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QUANTIFICATION OF ABOVEGROUND CARBON SEQUESTRATION IN DELTA TUMPAT MANGROVE FOREST

by

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A report submitted in fulfilment of the requirements for the degree of
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DECLARATION

I declare that this thesis entitled “Quantification of the Aboveground Carbon Sequestration in Delta Tumpat Mangrove Forest” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : 
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QUANTIFICATION OF ABOVEGROUND CARBON SEQUESTRATION IN DELTA TUMPAT MANGROVE FOREST

ABSTRACT

Mangrove forests are incredibly effective and significant carbon sinks, with the potential to absorb more carbon than other terrestrial forests. However, over time, the forests are subjected to severe environmental conditions such as land use change and unclear impact on carbon sequestration. The study about “Quantification of Aboveground Carbon Sequestration in Delta Tumpat Mangrove Forest” through five islands aims to assess carbon stock and to quantify aboveground carbon sequestration in Delta Tumpat Mangrove Forest. The method that were used such as measuring DBH and height, also with calculation of carbon stock, carbon sequestration and the basal area, tree volume and tree per hectare. A total of 155.29 tanC/ha and 18.96 tanC/ha/year are shown in the data, which was collected from five islands: Pulau Mas, Pulau Tujuh, Pulau Layang-Layang, Pulau Bedal A, and Pulau Bedal B. Pulau Bedal B has the greatest carbon stock of the five islands, 4.91 tanC/Ha/year, due to its planted areas, which have been there for nine years. The outcome was impacted by the gradual deterioration and reduction of factors including precipitation and soil pH.

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KUANTIFIKASI PENYERAPAN KARBON ATAS TANAH DI HUTAN BAKAU DELTA TUMPAT

ABSTRAK

Hutan bakau adalah penyerap karbon yang sangat berkesan dan ketara, dengan potensi untuk menyerap lebih banyak karbon daripada hutan daratan yang lain. Walau bagaimanapun, dari masa ke masa, hutan tertakluk kepada keadaan persekitaran yang teruk seperti perubahan guna tanah dan kesan yang tidak jelas terhadap penyerapan karbon. Kajian mengenai "Kuantiti Penyerapan Karbon Di Atas Tanah di Hutan Bakau Delta Tumpat" melalui lima pulau bertujuan untuk menilai stok karbon dan untuk mengukur penyerapan karbon di atas tanah di Hutan Bakau Delta Tumpat. Kaedah yang digunakan seperti mengukur DBH dan ketinggian, juga dengan pengiraan stok karbon, penyerapan karbon dan keluasan basal, isipadu pokok dan pokok sehektar. Sebanyak 155.29 tanC/ha dan 18.96 tanC/ha/tahun ditunjukkan dalam data, yang dikumpul dari lima pulau: Pulau Mas, Pulau Tujuh, Pulau Layang-Layang, Pulau Bedal A, dan Pulau Bedal B. Pulau Bedal B mempunyai stok karbon terbesar daripada lima pulau, 4.91 tanC/Ha/tahun, disebabkan kawasan penanamannya, yang telah berada di sana selama sembilan tahun. Hasilnya dipengaruhi oleh kemerosotan dan pengurangan secara beransur-ansur faktor termasuk pemendakan dan pH tanah.

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LIST OF ABBREVIATIONS

Tan C	Tonne in carbon
Mg C	Megagram Carbon
GHG	Greenhouse gases
CO ²	Carbon dioxide
mm	Millimetre
cm	Centimetre
Ha	Hectare
m	Meter
km	Kilometre
kg	Kilogram
TPH	Tree Per Hectare
BAF	Basal Area
BAT	Basal Area Per Tree
BAH	Basal Area Per Hectare
VOLT	Volume per Tree
VOLH	Volume per Hectare
FAO	Food and Agriculture Organization of the United Nations
GPS	Global Positioning System
DBH	Diameter at breast height

LIST OF SYMBOL AND APPENDICES

log	Number of 5m logs
ρ	Wood density
pH	Potential hydrogen
pi	Diameter
°C	Celsius



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CHAPTER 1

INTRODUCTION

1.1 Background of Study

The mangrove forest is a unique ecosystem and the second largest wetland forest type after the peat swamp forest. the mangrove forest is located at the lowest elevation, which is equivalent to sea level. The mangrove forest is generally found along sheltered coasts where it grows abundantly in saline soil and brackish water dominated mainly by trees (Omar *et al.*, 2020).

Delta Tumpat is one mangrove forest that located in east coast of Peninsular Malaysia and mainly known in Kelantan. The geography for the area are quite unique and different for their habitat flora and fauna consists of flowing rivers and several islands. For its specialty, it became demand to collect invertebrates such as shrimp and clams (Nurul Jannah. *et al.*, 2022). Shrimp farming became one of the activities economies in mangrove areas, the development on the farming could cause disturbance around the area (Rasid Abdul *et al.*, 2019). Latest status from Delta Tumpat, Kelantan was tree planting activities as long-term national programs, that will lead to strong and stable buffer zone form destruction of soil erosion, wave and provide safe place habitat for conservation and biodiversity (Jemali *et al.*, 2022).

Mangrove ecosystems provide to take large capacity to take carbon dioxide from the atmosphere and could store it in biomass and store in millennia. Carbon sequestration was one of the calling for international purposes to reduce carbon dioxide emission, blue carbon ecosystems (Kusumaningtyas *et al.*, 2023). The ability of mangrove to store carbon dioxide efficiently more than any plants makes it one of important forest to reserve. Carbon sequestration mainly determined by the biotic determinant of trees, such as variations in diameter, height diversity, stand density and stand basal area (Shahab *et al.*, 2023). Several factors to contribute the variation carbon sequestration in general are disturbances, climate, topography, stand age, availability nutrient elements, biological diversity, changes in species and ecosystem structure (Aryal *et al.*, 2023).

1.2 Problem Statement

Delta ecosystems are vital for their unique ecological services, includes their capacity to sequestration carbon and intrigute eliminate change impact. However, the Delta Tumpat in Kelantan is currently facing environment problem, land use change which is threatening its ability to function.

The ongoing restoration efforts and the region are essential for biodiversity conservation and habitat rehabilitation, but the specific impact on carbon sequestration remain unclear. The purpose of this study is to better understand how carbon is sequestered in Delta Tumpat. Thus, with the data obtain, will contribute in planning and managing restoration work for effective conservation.

1.3 Objectives

The objective of of this study as follows:-

- To asses current carbon stock in Delta Tumpat Mangrove Forest.
- To quantify the aboveground carbon sequestration in Delta Tumpat Mangrove Forest.

1.4 Scope of Study

The scope of this study encompasses an investigation into carbon stock and sequestration dynamics within restoration biomass current carbon levels. This research aims to contribute to the understanding of the intricate interplay between ecological restoration efforts and carbon storage in delta ecosystem. The findings will not only enrich the scientific discourse on delta ecology but also provide practical insist for informed decision making in sustainable land management of conservation strategies in the specific context of Delta Tumpat. Aboveground carbon sequestration is the process through carbon dioxide from the atmosphere absorbed by trees, plants and crops as carbon in biomass such as in tree trunks, branches, foliage and pneumatophores.

1.5 Significant of Study

This study is to adds a gap to understands aboveground carbon stock and sequestration dynamic in Delta Tumpat, Kelantan. The study also aim to provide valuable insight into sustainable management practices being done there. The findings have the potential to contribute to scientific knowledge of the delta ecosystem and carbon dynamics. All of these point significant to help and contribute to global effort in mitigation measures.



CHAPTER 2

LITERATURE REVIEW

2.1 Carbon Stock and Sequestration

Carbon stock define as the total number of living organisms in a certain area, it expressed in terms of mass either it is living or in dry state (dead) for each tree on certain area. In ecological term, carbon stock refers as the total of living in certain habitat, specified as mass or weight per population density.

In forestry context, it could be referred as the total of carbon that were keep in forest ecosystems, especially carbon stock that were keep in tree alive and organic matter in soil. Carbon stock also was keep on soil or dry leaves and twigs that left on forest floor that already dead and usually referred to carbon pool that measured in unit tan metric (tan C) or megagram (Mg C). There are five categories in carbon pool which is aboveground, belowground, dead trees carbon, litter, soil carbon (Omar & Misman., 2023).

According to Figure 2.1, carbon sequestration is a way to take carbon dioxide out of the air and store it in plants or deep underground. This could help reduce the amount of greenhouse gases that could lead to climate change. By this storage, it is functioned to cleaning up the air by capturing and locking the carbon dioxide inside the tree, so the carbon do not stay in the sky and trap heat. By removing carbon

dioxide from the air, carbon sequestration could help to fight global warming and makes the environment more healthier (NationalGrid, 2022).

The factors affecting carbon sequestration in trees are based on calculations of age, diameter, and height that could give the value of carbon sequestered itself. According to Afzal *et. al.* (2013), the higher the calculations on diameter, height, and total individuals, the higher the carbon sequestrations will be. The fixed allocations in sensing the factors affecting carbon sequestration are light intensity, species composition, nutrient and water availability, salinity, tides, waves, temperature, and climate.

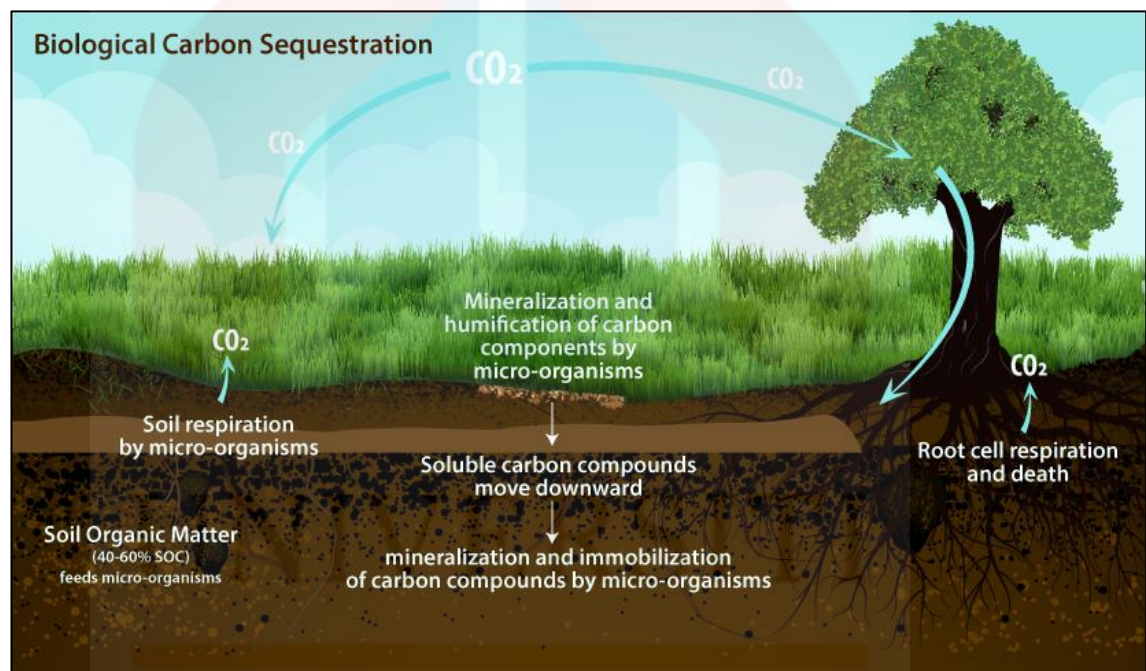


Figure 2.1: Carbon Sequestration (USGC, 2022)

In this study, the focused was on biological carbon sequestration which is use aboveground biomass as main focus to calculate the carbon stock and carbon sequestration.

2.2 Emission and Absorption of Carbon Dioxide Gas

Greenhouses gases (GHG) are gases that are released into the air due to human activities through industry, factories, agriculture, animal husbandry, transportation and so on. The example of GHG gases is carbon dioxide, methane, nitrate oxide, hydrofluorocarbon, sulphur hexafluorocarbon and perfluorocarbon. The GHG gases that released into the air through various way human activities could trap in atmosphere and could cause natural disasters. Each plant will carry out the photosynthesis for the growth process. During the photosynthesis process, carbon dioxide (CO^2) was absorbed by air as one of sources food then stored in the plant as form of carbon stock as stated above. If the plant being cut down, burnt or being destroyed, the carbon that were stored in the plant will release into the air through carbon released process. Likewise carbon stock will released within the decay process when the tree dies. On the other hand, the carbon stock will remain if the tree stored to kept alive as the size tree increase (Omar *et al.*,2020).

The Figure 2.1 show the process of capturing and storing carbon dioxide (CO^2) from the atmosphere, either through naturally or through artificial. The emission sources such as burning of fossil fuels, solid waste decomposition and deforestation are the main factor to calculate carbon stock to see the carbon sequestration. The carbon cycle describes how carbon, including CO^2 , cycles between the atmosphere, oceans, soil, plants and animals. Human activities are altering this cycle by adding more CO^2 to the atmosphere and influencing the ability of natural systems to absorb and store CO^2 animals (United States Environmental Protection Agency, 2024).

2.3 Delta Ecosystem

Deltaic flood plains provide important ecosystem for human including for food production, freshwater, flood control, and nutrient cycling (Gómez-Baggethun, *et. al*, 2019). Flood plains refer as flat area next to a river or stream, same goes with Delta Tumpat in Kelantan that were flat land and the bank of the river stretches the river to the outer edges of the valley (Evers *et al.*, 2023). Referring to Figure 2.2, delta also effects by tidal wave and tidal formation and form at the river and have connection between formation of soil and land. Several deltas in the Malaysia are Delta at Rajang River and Baram River at Sarawak and Delta Pahang at Pahang River (Zaini *et al.*, 2021).

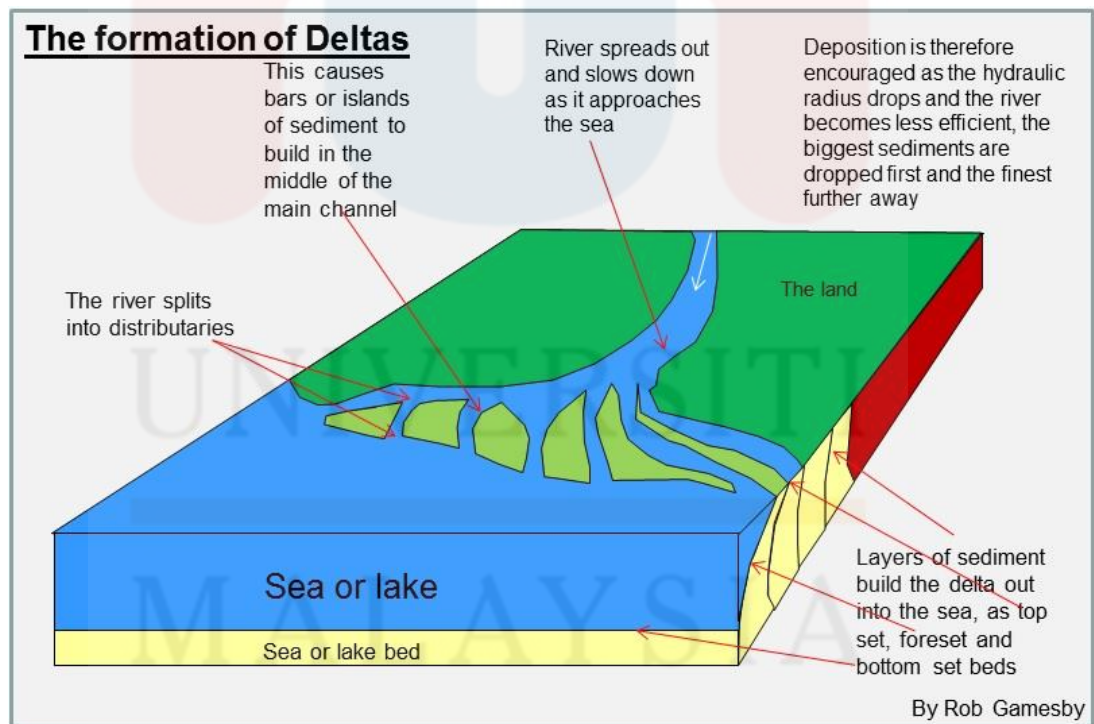


Figure 2.2: The Formation of Delta (Rob Gamsey, 2018)

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The changes of delta through the year also through the historical development of sedimentation processes and vegetation growth shaping their current structure and function. Delta also have widely enough of ecosystems services, such as agriculture and aquaculture, regulating services like water quality and flood control and cultural services could be represented through recreation and tourism. The combination of freshwater and marine influences moderates temperatures, allowing for wide range of species to come and produce widely habitat on delta ecosystems (Delta Stewardship Council, 2018).

The ecosystems is an important shelter for biological diversity consisting of diverse kingdoms especially for aquatic and terrestrial flora and fauna that include such as monkey, shrimp, oysters, fish, and and avian migrant birds. In the Niger Delta itself, mangroves affect fish distribution in the Gulf of Guinea because the fish were bred from mangroves in the delta. On the other side of this well ecosystem, in some regions it has threats such as overheating for fuel wood, oil spills, and wetland reclamation. which makes the worst scenario degraded globally for potential mangrove forests in Nigeria (Amarachi *et al.*, 2020).

Precipitation plays significant role in determining in the distribution and zonation of mangrove species. Moderately, warm and wet areas with high rainfall have rich supply of mangrove population, the less rainfall are unfavourable for mangrove growth. The *Rhizophora* spp. are known that use temperatures and precipitation that influence the species distribution (Aroloye & Camilo, 2017). Precipitation are one of resilience indicators for mangrove systems because of influenced by the weather patterns drive riverine, estuarine and coastal

hydrogeomorphology. It also relatively related with humid climates (Day *et al.*, 2018).

The key factors influencing carbon sequestration in Delta were land use change. Another factor was climate change, different land use, level of urbanisation, intensity locational conditions, and transportation activities. Climate change is a common and problematic factor that affects every natural ecosystem as because of they relate to each other. Land use change affects the ecosystems carbon cycle because it changes the structure and original function of the regional ecological systems due to urbanisation, which causes lower carbon sinks and increased carbon dioxide in the atmosphere (Xu *et al.*, 2017).

2.4 Mangrove Ecology and Importance

Mangrove forests are found in the intertidal zone (live between the ocean and the land, which is between high and low tides) along tropical and wetlands areas and play an important role in the coastal zone by providing the line range between ecosystem services and coastal populations. When the forest itself lives between ocean and land, the structure of the location itself must have some characteristics, such as strong tides, and the roots need to hold the waves that come to them.

Factors of tides are important to understanding how tidal work for coastal safety, navigation, and ecology. Topography means the arrangement of the natural and artificial physical features of an area. The local topography, which is influenced by strong tides during monsoons, is related to a lowkey change in mangrove distribution (Satyanarayana *et al.*, 2010).

Mangrove also serves many invertebrate species, such as shrimp, crabs, oysters, and mussels. The forest becomes a 'playground' for them to live and search for food. It is a nursery place for ideal breeding for these invertebrates. When it becomes an adult, the fish will let go of the open ocean to live, survive, and find more food. The swamp forest mangrove also provides homes for various kingdoms, such as fungi, and kingdom animals like crocodiles (Carugati *et al.*, 2018).

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2.5 Mangrove Restoration

According to Were (2019), restoration zone are important especially if the mangrove itself have been lost or degraded so the restoration the carbon sequestration could happen. He stated that the rate of restoration could have increased in at least a year in China and Europe land by using the degraded wetlands and restoring them will yield returns 100 times greater than those of other methods for mitigating climate change. Although it could happen in another region of world, some of the lost ecosystem functions are no longer fully recovered the carbon sequestration. The importance of restoring wetlands are because of ecological health, biodiversity, providing essential ecosystem services.

Other challenges that need to be face are the mangrove conservation are being poorly designed policies, inconsistent land-use planning, lack of local community involvement in making decision and to reconcile national economic development priorities with environmental protection (Pham, 2022). Restoration of mangrove surely includes various aspects for a country to be handle and due to long-term plan, the restoration became due rather than action.

CHAPTER 3

MATERIALS AND METHOD

3.1 Study Area

The study area are located in Delta Tumpat, Kelantan. The the area is located on the north side of the east coast, close to the Thailand border, near with Padang Kemahkotaan Tumpat or called as Pata Ndo and near with Stesen Keretapi Tumpat (KTMB). The islands are located right in front of Pata Ndo, by taking a boat to getting those five islands.

The Figure 3.1 consist of five different islands which is Pulau Bedal A, Pulau Bedal B, Pulau Mas, Pulau Layang-Layang and Pulau Tujuh. Through the Figure 3.1 it shows the location of five islands. Pulau Tujuh are the one near with Pata Ndo which is in front of it while the other islands are further away. Most of these island were planted with mangrove species mainly *Rhizophora apiculata* and *Rhizophora mucronata* since year 2000. Pulau Layang-Layang and Pulau Mas were planted during year 2003 and 2004, Pulau Tujuh and Pulau Bedal A planted during year 2006 while Pulau Bedal B planted during year 2008. Table 3.1 shows the coordinates location in every islands.

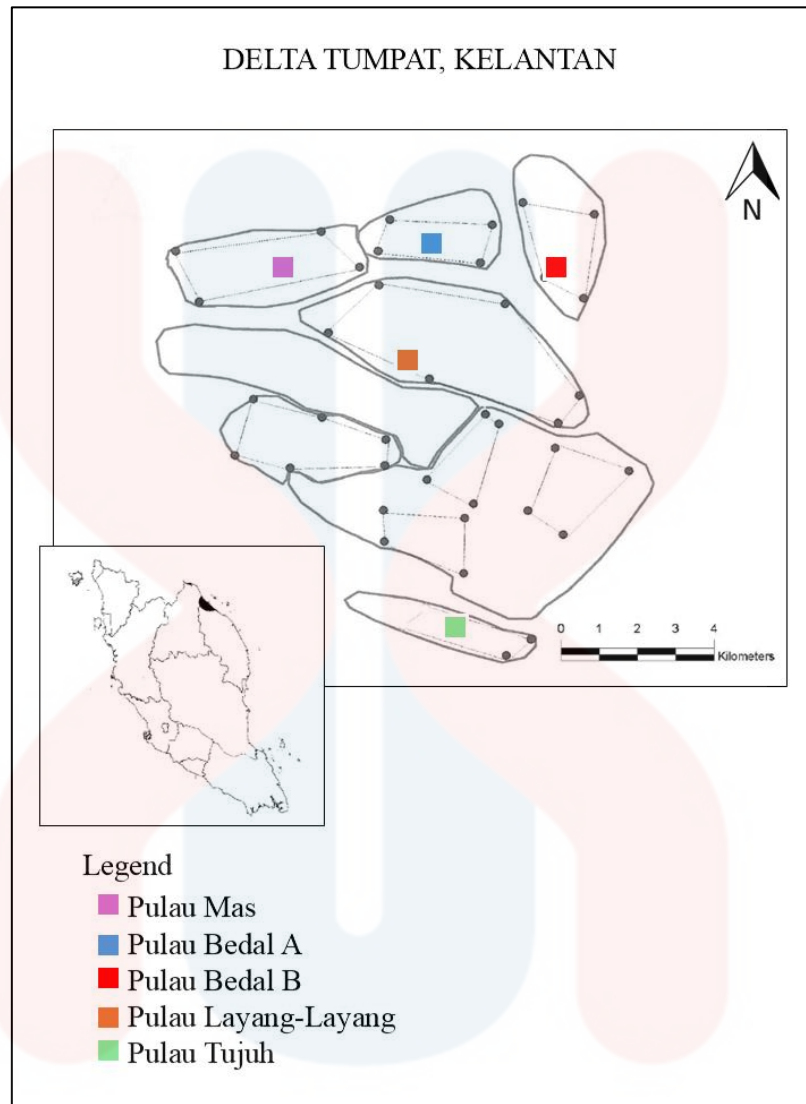


Figure 3.1: Delta Tumpat Map

Table 3.1: Coordinates Location

No.	Island	Coordinates Location
1	Pulau Mas	N6'12'43.70" E102'10'06.66
2	Pulau Bedal A	N5'43'53.99" E101'51'32.13
3	Pulau Bedal B	N6'12'45.98 E102'10'19.75
4	Pulau Layang-Layang	N5'43'53.99 E101'51'32.13
5	Pulau Tujuh	N6'12'11 E102'10'14

Naturally, Malaysia weather influenced by the wind blowing from the Indian Ocean (Southwest Monsoon from May until September) and the South China Sea (Northeast Monsoon from November to March). The annual rainfall is 80 percent per year which is between 2000 mm to 2500 mm (Jabatan Penerangan Malaysia, 2017).

The study was conducted when Northeast Monsoon happened, which is seasonal wind patterns that occurs form together with cold air flows from Siberia that bring heavy rain (MET, 2024). Northeast Monsoon happened from November to March, thus effect the day of do sampling. During Northeast Monsoon, which happen October until March were heavily affected on East Coast like Delta Tumpat, Kelantan itself. Nevertheless, the last months of monsoon happened on March make the precipitation and temperatures were stable to went down sampling.

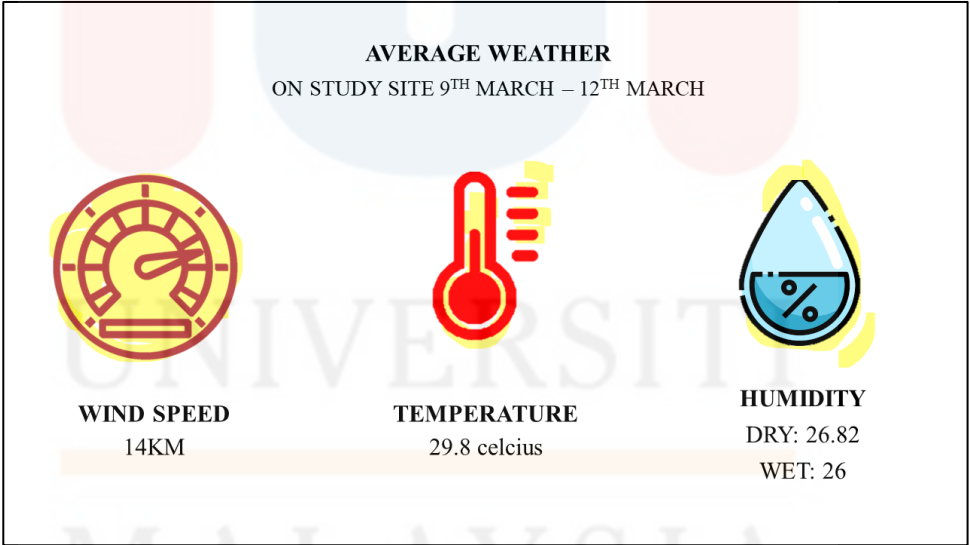


Figure 3.2: Average Weather on study sites

Figure 3.2 shows the average weather on study site using wind speed (14 km), temperature (29.8°C) and humidity which is dry 26.82 and wet 26. The best temperature for mangrove are between 20°C and 40 °C (Aroloye & Camilo, 2017) to support photosynthesis and other life processes, so the 29.8 °C in average is suitable for mangrove in Delta Tumpat, Kelantan.

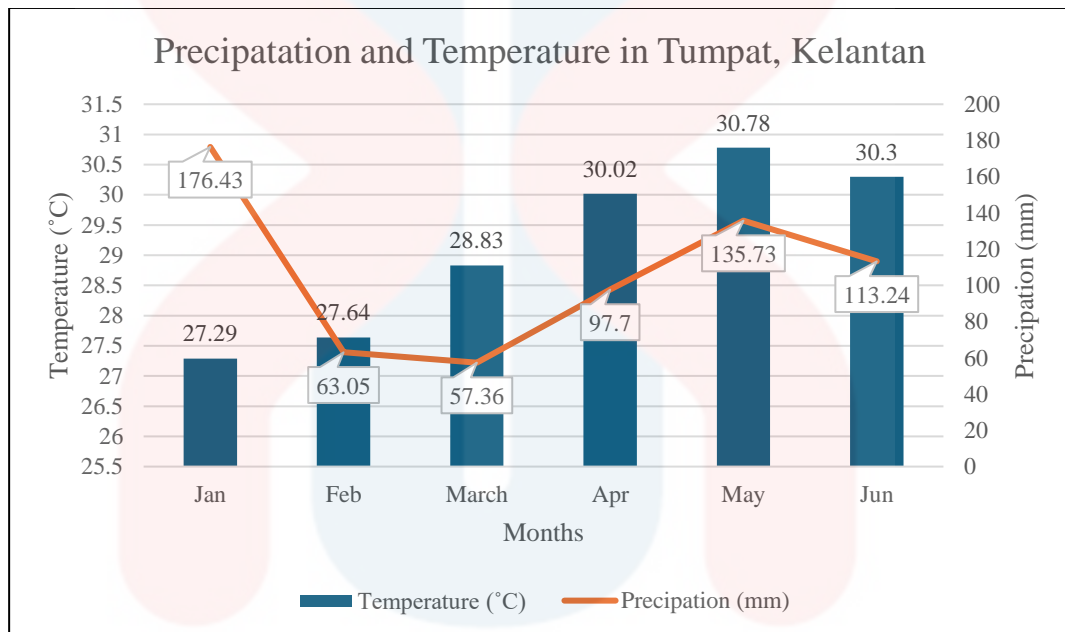


Figure 3.3: Precipitation and Temperature in Tumpat, Kelantan

Temperature and precipitation are important to use for one of crucial mangrove ecosystems as these influence various aspects of mangrove growth. Malaysia had experienced hot weather and humid every year. The average temperature of daily around Malaysia is between 21°C until 32°C.

Figure 3.3 showed precipitation and temperature in Tumpat, Kelantan from January 2024 to Jun 2024. The study was conducted on 9th March until 12th March within four days, showed that the temperatures are 28.83°C and 57.36mm for precipitation. The mid value between six months are suitable for went on sampling at Delta Tumpat. According to the (Aroloye & Camilo, 2017) mangroves thrive warm temperatures, typically between 20 °C to 35 °C, when the study it was conducted 28.33 °C which is it is above average (27.55 °C).

During March, the precipitation happened very low from January to Jun which is the mean is 57.36 mm per month. The Rhizophora species are species that heavily influence by temperatures and precipitation. The low the precipitation and with high temperature, the high salinity the soil will be.

3.2 Sampling Design

A random sampling approach were applied to select representative sites within the restoration zone. The selecting sample of observation from observation from a population is such a way that each item in the population has an equal chance of being selected (Taylor, 2024).

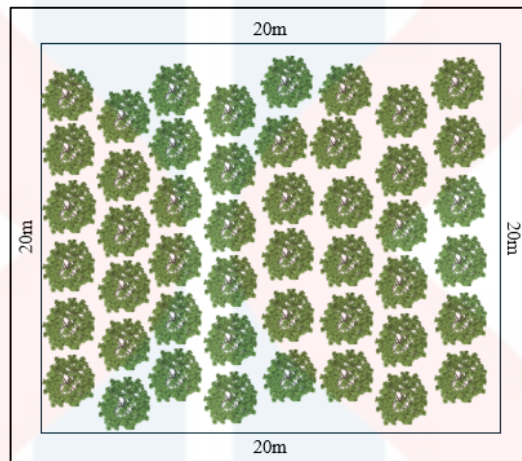


Figure 3.4: Sampling design 20m x 20m

In methodology, the protocols and procedures Kauffman and Donato are used for measurement of structure, biomass and carbon stocks in mangrove forests. The materials that used such as DBH tape, meter tape, compass, GPS, hypsometer and pencil and papers. The function as mentioned below in Table 3.2.

Table 3.2: Materials and function

No	Materials	Function
1.	DBH Tape	Displays the diameter measurement when wrapped around the circumference of a tree.
2.	Meter Tape	Used to measure distance or size.
3.	Compass	Navigation to find direction on finding north, west, south and east.
4.	GPS	To coordinate, navigation, tracking, mapping and timing.
5.	Pencil and Papers	To jot down the measurements on paper, using pencil are more safe in coastal area due to the carbon keep the ink.
6.	Hypsometer	To estimate the height of tree, by taking shot from root until up to the tree.

3.3 Data Collection

Field measurement involved data collection to calculate of biomasses, carbon stock and sequestration through non-destructive sampling technique using allometric equation. Since year 2000, State Forestry Department of Kelantan initiated a protection and conservation programme on this area through Pulau Layang-Layang, Pulau Tujuh, Pulau Mas, Pulau Bedal A and Pulau Bedal B.

The live-stand tree was the focus of the data collection. The diameter and the height of the stem diameter (DBH) are the two parameters that need to be measured. One individual had to climb on roots to take DBH since the mangrove roots are stilt. Using metre tape, measure the diameters at 1.3 meters above the roots, wrap the tape around the main stem of the tree, and record the results (Washington State University, 2009).

The hypsometer is used to estimate height. Hold the hypsometer at eye level, measure from a location to the base of the tree. Add the eye height from the base tree to the top to determine the overall height of the tree (Barkan, 2024).

3.4 Data Analyses

Regression analysis were employed to quantify the relationship between vegetation biomass and soil carbon content. There are four main biophysical parameters that are often used in forest carbon reports. First is tree per hectare, the second is basal area, third is tree volume and lastly biomass and carbon stock.

Table 3.3: Formula for tree per hectare, basal area, and volume

No	Parameter	Equation	Detail
1.	Tree Per Hectare (trees/ha)	$TPH = BAF/BAT$	TPH – Tree Per Hectare (trees/ha) BAF – 4 BAT – Basal Area tree (m ²)
2.	Basal Area (one tree)	$BAT = \pi \times (DBH)^2 / 40000$	BAT = Basal Area for one (1) tree (m ²) $\pi = 3.142$ DBH – Diameter at breast height (cm)
	Basal Area (per hectare)	$BAH = (BAT \times TPH)$	BAH – Total basal area in one hectare (m ² ha ⁻¹) BAT – Basal Area tree (m ²).
3.	Tree Volume (one tree)	$VOLT = BAT \times 0.65 \times \log \times 5$	VOT – tree volume for 1 tree (m ³) Log = 1 (<30cm DBH)
	Total Volume (one hectare)	$VOLH = (TPH \times VOLT)$	VOLH - Total tree volume per hectare for on plot (m ² ha ¹) TPH – Tree Per Hectare (trees/ha) VOLT – tree volume for 1 tree (m ³)

In Table 3.3, the parameter and equation were explained. Tree Per Hectare are measure of the number of trees in a specific area, this helps to understanding the density of the stand and used for management activities. Basal area are cross-sectional area of a DBH, used to estimate the volume of tree and are sign determine for overall health and competition within a stand. Tree volume are total volume, determining the overall volume of a stand and for planning logging operations (Abed *et al.*, 2003).

Table 3.4: List of AGB formulas

No	Species	Equation	Study location	Year	Source
1.	<i>Rhizophora mangle</i>	$\log_e B = 2.5072 \times \log_e DR - 1.5605$	Brazil	1987	Day <i>et al.</i>
2.	<i>Rhizophora apiculata</i>	$0.0444 \times (D^2H)^{0.96842} \times \rho$	Indonesia	2012	Kauffman & Cole
3.	<i>Rhizophora mucronata</i>	$0.0311 \times (D^2H)^{1.00741} \times \rho$	Indonesia	2012	Kauffman & Cole

H= height (m), D = diameter at breast height (cm), ρ = wood density (g cm⁻³)

In Table 3.4 the listed of aboveground biomass (AGB) in other study was used to see the applicability with species in Delta Tumpat Kelantan Mangrove Forest. The species consists of only *Rhizophora apiculata* and *Rhizophora mucronate* using Kauffman and Cole (2012) was chosen because of the accuracy of the species that were collected. Since Kauffman formula did not specify the value of ρ which is the wood density, it utilised the standard 900 g cm⁻³ developed by MTC by Wong, 1982.

After the calculation of biomass, the calculation of carbon stock are use 0.47 as suggested by (IPCC, 2006; N.A.M. Zaki *et al.*, 2018) that were expected to be the carbon of all segment of all kind of tree as default value. The last is carbon sequestration which is the carbon stock divide by year as it is the tree age to know the weight of CO² that were absorbed through years as shown on Table 3.5.

Table 3.5: Formula calculating carbon stock and sequestration

No	Parameter	Equation	Year	Author
1.	Carbon stock (tan/C/Ha)	$0.47 \times \text{AGB}$	2006	IPCC
2.	Carbon sequestration (tan/C/Ha/year)	Carbon stock / year	2014	Alongi

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Forest Structure

In this study, five island consist of Pulau Tujuh, Pulau Mas, Pulau Layang-Layang, Pulau Bedal A and Pulau Bedal B, had total of 214 individuals in mangrove tree that were recorded. This include the total number are 214 trees which is standing-tree are 194 individuals, while the other 20 individuals were dead-tree are not counted as the study aim for living stand-trees.

Rhizophora mucronata has been planted on three islands which is Pulau Mas, Pulau Layang-Layang and Pulau Tujuh except for Pulau Bedal A and Pulau Bedal B, has been planted with *Rhizophora apiculata* species. Forest density is critical measure that strongly affects forest health, plant composition, stand structure and ecological function. Generally, one parameters that measure forest density are by expressed through basal areas (BA), which is the cross-sectional area of all trees at 4.5 feet from the ground (Cook, 2016).

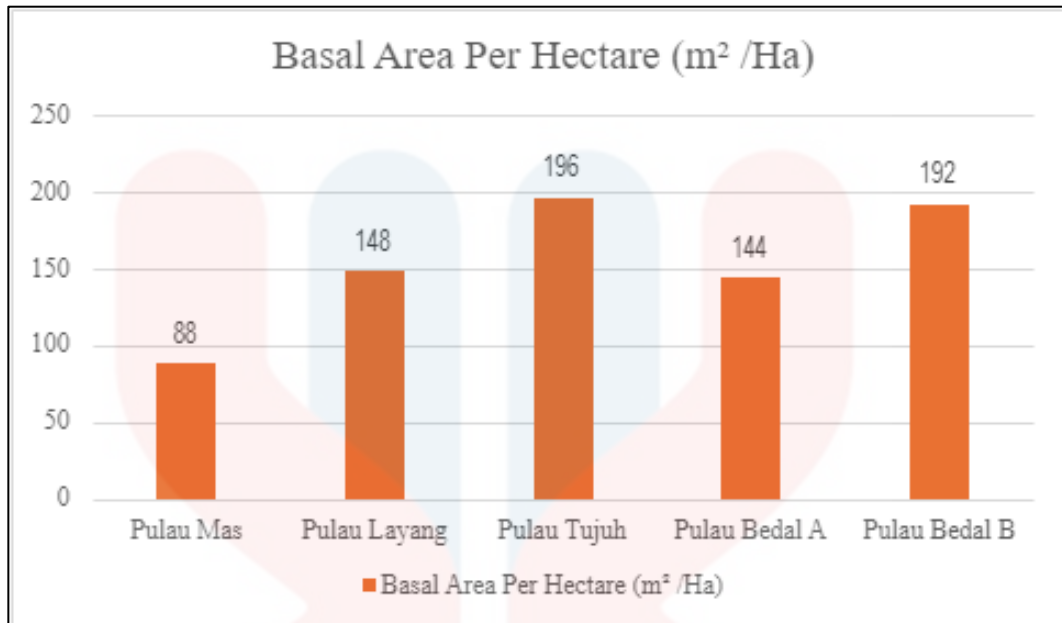


Figure 4.1: Basal Area Per Hectare (m²/ha)

Basal Area Per Hectare is sum of the basal area for all trees in the stand per unit area, typically measured in square meters per hectare (m²/ha). Basal area is the cross-sectional area of tree at breast height, typically measured in square meters per hectare. The basal area of forest is found by adding the basal areas of all trees in an area and dividing by the area of land in which the trees were measured (Elledge *et al.*, 2018).

Figure 4.1 shows basal area per hectare, the highest is Pulau Tujuh (196) and the lowest is Pulau Mas (88) respectively. The change of basal area related with stand age, and rate of diameter growth (Woodall, 1997), so the total of Pulau Tujuh 196 m²/ha have averaged DBH 13.4 cm, a basal area of 196 could assumed that the island have high density of trees in the area, it also implies that the majority of trees in the area are relatively medium-sized. The tree also have mature forest, as the total of Pulau Tujuh are higher among other (55). Pulau Mas have total basal area 88 that relatively low to moderate density of trees in the area. The average DBH which is 13

cm implies that the majority of trees in the area are relatively small to medium-sized, this could be explain by the forest are younger, as the total of Pulau Mas are less among others (23).

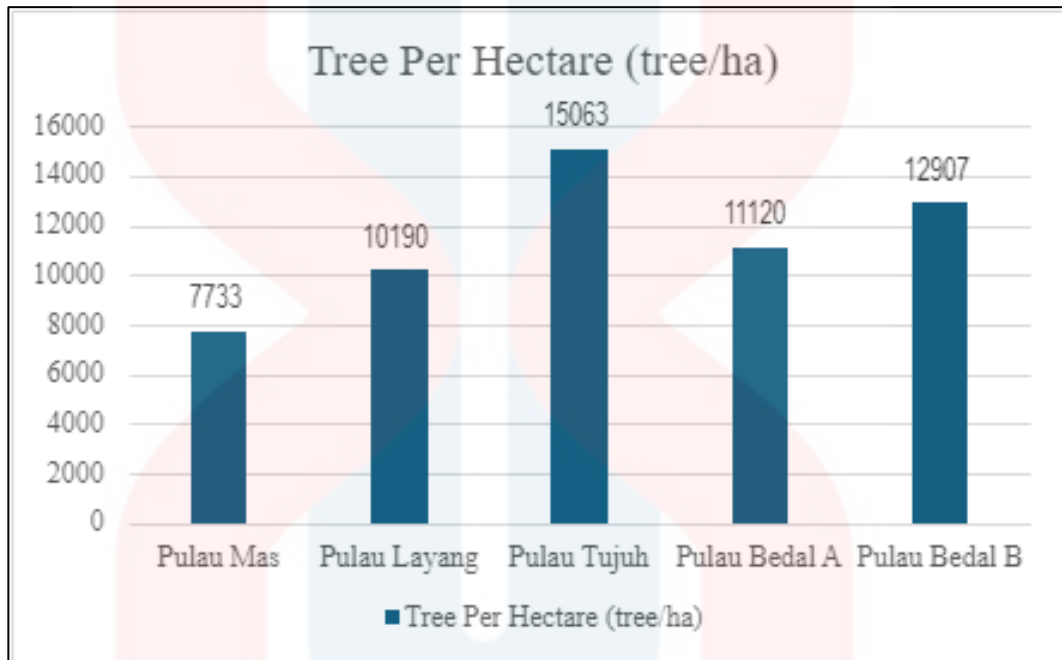


Figure 4.2: Tree Per Hectare (tree/ha)

Tree per hectare (tree/ha) needed to fully understand and measure forest density. It is crucial functional and structural variable of forest ecosystems. TPH is to calculate the number of trees within a specific area, typically measured in trees per hectare (trees/ha). The highest tree per hectare is Pulau Tujuh (15,063) and the lowest is Pulau Mas (7,733). Although the number of trees planted per hectare are reach thousands, the actual number are vary hugely depending on the species and type of planting (NHS Forest, 2024).

The canopy relatively related with the tree per hectare as it tooks space to grow, as example for *Rhizophora mucronata* for both islands tooks larger amounts of space to cover. Pulau Tujuh may contain high tph but it has small crown volume (36.24) than Pulau Mas (138.02). As higher the number of tree per hectare, the lower the crown volume has as the canopy cannot expand because of limited space as trees compete for light and resources (Galvin *et al.*, 2004).

Same goes for volume of tree (m^3/ha), the lowest are Pulau Mas and the highest are Pulau Layang-Layang. Pulau Layang- Layang showed dominate the base of forest density among the other five islands. Tree volume important aspect directly affects the overall biomass and carbon stock within the forest.

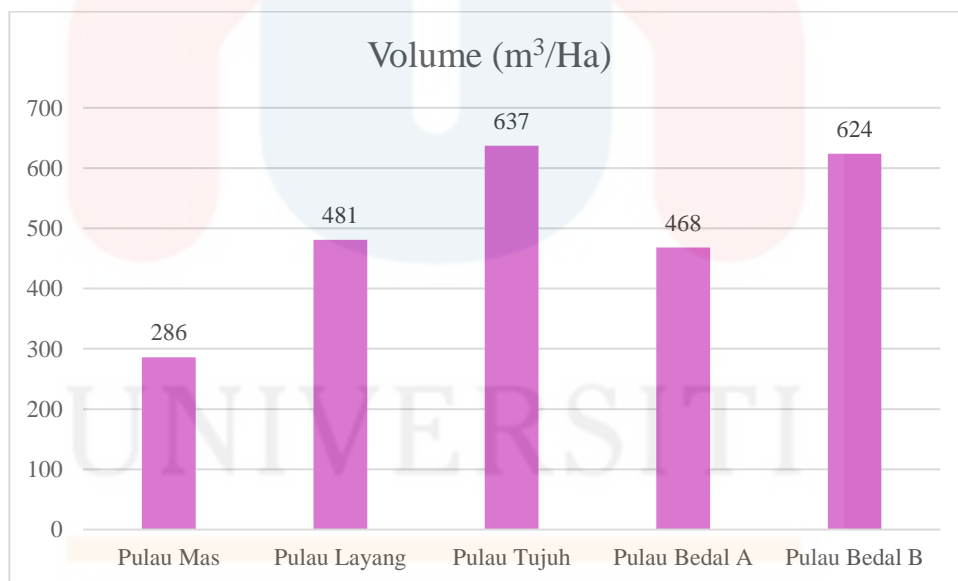


Figure 4.3: Tree Volume (m^3/ha)

The analysis of the plots placed in the different strata. Pulau Tujuh (637) and Pulau Mas (286) win the highest and lowest of the total all three figures, Pulau Bedal B also place on third place (624). As the number of trees per hectare in Pulau Tujuh are higher, the total volume also higher same goes with Pulau Mas the lowest tree per hectare are lowest the total volume is. However, the volume increment per tree can went decreases as the number of trees per hectare increases such as Pulau Bedal A. The total volume tree are 468 m³/ha and tree per hectare 1,120 tree as referred to Figure 4.2. This due to to increased competition among them to get resources like water, soil and water. The relationship between these two are not linear as the higher TPH, the volume could decrease or level off. (Allen *et. al.*, 2020)

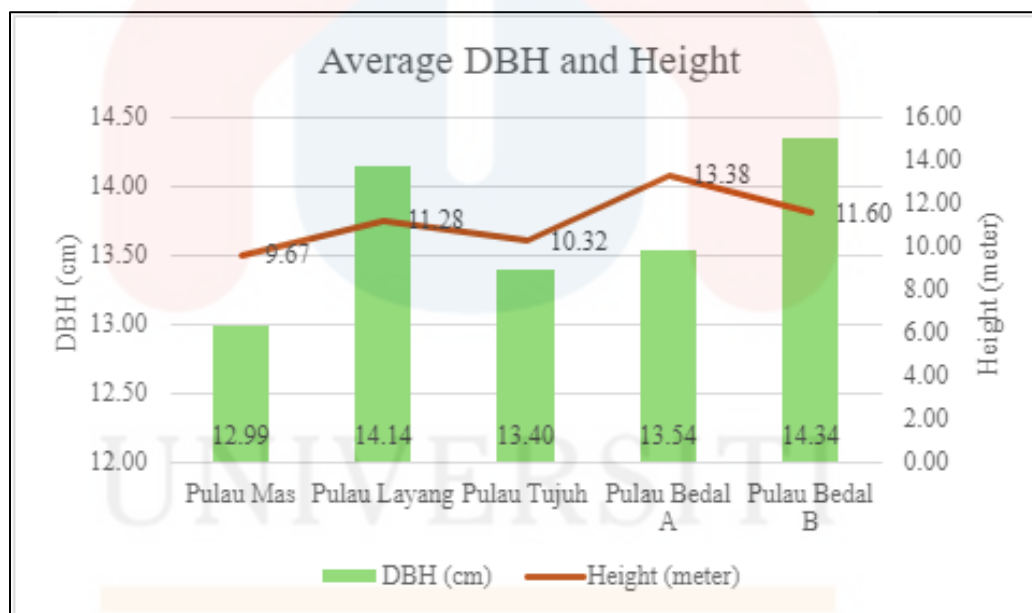


Figure 4.4: Average DBH and Height of *Rhizophora sp.*

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Figure 4.4 shows the total average DBH (cm) on these five islands are similar, with range from smallest 13 cm to 14.34 cm. For the height the range started from 9.67 meter to 11.6 meter. The highest average of DBH is Pulau Bedal B which is 14.34 cm, and for height also which is 11.6 meter. The total average of DBH is 13.68cm and total average of height is 11.25 meter.

These two variables are non-linear, but it used as main variable in calculation of estimate biomass allometric equation. The relationship between DBH and height is influenced by various stand variables such as stand age, density, and site conditions. For example the rate increases in height is higher at lower DBH values, but it also could slows down as DBH increases further such as Pulau Layang-Layang and Pulau Bedal B could have a linear that connect the dot between them while the other islands cannot dot together as the DBH are slows down to increase height to go further. The stand age are plays role with tree height increasing with age within same diameter class (Li *et. al.*, 2015)

4.2 Estimation of Biomass

Biomass equation that were used was formulated by Kauffman and Cole (2012). Below Table 4.2 is the average of biomass using the calculation.

Table 4.1: Total biomass (tan/Ha)

Islands	Biomass (tan/Ha)
Pulau Tujuh	27,702
Pulau Mas	12,131
Pulau Bedal A	32,870
Pulau Bedal B	38,353
Pulau Layang-Layang	29,200
Total Biomass	140,256

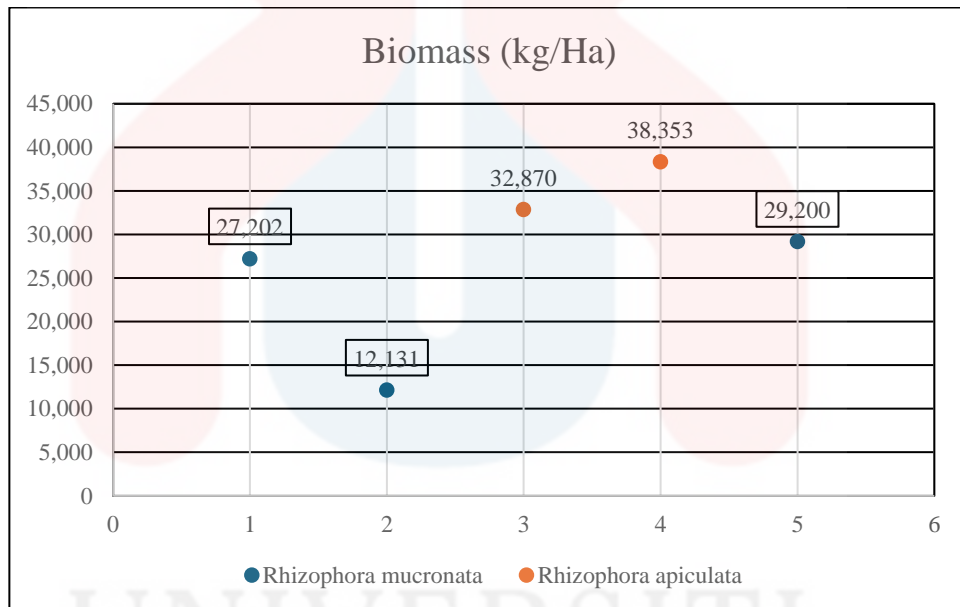


Figure 4.5 : Biomass on each of islands

Based on Table 4.2 the highest average of biomass for Pulau Layang-Layang followed by Pulau Bedal B, Pulau Bedal A, Pulau Tujuh and Pulau Mas. The total biomass of these five islands as much as 140,256 kg.

The highest total biomass is Pulau Bedal B (38,353 kg) and the lowest total biomass is Pulau Mas (12,131 kg). Biomass can be very different depending on several mass of the living matter, one of them is density. Figure 4.3 shows the tree

per hectare for Pulau Bedal B is the second highest (12,907 kg/ha). Representing *Rhizophora apiculata* with 48 individual tree that were collected, the higher mangrove density leads to denser canopy which reduced light penetration to the understory. These indeed show the relationship between biomass and density are related together.

The Figure 4.5 shows DBH and biomass are related as well, as the hypothesis goes the higher and wider the height and tree trunk, the more the biomass will be as using allometric equations that specific species develop by Kauffman & Cole, 2012. The allometric equations are one of effective than generic models, as the Kauffman prepares unique equations characteristics of each species. The formula for *Rhizophora mucronata* and *Rhizophora apiculata* have slightly different. The generic allometric models such as Komiyama and Chave tend to have over-estimated compared to the specific-specific models, they showed significantly AGB differences. By improving estimates of AGB, it will the understanding of the productivity of mangrove forest to have understand with long-term conservation and fragile ecosystem around (Rahman *et al.*,2021).

4.3 Calculation Carbon Sequestration

The total of five islands in biomass is 328.89 (tan/ha), the total for carbon stock is 154.57 (tanC/ha) and for the carbon sequestration the total is 8.61 (tanC/ha/year).

Table 4.2: Total of Biomass, carbon stock and carbon sequestration

Islands	Biomass (tan/ha)	Carbon Stock (tanC/ha)	Carbon Sequestration (tanC/ha/year)
Pulau Tujuh	70.77	33.26	4.07
Pulau Mas	30.33	14.25	2.04
Pulau Layang-Layang	64.35	30.25	3.78
Pulau Bedal A	70.89	33.32	4.16
Pulau Bedal B	94.06	44.21	4.91
Total	330.4	155.29	18.96

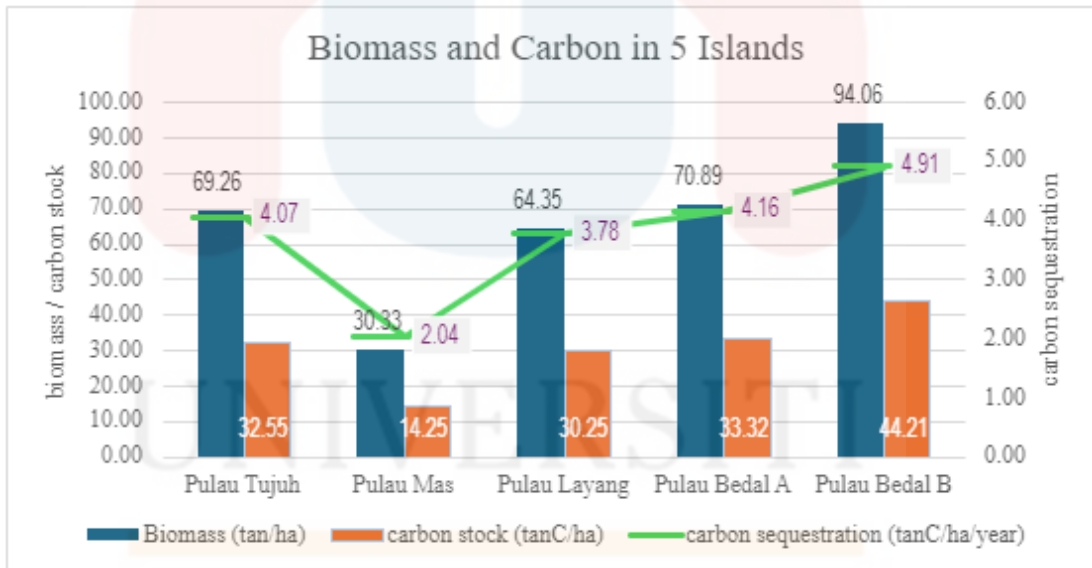


Figure 4.6: Total of Biomass, Carbon Stock and Carbon Sequestration

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In Table 4.2, shows of three variables which is the total of biomass, carbon stock and carbon sequestration on five islands. The top highest are Pulau Bedal B while Pulau Mas are the lowest among five islands. The higher the biomass is, the lower the carbon stock will be, as shown on Figure 4. Carbon stock relies on photosynthesis of vegetation to import the carbon from atmosphere as to increase it. Then, the carbon that were produced distributed to other part such as root and litter as well (Meng *et al.*, 2021).

The relationship between total carbon stock and restoration age in mangroves is that it significantly increases with the developing forest age. Carbon stock use as a proxy for restoration success, the higher the carbon stocks in restored sites, it can indicated the effectiveness of restoration in enhancing ecosystem carbon sequestration (Osuri *et al.*, 2019). The area may establish since 16 to 21 years ago but the year planted of each islands as shown on Table 4.3, the most longest planted was Pulau Bedal B and the most brief planted was Pulau Mas.

Table 4.3: Carbon Stock Table

Islands	Carbon Stock	Year planted	Area Establishment
Pulau Tujuh	32.55	8	18
Pulau Mas	14.25	7	21
Pulau Layang-Layang	30.25	8	20
Pulau Bedal A	33.32	8	18
Pulau Bedal B	44.20	9	16

Since Pulau Bedal B are the longest was planted mangrove, it also got the highest among others and the factors show itself such as the tree age, the tree species itself, the diameter and height, environmental factors and crop density (Polglase *et al.*, 2011). Tree age significantly influences carbon sequestration, with species having varying capacities. Larger trunks sequester more carbon, while environmental

factors like climate, soil nutrients, and elevation influence forests. Crop density is not taken due to sampling limitations, and tree growth depends on these factors.

Table 4.4: Soil pH

Islands	Soil pH
Pulau Mas	4
Pulau Layang-layang	6.2
Pulau Tujuh	3
Pulau Bedal A	6.2
Pulau Bedal B	5.8

The environmental factors due to the climate change and the changes of soil pH could influence the carbon sequestration. The range of acidic soil start from 1 to 6.5, from 6.5 to 7.5 are neutral and over 7.5 are alkaline (Queensland, 2013). The best growth range for soil pH are between range 5.16 to 7.72 because they could adapt to the harsh environmental conditions and low nutrient availability. Outside from this range, the mangrove could not tolerate because of the nutrients cannot be accessible to the mangrove (Alsumaiti *et al*, 2018).

Amount of acidic element could reduce the amount of organic matter in the soil. Table 4.4 explained the soil pH on these five islands, Pulau Tujuh has acidic soil (3) that could effect the nutrient of mangrove trees, and then proceed to the Pulau Mas (4) that also have high concentrations of acidic organic matter. The best growth are Pulau Layang-Layang (6.2), Pulau Bedal A (6.2), Pulau Bedal B (5.8) which shows the relationship between soil and biomass that are relatively higher together. The soil pH range could help mangrove to survive better which can lead to increased microbial activity and nutrient cycling, which can enhance carbon storage and sequestration (He *et. al.*, 2024). Thus, could help to attribute with restoration age.

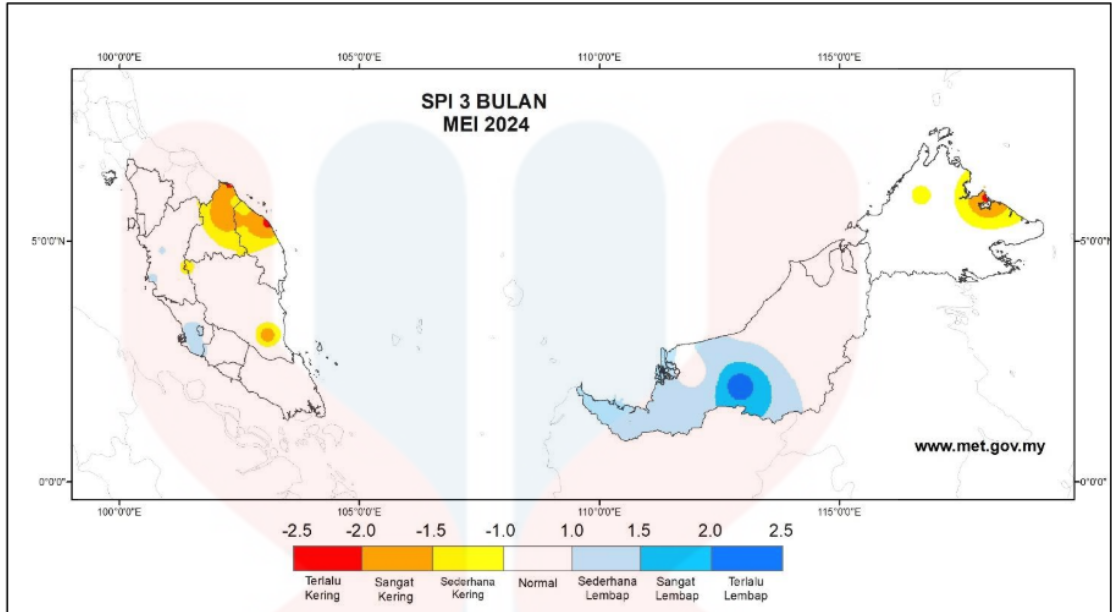


Figure 4.7: SPI 3 months from March – May 2024 (MET, 2024)

Rainfall and temperature are also one of main drivers for mangrove carbon sequestration. The mangrove regions with lower rainfall and higher temperatures could give more than those regions with higher rainfall and lower temperatures. Tropical sites also known as have higher aboveground carbon stock because of the annual of precipitation.

During the days, the precipitation has average which is the precipitation are 57.36 mm and temperatures are 28.83 °C. Figure 4.6 shows most of places in Peninsular Malaysia recorded as normal scale except for Kota Bharu and Kuala Krai meteorology station that were recorded as very dry with SPI index readings as -2.04 and -1.97 deficit with total cumulative rain are 3 months within 35%. The negative total shows that Kota Bharu and Kuala Krai are achieve status of very drought that lead to dry soil and less precipitation. Kota Bharu stated the total of rainfall from

March to May 2024 were 72.1 mm (Jabatan Meterologi Malaysia, 2024). These totals were too little with what the mangrove forest should receive.

Mangrove forests should have total annual rainfall varies from 1000 to 1500 mm and the average monthly temperatures in a mangrove forest vary from a minimum of 25.0°C to 27.8°C. Rhizophora are species have low tolerance for temperatures below 0°C and above 38°C. Although Rhizophora could live in those circumstances, but Rhizophora are intolerable with precipitation below 40 mm due to the species are less likely halophilic which means the species are unlikely with salty environments. The unlikely becoming that during drought season, low precipitation happens and the salinity levels in soils happens which lead to the migration of Rhizophora species to the areas of lesser salinity (Aroloye & Camilo, 2017).

The less precipitation with increases temperatures influences the structure, functions, dynamics and distribution of forest vegetation and thus influences the carbon sequestration (Zhou et al., 2022). These can be seen that temperatures effect the growth rate that require a certain warm temperature to ensure respiration rates sufficient for maintenance and growth. The best temperature for growth are between 20 and 30 with a threshold temperature of 12.2 for maintenance and growth (Inoue *et al.*, 2021). The temperature were effect to the tree diameter and height in determining the stand age. The wider diameter is the older the tree is, same goes with height.

The calculation of carbon stock was done by using the calculation of biomass, which is done by measuring DBH and height. Abiotic factors such as precipitation, temperature, and tropical cyclone frequency influence the production of biomass and carbon. Meanwhile, the age is one of the biotic factors. The stand-age for five islands is not fully growing, as the carbon stock table said, such as Pulau Tujuh that has been planted 18 years ago, only growth like 8 years old plants due to influences of soil, temperature, and precipitation.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Carbon stock represents the total amount of carbon that has been sequestered. The total of carbon stock for these five islands 154.57 tanC/Ha and the total average is 30.91 tanC/Ha. The biomass effected the result of carbon stock and one of the factor due to soil, precipitation and temperature are very drought in those area and that time.

Aboveground carbon sequestration only calculated with various parameters such as breast height (DBH), total height and using formula above-ground biomass (AGB). The content of carbon sequestration are higher in Pulau Bedal B (4.91 tanC/Ha/year) in 9 year, and the lowest were Pulau Mas (2.04 tanC/Ha/year) in 7 year. These rates are lower than the potential in mangrove forest around world, but are higher among these five island in Delta Tumpat, Kelantan.

5.2 Recommendation

However, the study found limitation with single method, uncertainty in calculations and specific location. To collect the data, as a researcher only use once chance to collect data, which may not capture all the details of the mangrove ecosystem. Limited time due the weather and tidal, cannot use another type of

carbon for take data. The uncertainty in estimates the best calculations for mangrove also limited to get the accuracy of the results and the location of Tumpat itself cannot represent the entire forest. The different areas may store different amounts of carbon. For further study, it is suggested that gave large group to collect the data for collect five type of carbon to get the optimal results and to get the best data for future references for Delta Tumpat.

Due to the low total of sequestration, the study shows that more parameters need to be taken in future such as litter and soil. Soil is known to have potential of biggest amount of carbon sequestration. This study highlights the significant role of trees in storing carbon and their potential contribution and more outcomes should offer in next time.

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APPENDIX

APPENDIX A

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APPENDIX B

No	Pulau	Species	DBH (cm)	Height (cm)	Biomass (tan/ha)	Carbon Stock (tanC/ha)	Carbon Sequestration (tanC/ha/year)
1	Pulau Tujuh	<i>R. mucronata</i>	10	6.4	0.0470	0.0221	0.0028
2		<i>R. mucronata</i>	15.5	9.6	0.1709	0.0803	0.0100
3		<i>R. mucronata</i>	11.8	8	0.0821	0.0386	0.0048
4		<i>R. mucronata</i>	19.8	9.6	0.2799	0.1316	0.0164
5		<i>R. mucronata</i>	15.7	11.2	0.2049	0.0963	0.0120
6		<i>R. mucronata</i>	10	11.2	0.0826	0.0388	0.0049
7		<i>R. mucronata</i>	17.2	9.6	0.2108	0.0991	0.0124
8		<i>R. mucronata</i>	17.5	9.6	0.2183	0.1026	0.0128
9		<i>R. mucronata</i>	13.5	11.2	0.1511	0.0710	0.0089
10		<i>R. mucronata</i>	10.9	11.2	0.0982	0.0462	0.0058
11		<i>R. mucronata</i>	Dead	Dead	0.0000	0.0000	0.0000
12		<i>R. mucronata</i>	13.5	9.6	0.1294	0.0608	0.0076
13		<i>R. mucronata</i>	13.5	9.6	0.1294	0.0608	0.0076
14		<i>R. mucronata</i>	12.8	11.2	0.1358	0.0638	0.0080
15		<i>R. mucronata</i>	13.1	11.2	0.1422	0.0669	0.0084
16		<i>R. mucronata</i>	15.6	11.2	0.2022	0.0951	0.0119
17		<i>R. mucronata</i>	14.4	12.8	0.1969	0.0925	0.0116
18		<i>R. mucronata</i>	11.5	11.2	0.1094	0.0514	0.0064
19		<i>R. mucronata</i>	16.2	11.2	0.2182	0.1026	0.0128
20		<i>R. mucronata</i>	11.6	11.2	0.1113	0.0523	0.0065
21		<i>R. mucronata</i>	13.5	8	0.1077	0.0506	0.0063
22		<i>R. mucronata</i>	18.6	9.6	0.2468	0.1160	0.0145
23		<i>R. mucronata</i>	14.2	11.2	0.1673	0.0786	0.0098
24		<i>R. mucronata</i>	12.6	11.2	0.1315	0.0618	0.0077
25		<i>R. mucronata</i>	10.5	9.6	0.0780	0.0367	0.0046
26		<i>R. mucronata</i>	10.77	9.6	0.0821	0.0386	0.0048
27		<i>R. mucronata</i>	Dead	Dead	0.0000	0.0000	0.0000
28		<i>R. mucronata</i>	Dead	Dead	0.0000	0.0000	0.0000
29		<i>R. mucronata</i>	14	11.2	0.1626	0.0764	0.0096
30		<i>R. mucronata</i>	15	9.6	0.1600	0.0752	0.0094
31		<i>R. mucronata</i>	10.1	11.2	0.0842	0.0396	0.0049
32		<i>R. mucronata</i>	14	11.2	0.1626	0.0764	0.0096
33		<i>R. mucronata</i>	11.5	9.6	0.0937	0.0440	0.0055
34		<i>R. mucronata</i>	11.1	9.6	0.0872	0.0410	0.0051
35		<i>R. mucronata</i>	11.5	9.6	0.0937	0.0440	0.0055
36		<i>R. mucronata</i>	15.2	9.6	0.1643	0.0772	0.0097
37		<i>R. mucronata</i>	11.2	9.6	0.0888	0.0417	0.0052
38		<i>R. mucronata</i>	15.5	11.2	0.1996	0.0938	0.0117
39		<i>R. mucronata</i>	13.6	9.6	0.1313	0.0617	0.0077

40		<i>R. mucronata</i>	15.8	11.2	0.2075	0.0975	0.0122
41		<i>R. mucronata</i>	11.4	9.6	0.0920	0.0433	0.0054
42		<i>R. mucronata</i>	10.4	9.6	0.0765	0.0360	0.0045
43		<i>R. mucronata</i>	12.7	9.6	0.1144	0.0538	0.0067
44		<i>R. mucronata</i>	12.65	12.8	0.1517	0.0713	0.0089
45		<i>R. mucronata</i>	11.75	12.8	0.1307	0.0614	0.0077
46		<i>R. mucronata</i>	15	8	0.1331	0.0626	0.0078
47		<i>R. mucronata</i>	12.8	8	0.0967	0.0455	0.0057
48		<i>R. mucronata</i>	12.43	11.2	0.1280	0.0601	0.0075
49		<i>R. mucronata</i>	13.6	11.2	0.1534	0.0721	0.0090
50		<i>R. mucronata</i>	15.4	12.8	0.2254	0.1059	0.0132
51		<i>R. mucronata</i>	11.85	9.6	0.0995	0.0468	0.0058
52		<i>R. mucronata</i>	13.65	11.2	0.1545	0.0726	0.0091
TOTAL					69.257	32.5507	4.0688

No	Pulau	Species	DBH (cm)	Height (cm)	Biomass (tan/ha)	Carbon Stock (tanC/ha)	Carbon Sequestration (tanC/ha/year)
1	Pulau Layang	<i>R. mucronata</i>	11.4	11.2	0.10750	0.05053	0.00632
2	Layang	<i>R. mucronata</i>	13.85	11.2	0.15913	0.07479	0.00935
3	-	<i>R. mucronata</i>	Dead	Dead	0.00000	0.00000	0.00000
4	Layang	<i>R. mucronata</i>	12.35	8	0.09000	0.04230	0.00529
5		<i>R. mucronata</i>	Dead	9.6	0.00000	0.00000	0.00000
6		<i>R. mucronata</i>	Dead	11.2	0.00000	0.00000	0.00000
7		<i>R. mucronata</i>	13.9	11.2	0.16029	0.07534	0.00942
8		<i>R. mucronata</i>	Dead	Dead	0.00000	0.00000	0.00000
9		<i>R. mucronata</i>	12.5	11.2	0.12942	0.06083	0.00760
10		<i>R. mucronata</i>	12.3	9.6	0.10726	0.05041	0.00630
11		<i>R. mucronata</i>	17.87	8	0.18947	0.08905	0.01113
12		<i>R. mucronata</i>	Dead	Dead	0.00000	0.00000	0.00000
13		<i>R. mucronata</i>	13.75	11.2	0.15682	0.07371	0.00921
14		<i>R. mucronata</i>	15.8	11.2	0.20750	0.09752	0.01219
15		<i>R. mucronata</i>	15.43	17.6	0.31191	0.14660	0.01832
16		<i>R. mucronata</i>	10.5	11.2	0.09109	0.04281	0.00535
17		<i>R. mucronata</i>	10.5	14.4	0.11733	0.05514	0.00689
18		<i>R. mucronata</i>	12.62	9.6	0.11296	0.05309	0.00664
19		<i>R. mucronata</i>	11	6.4	0.05693	0.02676	0.00334
20		<i>R. mucronata</i>	13.5	12.8	0.17289	0.08126	0.01016
21		<i>R. mucronata</i>	10.8	11.2	0.09640	0.04531	0.00566
22		<i>R. mucronata</i>	16.1	11.2	0.21551	0.10129	0.01266
23		<i>R. mucronata</i>	13.8	9.6	0.13525	0.06357	0.00795
24		<i>R. mucronata</i>	Dead	Dead	0.00000	0.00000	0.00000
25		<i>R. mucronata</i>	12	8	0.08493	0.03992	0.00499

26		<i>R.mucronata</i>	14.6	11.2	0.17697	0.08318	0.01040
27		<i>R.mucronata</i>	15.3	12.8	0.22248	0.10457	0.01307
28		<i>R.mucronata</i>	Dead	Dead	0.00000	0.00000	0.00000
29		<i>R.mucronata</i>	14.5	11.2	0.17454	0.08203	0.01025
30		<i>R.mucronata</i>	18	14.4	0.34757	0.16336	0.02042
31		<i>R.mucronata</i>	16.57	11.2	0.22838	0.10734	0.01342
32		<i>R.mucronata</i>	21.5	6.4	0.21964	0.10323	0.01290
33		<i>R.mucronata</i>	17.5	14.4	0.32839	0.15434	0.01929
34		<i>R.mucronata</i>	12.6	8	0.09371	0.04404	0.00551
35		<i>R.mucronata</i>	12.5	8	0.09221	0.04334	0.00542
36		<i>R.mucronata</i>	14.75	12.8	0.20666	0.09713	0.01214
37		<i>R.mucronata</i>	11.85	12.8	0.13296	0.06249	0.00781
38		<i>R.mucronata</i>	14.45	14.4	0.22326	0.10493	0.01312
39		<i>R.mucronata</i>	13.1	12.8	0.16273	0.07648	0.00956
40		<i>R.mucronata</i>	17.5	12.8	0.29165	0.13707	0.01713
41		<i>R.mucronata</i>	15.6	14.4	0.26051	0.12244	0.01530
42		<i>R.mucronata</i>	14	11.2	0.16262	0.07643	0.00955
43		<i>R.mucronata</i>	13.5	11.2	0.15113	0.07103	0.00888
44		<i>R.mucronata</i>	15.5	14.4	0.25715	0.12086	0.01511
TOTAL					64.3515	30.2452	3.78065

No	Pulau	Species	DBH (cm)	Height (cm)	Biomass (tan/ha)	Carbon Stock (tanC/ha)	Carbon Sequestration (tanC/ha/year)
1	Pulau Mas	<i>R.mucronata</i>	11.2	6.4	0.0590	0.0277	0.0040
2		<i>R.mucronata</i>	13	8	0.0998	0.0469	0.0067
3		<i>R.mucronata</i>	11.8	8	0.0821	0.0386	0.0055
4		<i>R.mucronata</i>	12.1	8	0.0864	0.0406	0.0058
5		<i>R.mucronata</i>	13.95	9.6	0.1382	0.0650	0.0093
6		<i>R.mucronata</i>	10.3	9.6	0.0750	0.0353	0.0050
7		<i>R.mucronata</i>	12.8	8	0.0967	0.0455	0.0065
8		<i>R.mucronata</i>	12.5	9.6	0.1108	0.0521	0.0074
9		<i>R.mucronata</i>	11.4	9.6	0.0920	0.0433	0.0062
10		<i>R.mucronata</i>	10	9.6	0.0707	0.0332	0.0047
11		<i>R.mucronata</i>	11.1	9.6	0.0872	0.0410	0.0059
12		<i>R.mucronata</i>	10.55	11.2	0.0920	0.0432	0.0062
13		<i>R.mucronata</i>	19.5	9.6	0.2714	0.1276	0.0182
14		<i>R.mucronata</i>	11.5	11.2	0.1094	0.0514	0.0073
15		<i>R.mucronata</i>	27.8	9.6	0.5546	0.2607	0.0372
16		<i>R.mucronata</i>	13.5	9.6	0.1294	0.0608	0.0087
17		<i>R.mucronata</i>	10.2	9.6	0.0736	0.0346	0.0049
18		<i>R.mucronata</i>	10.4	11.2	0.0893	0.0420	0.0060
19		<i>R.mucronata</i>	11.87	11.2	0.1166	0.0548	0.0078

20		<i>R.mucronata</i>	12.3	9.6	0.1073	0.0504	0.0072
21		<i>R.mucronata</i>	17.9	11.2	0.2668	0.1254	0.0179
22		<i>R.mucronata</i>	10.3	11.2	0.0876	0.0412	0.0059
23		<i>R.mucronata</i>	12.85	11.2	0.1368	0.0643	0.0092
TOTAL					30.3289	14.2546	2.0364

No	Pulau	Species	DBH (cm)	Height (cm)	Biomass (tan/ha)	Carbon Stock (tanC/ha)	Carbon Sequestration (tanC/ha/year)
1	Pulau Bedal A	<i>R. apiculata</i>	Dead	Dead	0.0000	0.0000	0.0000
2		<i>R. apiculata</i>	13.7	14.8	0.2160	0.1015	0.0127
3		<i>R. apiculata</i>	14.6	19.6	0.3208	0.1508	0.0188
4		<i>R. apiculata</i>	Dead	Dead	0.0000	0.0000	0.0000
5		<i>R. apiculata</i>	Dead	Dead	0.0000	0.0000	0.0000
6		<i>R. apiculata</i>	Dead	Dead	0.0000	0.0000	0.0000
7		<i>R. apiculata</i>	16	14.8	0.2918	0.1371	0.0171
8		<i>R. apiculata</i>	14.8	16.4	0.2771	0.1302	0.0163
9		<i>R. apiculata</i>	Dead	Dead	0.0000	0.0000	0.0000
10		<i>R. apiculata</i>	Dead	Dead	0.0000	0.0000	0.0000
11		<i>R. apiculata</i>	Dead	Dead	0.0000	0.0000	0.0000
12		<i>R. apiculata</i>	12.3	16.4	0.1936	0.0910	0.0114
13		<i>R. apiculata</i>	11.4	13.2	0.1355	0.0637	0.0080
14		<i>R. apiculata</i>	15	14.8	0.2575	0.1210	0.0151
15		<i>R. apiculata</i>	14.9	13.2	0.2275	0.1069	0.0134
16		<i>R. apiculata</i>	19.3	13.2	0.3756	0.1765	0.0221
17		<i>R. apiculata</i>	15.5	14.8	0.2744	0.1290	0.0161
18		<i>R. apiculata</i>	15.2	14.8	0.2642	0.1242	0.0155
19		<i>R. apiculata</i>	13.4	14.8	0.2070	0.0973	0.0122
20		<i>R. apiculata</i>	10.6	16.4	0.1452	0.0682	0.0085
21		<i>R. apiculata</i>	12.2	14.8	0.1726	0.0811	0.0101
22		<i>R. apiculata</i>	13.4	18	0.2502	0.1176	0.0147
23		<i>R. apiculata</i>	13.8	10	0.1499	0.0704	0.0088
24		<i>R. apiculata</i>	11.2	11.6	0.1155	0.0543	0.0068
25		<i>R. apiculata</i>	25.3	10	0.4848	0.2279	0.0285
26		<i>R. apiculata</i>	14.7	11.6	0.1956	0.0919	0.0115
27		<i>R. apiculata</i>	13.9	11.6	0.1755	0.0825	0.0103
28		<i>R. apiculata</i>	11	13.2	0.1264	0.0594	0.0074
29		<i>R. apiculata</i>	10.4	13.2	0.1134	0.0533	0.0067
30		<i>R. apiculata</i>	11.2	13.2	0.1309	0.0615	0.0077
31		<i>R. apiculata</i>	16.5	11.6	0.2446	0.1150	0.0144
32		<i>R. apiculata</i>	14.7	11.6	0.1956	0.0919	0.0115
33		<i>R. apiculata</i>	10.3	11.6	0.0982	0.0462	0.0058
34		<i>R. apiculata</i>	11	13.2	0.1264	0.0594	0.0074
35		<i>R. apiculata</i>	11.6	13.2	0.1401	0.0658	0.0082
36		<i>R. apiculata</i>	12	13.2	0.1496	0.0703	0.0088
37		<i>R. apiculata</i>	10.4	11.6	0.1001	0.0470	0.0059

38		<i>R. apiculata</i>	10.9	13.2	0.1242	0.0584	0.0073
39		<i>R. apiculata</i>	10	11.6	0.0927	0.0436	0.0054
40		<i>R. apiculata</i>	13.3	11.6	0.1611	0.0757	0.0095
41		<i>R. apiculata</i>	13	11.6	0.1541	0.0724	0.0091
42		<i>R. apiculata</i>	15.1	11.6	0.2060	0.0968	0.0121
43		<i>R. apiculata</i>	14.7	11.6	0.1956	0.0919	0.0115
44		<i>R. apiculata</i>	Dead	Dead	0.0000	0.0000	0.0000
TOTAL					70.8911	33.3188	4.1649

No	Pulau	Species	DBH (cm)	Height (cm)	Biomass (tan/ha)	Carbon Stock (tanC/ha)	Carbon Sequestration (tanC/ha/year)
1	Pulau Bedal B	<i>R.apiculata</i>	11	14.4	0.13752	0.06463	0.00718
2		<i>R.apiculata</i>	13	12.8	0.16957	0.07970	0.00886
3		<i>R.apiculata</i>	18.1	17.6	0.43819	0.20595	0.02288
4		<i>R.apiculata</i>	14	14.4	0.21939	0.10311	0.01146
5		<i>R.apiculata</i>	13.2	12.8	0.17466	0.08209	0.00912
6		<i>R.apiculata</i>	12.8	14.4	0.18443	0.08668	0.00963
7		<i>R.apiculata</i>	13.3	12.8	0.17723	0.08330	0.00926
8		<i>R.apiculata</i>	14.4	14.4	0.23169	0.10889	0.01210
9		<i>R.apiculata</i>	15.2	16	0.28491	0.13391	0.01488
10		<i>R.apiculata</i>	19	16	0.43894	0.20630	0.02292
11		<i>R.apiculata</i>	10.5	11.2	0.09852	0.04630	0.00514
12		<i>R.apiculata</i>	24	14.4	0.62315	0.29288	0.03254
13		<i>R.apiculata</i>	Dead	Dead	0.00000	0.00000	0.00000
14		<i>R.apiculata</i>	14.7	12.8	0.21514	0.10111	0.01123
15		<i>R.apiculata</i>	11.2	11.2	0.11164	0.05247	0.00583
16		<i>R.apiculata</i>	Dead	Dead	0.00000	0.00000	0.00000
17		<i>R.apiculata</i>	12.5	12.8	0.15716	0.07387	0.00821
18		<i>R.apiculata</i>	13.7	12.8	0.18770	0.08822	0.00980
19		<i>R.apiculata</i>	14.5	12.8	0.20950	0.09847	0.01094
20		<i>R.apiculata</i>	15.6	14.4	0.27054	0.12716	0.01413
21		<i>R.apiculata</i>	11.2	12.8	0.12705	0.05971	0.00663
22		<i>R.apiculata</i>	16.8	16	0.34585	0.16255	0.01806
23		<i>R.apiculata</i>	17.5	8	0.19129	0.08991	0.00999
24		<i>R.apiculata</i>	18.1	9.6	0.24363	0.11451	0.01272
25		<i>R.apiculata</i>	11.7	8	0.08771	0.04122	0.00458
26		<i>R.apiculata</i>	16.3	9.6	0.19890	0.09348	0.01039
27		<i>R.apiculata</i>	12.7	9.6	0.12266	0.05765	0.00641
28		<i>R.apiculata</i>	12	11.2	0.12760	0.05997	0.00666
29		<i>R.apiculata</i>	14.5	11.2	0.18409	0.08652	0.00961
30		<i>R.apiculata</i>	17.7	11.2	0.27088	0.12731	0.01415
31		<i>R.apiculata</i>	12.1	9.6	0.11169	0.05249	0.00583
32		<i>R.apiculata</i>	14.3	9.6	0.15435	0.07255	0.00806
33		<i>R.apiculata</i>	18	9.6	0.24103	0.11329	0.01259
34		<i>R.apiculata</i>	17	11.2	0.25051	0.11774	0.01308
35		<i>R.apiculata</i>	12.5	11.2	0.13810	0.06491	0.00721
36		<i>R.apiculata</i>	14.5	11.2	0.18409	0.08652	0.00961
37		<i>R.apiculata</i>	12.7	9.6	0.12266	0.05765	0.00641

38	<i>R.apiculata</i>	15.3	11.2	0.20427	0.09601	0.01067
39	<i>R.apiculata</i>	12.1	9.6	0.11169	0.05249	0.00583
40	<i>R.apiculata</i>	12.4	9.6	0.11711	0.05504	0.00612
41	<i>R.apiculata</i>	12.6	9.6	0.12080	0.05677	0.00631
42	<i>R.apiculata</i>	12.2	9.6	0.11348	0.05334	0.00593
43	<i>R.apiculata</i>	14.4	9.6	0.15645	0.07353	0.00817
44	<i>R.apiculata</i>	17.7	11.2	0.27088	0.12731	0.01415
45	<i>R.apiculata</i>	14	11.2	0.17200	0.08084	0.00898
46	<i>R.apiculata</i>	15	11.2	0.19658	0.09239	0.01027
47	<i>R.apiculata</i>	13.7	9.6	0.14206	0.06677	0.00742
48	<i>R.apiculata</i>	11.8	8	0.08917	0.04191	0.00466
49	<i>R.apiculata</i>	15	9.6	0.16932	0.07958	0.00884
50	<i>R.apiculata</i>	12	9.6	0.10991	0.05166	0.00574
TOTAL				94.05686	44.20672	4.91186