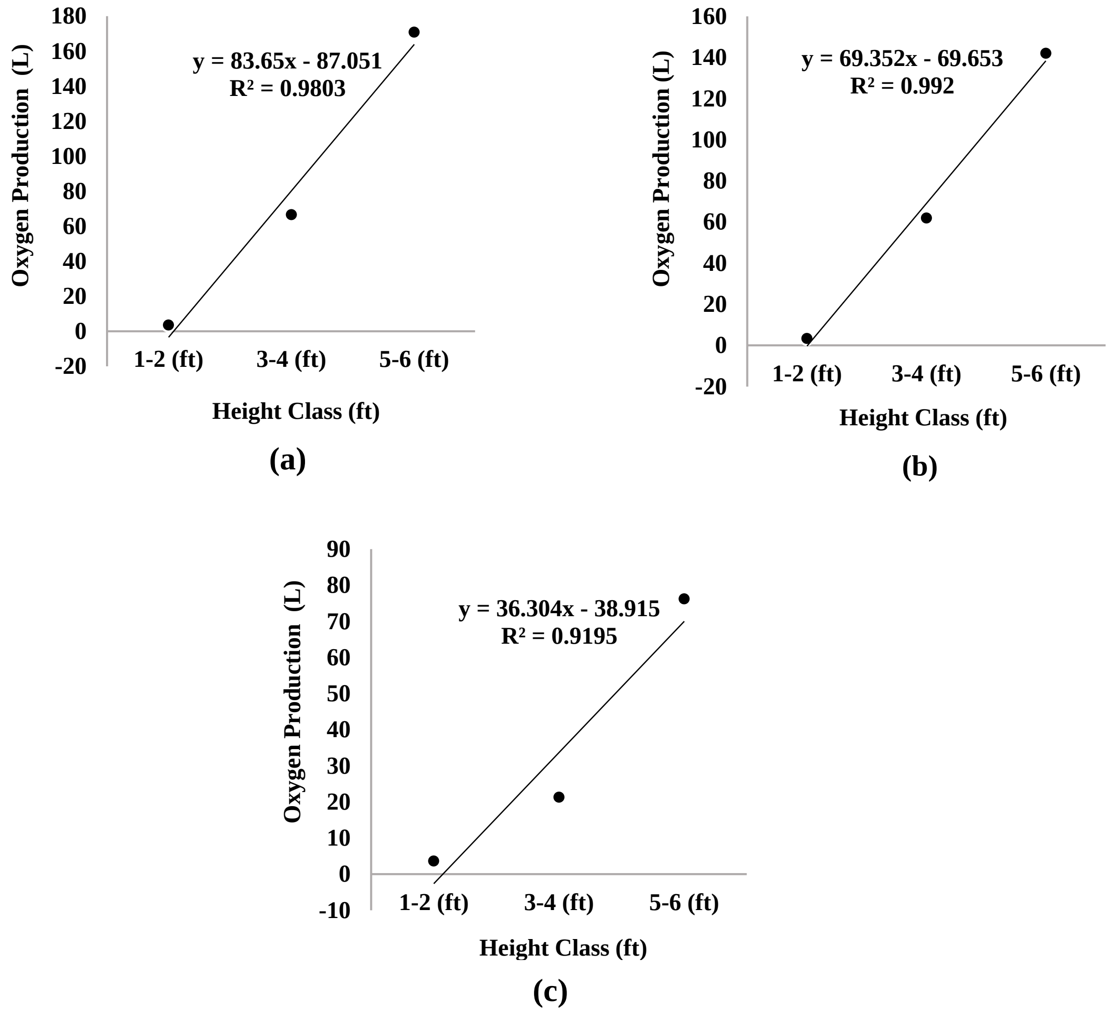


Figure 9. Relationship between Oxygen Production and the height of natural mangrove (a. *Bruguiera gymnorhiza*, b. *Ceriops tagal*, c. *Rhizophora apiculata*)

Table 23. Regression Factors between the Oxygen Production of the selected species and selected factors of height

Species	R^2	Equation	Slope (b)
Bruguiera gymnorhiza	0.9803	y = 83.65x - 87.051	83.650
Ceriops tagal	0.9920	y = 69.352x - 69.653	69.352
Rhizophora apiculata	0.9195	y = 36.304x - 38.915	36.304

4.3.3. Relationship between water production and the height of natural mangrove

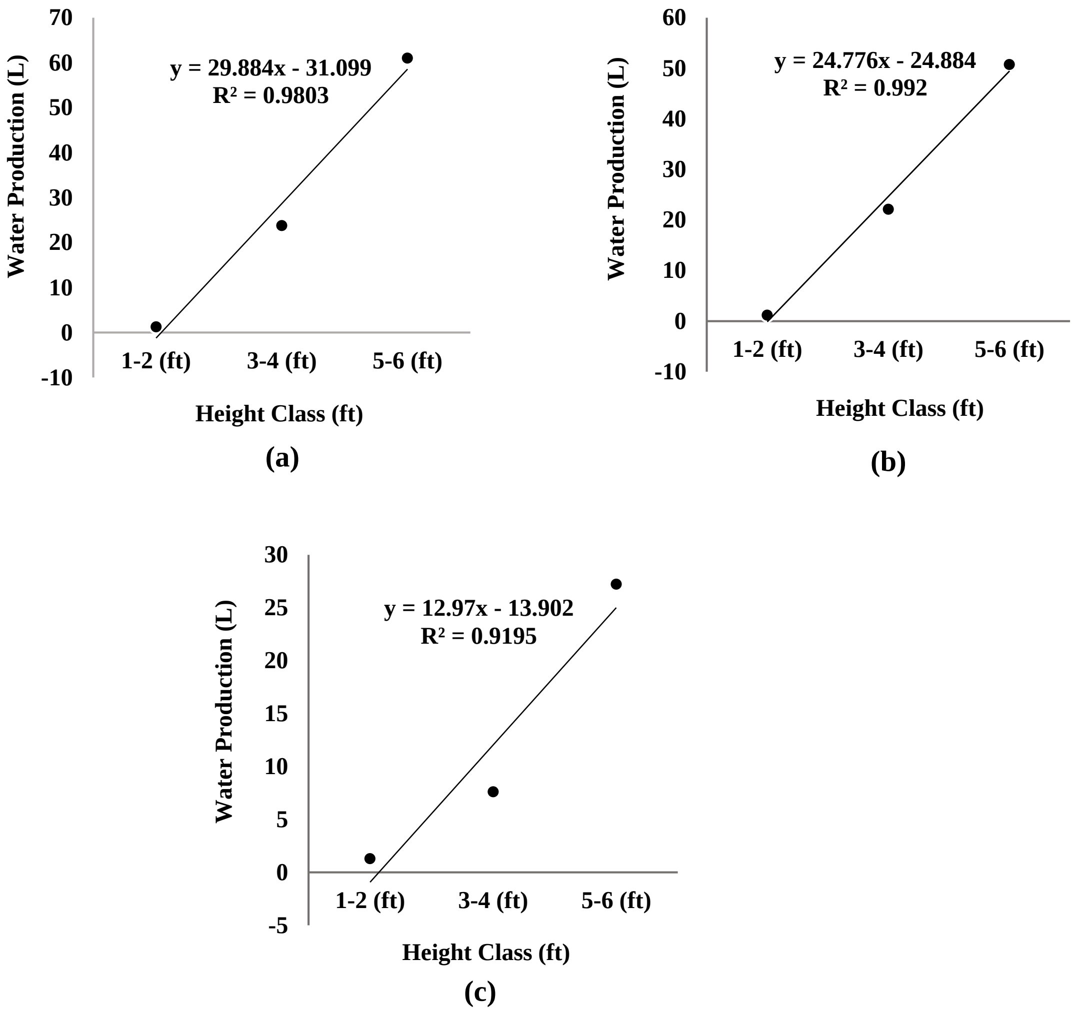


Figure 10. Relationship between Water Production and the height of natural mangrove (a. *Bruguiera gymnorhiza*, b. *Ceriops tagal*, c. *Rhizophora apiculata*)

Table 24. Regression Factors between the Water Production of the selected species and selected factors of height

Species	R^2	Equation	Slope (b)
Bruguiera gymnorhiza	0.9803	y = 29.884x - 31.099	29.884
Ceriops tagal	0.9920	y = 24.776x - 24.884	24.776
Rhizophora apiculata	0.9195	y = 12.970x - 13.902	12.970

CHAPTER 5

DISCUSSION

The average aboveground biomass data of selected individual species increased with age in restored mangrove as well as height in natural mangrove. In restored mangrove, the highest accumulation of photosynthetic biomass was observed in *Bruguiera gymnorhiza* and followed by *Rhizophora apiculata*. The lowest accumulation of photosynthetic biomass was occurred in *Ceriops tagal*. Additionally, *Bruguiera gymnorhiza* represented the highest slope value (178.53) out of all selected species. Secondly, *Rhizophora apiculata* represented the slope value of 151.58 while *Ceriops tagal* shows the lowest slope value (117.07). As shown in Fig. 6, photosynthetic biomass of all selected species expressed that they were positively correlated with the age and it shows exponential after the age of 3 years.

According to the regression curves derived from oxygen production of selected species of restored mangrove (Fig. 7), it has been exponentially increased after the age of 3 years. According to Table 11, *Bruguiera gymnorhiza* was found the slope value of 49.795. It is the highest slope value out of all species and its oxygen production was also represented the highest production. Then, the second highest oxygen production was found in *Rhizophora apiculata* with the slope value of 42.428 compared to the *Ceriops tagal* that has the lowest oxygen production as well as the lowest slope value, 32.769.

Regression curves derived from the water production of selected species described that water production has a positive correlation with their age. Among them, *Bruguiera gymnorhiza* represented the highest production of water and *Rhizophora apiculata* the second highest production was observed in *Rhizophora apiculata*. On the other hand, *Ceriops tagal* was found the lowest water production. Table 12 describes that the highest slope value (17.849) was found in *Bruguiera gymnorhiza*,15.158 in *Rhizophora apiculata* and the slope value, 17.707 that represented the lowest value was found in *Ceriops tagal*.

As for the natural mangrove, the photosynthetic biomass accumulation of all species was not quite different in the height class of 1-2 ft. The highest accumulation was recorded in *Bruguiera gymnorhiza* and followed by *Ceriops tagal* while *Rhizophora apiculata* shows the lowest accumulation. *Bruguiera gymnorhiza* has the highest slope value (298.84) and secondly, *Ceriops tagal* with the slope value of 247.76 and the lowest value (129.70) was observed in *Rhizophora apiculata* (Table 22).

Oxygen production was observed exponential after the height class of 5-6 ft in all selected species of natural mangrove. The highest production was found in *Bruguiera gymnorhiza* that has the highest slope value too. *Ceriops tagal* expressed the second highest production with the slope value of 69.352. Whereas *Rhizophora apiculata*, it represented the lowest production rate as well as the lowest slope value (36.304).

According to the regression curves that shows the relationship between water production and the height of natural mangrove (Fig. 11), water production yield found highest in *Bruguiera gymnorhiza*, followed by *Ceriops tagal* and the lowest in *Rhizophora apiculata*. As for the slope value, 29.884 was observed in *Bruguiera gymnorhiza* and 24.776 in *Ceriops tagal*. *Rhizophora apiculata* was observed the lowest slope value (12.970) out of all selected species of natural mangrove.

CHAPTER 6

CONCLUSIONS

The results derived from the measurement of aboveground biomass data shows the highest accumulation of photosynthetic biomass and subsequently, the highest production of both oxygen and water were observed in *Bruguiera gymnorhiza* for both restored and natural mangroves. The lowest accumulation of photosynthetic biomass, oxygen production and water production were recorded in *Ceriops tagal* of restored mangrove. Apart from restored mangrove, the lowest photosynthetic biomass, the production of oxygen and water yield was observed in *Rhizophora apiculata*.

All of the selected species have a positive correlation of photosynthetic biomass, oxygen production, water production with the age of restored mangrove in contrast with the height of natural mangrove. The exponential increase of restored mangrove was observed after the age of 3 years in compared with natural mangrove that was observed after the height class of 5-6 ft.

Thus, the present study towards the realization of Photosynthetic Efficiency of mangrove that are critical in maintaining the life support system of our planet. Therefore, to explore such a valuable supporting services and ecological value of mangrove ecosystems, more research works should also be developed in the future.

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APPENDIX

Date:

Species name:

Block code:

Planted/Wild:

No.	Geographical location	Tree height (m)	Stem diameter (cm)	Canopy size		Leaf size		Leaf weight (g)	No. of branch
				Height (m)	Width (m)	Length (cm)	Width (cm)		
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									

Figure 11. Datasheet sample for the field used