ESTIMATION OF ABOVEGROUND BIOMASS ON *RHIZOPHORA MUCRONATA* AT PULAU TUJUH DELTA TUMPAT, KELANTAN

by

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A final year project report submitted in fulfillment of the requirements for the degree of Bachelor of Applied Science (Natural Resource Science) with Honours

FACULTY OF EARTH SCIENCE
UNIVERSITI MALAYSIA KELANTAN

2024

DECLARATION

I declare that this thesis entitled "Estimation of Aboveground Biomass on *Rhizophora Mucronata* at Pulau Tujuh Delta Tumpat, Kelantan" 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.

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ACKNOWLEDGEMENT

I would like to express my deepest gratitude to my supervisor, Ts Dr. Noor Janatun Naim Binti Jemali, whose expertise, guidance, and patience were instrumental in the completion of this thesis. The examiners and FYP coordinator that provided invaluable feedback and encouragement throughout the entire research process, ensuring that I stayed focused and motivated. Your dedication to academic excellence and commitment to student success have profoundly influenced my approach to research.

I am also incredibly thankful to my friends, who offered unwavering support and companionship during the highs and lows of my academic journey. Syahir, Ammar, Hairi, Imran, Faatihah and Jess were always there to lend a listening ear, provide thoughtful advice, and remind me to take breaks when needed. Their friendship has been a constant source of strength and joy, making the challenging moments more bearable and the successes even sweeter.

Lastly, I owe an immense debt of gratitude to my parents, whose love and encouragement have been the foundation of all my achievements. Their belief in my abilities and constant support have given me the confidence to pursue my goals relentlessly. They have sacrificed much to ensure I had the best opportunities, and for that, I am eternally grateful. This thesis is as much a testament to their faith in me as it is a reflection of my hard work and dedication.

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ABSTRACT

Mangrove forests play an important role in sequestering carbon dioxide from the atmosphere. There are many studies on mangroves in dense deltas. However, information about mangrove trees on Pulau Tujuh is still scarce especially on above-ground biomass and carbon storage of *Rhizophora mucronata*. The objective of this study is to analyze the above-ground biomass (AGB) in the mangrove forest in Pulau Tujuh Delta Tumpat. Within the 8 plots set-up with size of 20x20m, 384 trees of *R.mucronata* were measured and recorded. The total AGB of the area is calculated at 767.90 t/ha, while the total carbon stock is 383.95 tC/ha. Plot 6 has the greatest number of trees with the highest above-ground biomass (AGB) and carbon stock value with 153.13 t/ha and 76.56 tc/ha, respectively. The findings emphasize the need for conservation efforts to protect and maintain these mangrove forests. Effective management strategies should be implemented to preserve these critical ecosystems, which are vital for both local biodiversity and global climate regulation.

ANGGARAN BIOMASS DI ATAS TANAH PADA *RHIZOPHORA MUCRONATA* DI PULAU TUJUH DELTA TUMPAT, KELANTAN

ABSTRAK

Hutan bakau memainkan peranan penting dalam mengasingkan karbon dioksida daripada atmosfera. Terdapat banyak kajian tentang bakau di delta yang padat. Bagaimanapun, maklumat mengenai pokok bakau di Pulau Tujuh masih kurang terutamanya mengenai biojisim di atas tanah dan simpanan karbon oleh spesis *Rhizophora mucronata*. Objektif kajian ini adalah untuk menganalisis biojisim atas tanah (AGB) dan stok karbon di hutan bakau di Pulau Tujuh Delta Tumpat. Dalam 8 petak yang dibuka dengan saiz 20x20 m, 384 pokok *R.mucronata* telah diukur dan direkodkan. Jumlah AGB kawasan itu dikira pada 767.90 t/ha, manakala jumlah stok karbon ialah 383.95 tC/ha. Plot 6 mempunyai bilangan pokok terbanyak dengan nilai biojisim atas tanah (AGB) dan stok karbon tertinggi iaitu masing-masing 153.13 t/ha dan 76.56 tc/ha. Penemuan ini menekankan keperluan usaha pemuliharaan untuk melindungi dan mengekalkan hutan bakau ini. Strategi pengurusan yang berkesan harus dilaksanakan untuk memelihara ekosistem kritikal ini, yang penting untuk kedua-dua biodiversiti tempatan dan peraturan iklim global.

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LIST OF ABBREVIATIONS

AGB	Above Ground Biomass
BGB	Below Ground Biomass
DBH	Diameter At Breast Height
GPS	Global Positioning System

LIST OF SYMBOLS

°c	Celsius
cm	Centimeter
ha	Hecter
kg/ha	Kilogram Per Hectare
mg/ha	Megagram Per Hectare
tc/ha	Total Carbon Per Hectare
t/ha	Ton Per Hectare

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Mangroves are a special type of coastal environment that differ from terrestrial vegetation in a number of ways. They are members of the Plant Kingdom and have adapted to survive in the harsh intertidal environment. Mangroves are distinguished by their exceptional ability to withstand high salinities, a quality that enables them to flourish in brackish seas. Numerous plant species can be found in these ecosystems, such as the well-known genera *Rhizophora* and *Avicennia*, which are distinguished by their distinct prop roots and salt-filtering roots (Eslami-Andargoli et al., 2015).

In contrast to most terrestrial plants, mangrove trees have developed intricate root systems to withstand environmental obstacles. Pneumatophores, specialised root structures that rise above the water's surface and allow gas exchange while filtering out excess salt, are found in species of *Rhizophora*. They are able to breathe in the oxygen-starved, wet sediments where they are growing because of this adaption. Conversely, *Avicennia* species are anchored in the muddy substrate and help to absorb oxygen thanks to their stilt-like prop roots. Their survival in salty environments is largely dependent on these root adaptations.

Four countries contain about 42 percent of the world's mangroves: Brazil, Australia, Mexico, and Indonesia. Ten countries house the majority, specifically sixty-four percent, of the world's mangroves (Giri et al., 2011). Giesen et al. assert that Southeast Asian mangroves are well developed and potentially the most species-rich globally. However, there aren't many carbon studies on mangroves. Blue carbon studies are those that examine carbon in mangrove and ocean ecosystems (McLeod et al., 2011). There is no information provided in the user's text. Pendleton et al., (2012) defines "blue carbon" as coastal ecosystems with vegetation that have the capacity to store significant quantities of carbon, such as mangrove forests, Tidal marshes and seagrass meadows. The term "blue carbon" refers to carbon that is emitted, stored, or captured from specific types of vegetated coastal ecosystems, as defined by Herret et al., (2012). Coastal vegetation is still disappearing and degrading despite this due to ongoing development pressures.

The entire area of mangroves in Malaysia is estimated to be 537,686 hectares, of which 364,100 hectares are in Sabah. In the meantime, mangroves cover 132,000 hectares (23%) and 104,181 hectares (18%) of Peninsular Malaysia and Sarawak, according to Olaniyi et al., (2012), Marzuki 2019; Tangah et al. 2020, respectively. Mangrove forests store carbon three to five times better than other forest types, with the soil storing 70 to 90 percent of it, according to Donato et al. (2011). (Hance, 2011) These figures highlight the significance of accurately measuring the carbon storage capacity of mangrove forests. Even though the mangrove forest's carbon pools are very good at storing carbon for a long time, there is still a dearth of knowledge on this topic, particularly with regard to the carbon pools that are below ground.

Problem Statement

The apparent absence of recent research data on aboveground biomass in mangrove forests at Delta Tumpat Kelantan specifically at Pulau Tujuh underlines a large knowledge gap that not only hinders the ability to comprehensively understand the dynamic nature of carbon storage in this ecosystem but also leaves a void in understanding its importance and role in carbon sequestration. The lack of recent research not only limits insights into the complex dynamics of carbon in future conservation planning,

Objective

The objective of this study is to estimates the aboveground biomass and carbon stock of mangrove forest species of *R.mucronata* in Pulau Tujuh Delta Tumpat, Kelantan.

Scope of Study

The study was conducted at the mangrove forest in the Pulau Tujuh Delta Tumpat, Kelantan. This study focused only on aboveground biomass and carbon stock assessment of specific mangrove species of *Rhizophora mucronata*. This estimates the ABG and carbon stock of selected species using allometric equation created by Adame et al (2017).

Significant of Study

Study on carbon stock and biomass content of *Rhizopora mucronata* in Pulau Tujuh is very scarce. Hence, the available data is outdated. Therefore this research was carried out to provide updated and comprehensive data on the carbon stock and biomass content of the selected mangrove species. It is also to enhance our understanding of its ecological role and contribution to carbon sequestration in the region. If we know about the carbon stock of mangrove forests, we can better understand their role in mitigating climate change, guide conservation efforts, and develop effective policies for carbon sequestration and coastal ecosystem management. Results from this study can be used for improving the development and implementation of targeted interventions, informing policy decisions, enhancing educational programs, guiding future research, and contributing to the broader understanding of the subject matter.

CHAPTER 2

LITERATURE REVIEW

2.1 Mangrove and mangrove forest

Mangroves have been recognised and investigated since antiquity. The earliest known accounts of *Rhizophora* plants in the Persian Gulf and the Red Sea were provided by Nearchus (325 B.C.), Theophrastus (305 B.C.), and Plutarch (70 A.D.), and Abou'l Abass, in 1230, documented the characteristics of *Rhizophora* and its young plants (MacNae, 1968; Chapman, 1976). Mangroves have had a significant and enduring connection with human culture and civilization throughout history. In the Solomon Islands, deceased individuals undergo certain ceremonies before being disposed of by being cast into the mangrove seas. (Vannucci, 1997). In the 1800s, the British employed the hands-on experience that Indians had amassed over many years to manage the mangrove plantations in the Sunderbans for the production of lumber for commercial use (Vannucci, 1997).

Conducting biochemical and genetic analyses of mangroves is expected to yield valuable insights regarding the evolutionary processes and geographical distribution of these plants. For instance, Significant genetic variation was found between mangroves in the eastern and western Atlantic regions by Dodd et al. (1998). Three species originating from western Africa had notably elongated carbon chains and a greater range of lipids compared to their counterparts from eastern South America, indicating that mangroves in the western Atlantic possess distinctive attributes. Ultimately, this evidence indicates that the dispersal of

Atlantic mangroves from the Tethys to the Pacific is improbable. *Avicennia* and *Rhizophora* likely emerged as the initial genera to develop, emerging during the later stages of the Cretaceous epoch (Chapman, 1976). Pollen records yield crucial data regarding following radiations. According to Y. Zhang et al. (1997), fossilised pollen discovered in strata on China's Leizhou Peninsula suggests that mangroves progressively expanded from the southern to the northern regions, reaching their northernmost point in the Changjiang Delta during the mid-Holocene.

Mangrove forests are found along tropical and subtropical coasts and have distinct zonation patterns, with each zone marked by a dominant species of mangrove (Duke et al., 1998, Tomlinson 2016). A mangrove forest is a type of forest with a unique environment. The plant population within this forest has evolved unique adaptations to flourish in harsh environments such as high salinity, high tides, and muddy soil (Giri et al., 2011). The global mangrove area is predicted to be between 14-15 million hectares, based on data from 1990-2020. Asia has the highest share, according to FAO 2020 and Kauffman and Donato 2012, the area is around 6.8 million hectares. Southeast Asia's mangroves are well-established and possibly have the largest species diversity worldwide (Giesen et al., 2007).

Malaysian mangroves cover an area of approximately 537,686 hectares, with Sabah accounting for more than half of this total area, particularly 364,100 hectares. According to Olaniyi et al. (2012), mangroves span an area of 132,000 ha (23%) in Sarawak and 104,181 hectares (18%) in Peninsular Malaysia, Marzuki (2019), and Tangah et al., (2020). Malaysia is endowed with a plethora of mangrove tree species. Malaysia is ranked second, after Indonesia, in terms of the number of real mangrove species discovered, with approximately 41 species (FAO 2007). Mangrove vegetation in Penang is primarily found in the intertidal zone on the west coast. The Lower Kelantan River expands into a broad delta measuring 1200 hectares, with bays, mangroves, and estuaries along the northeast coast of Peninsular Malaysia (Sefie et al., 2018).

2.2 Anatomy and Morphology

Mangrove trees are uniquely equipped to survive in coastal environments, with specialized roots, leaves, and reproductive strategies. Their adaptations not only allow them to thrive in saline, waterlogged conditions but also play a critical role in coastal ecosystem stability and health.

Plasticity is the ability of an organism to change its shape and/or physiology in response to changing environmental factors, such as light, and it is demonstrated by mangrove's leaves, the most productive organ in plants (Evans, 1999; Khan et al., 2004; Gratani et al., 2006; Rozendaal et al., 2006). Compared to other organs, leaves exhibit greater sensitivity and flexibility to changes in their environment (Shi and Cai, 2009). Mangroves produce a variety of salt adaptation mechanisms as a result of the main influence of soil salinity on leaf plasticity (Alam et al., 2018).

Mangroves leaves has lack sheath veins and have almost leathery texture (Feller et al., 2010). The plant seems glossy because of its thick, smooth cuticle that is dotted with tiny hairs. The medium-sized leaves are grouped in a bijugate pattern, it is a decussate pattern modified with each pair of leaves angled at a less than 180°

angle to the one before it. By reducing self-shading, this design creates a branching system that uses the most effective photosynthetic methods to fill the available area (Tomlinson, 1986). Specialized idiolect cells found in mangrove leaves tannic cells (*Rhizophoraceae*), mucous cells (*Rhizophora, Sonneratia*), oil cells (*Osbornia*), and laticifer cells (*Excoecaria*; Tomlinson, 1986), and crystal cells (*Rhizophoraceae*).

Mangroves are exceptionally adapted to coastal settings due to their exposed root respiration, many support roots and buttresses, salt- releasing leaves, and viviparous water-dispersed propagules. The physico-chemical characteristics of the habitat and taxonomic group affect this adaptation (Duke, 1992). The intricate root system that anchors and promotes gas exchange in the hypoxic mangrove forest environment is one of the key morphological forms (Kathiresan and Bingham 2001). Aerial roots, a highly distinctive property of more specialised mangroves where a portion of the root system is exposed to the atmosphere at least during low tide, aid in the process of storing and transporting water (Tomlinson 1994). Mangrove roots serve as a mechanism to capture silt that may reach the coastal area through river discharge, dredging, and floods in addition to their role in aerating the trees (Kathiresan, 2003).

Spongy pneumatophores are typically small (less than 30 cm), but in *Avicennia marina*, which survives in oil-contaminated anaerobic settings, they grow larger and more abundant. This phenotypic response appears to increase the surface area for gas exchange, according to Saifullah and Elahi (1992). Due to subsequent significant thickening, Sonneratia pneumatophores can be robust and three metres long (Tomlinson, 1986). Additionally, *R. apiculata* possesses two kinds of adventitious roots. both taproots and aerial roots. Due to environmental influences, both kinds of roots have evolved to tolerate or resist. Their typical characteristics include a root cap, naturally occurring lateral roots, exarch protoxylem, and alternating strands of primary phloem and xylem. The remaining ones have a big parenchymatous medulla and expanded polyarch stele. Specialised aerial roots are needed for above-ground living. They feature an elongated zone behind the apical meristem, compared to underground roots (Tomlinson, 1986).

Rhizophora mucronata, commonly known as the red mangrove, is a key species in tropical and subtropical coastal regions. It is known for its distinctive prop roots, which provide stability in the soft, muddy substrates where it typically grows. *R. mucronata is* characterized by prop roots. These are aerial roots that extend from the trunk and lower branches into the mud. They provide structural support and facilitate gas exchange in the anoxic (oxygen-poor) soil. The stem is typically straight and can grow up to 20-25 meters in height. And the bark is grey to brown and becomes fissured with age. The leaves shaped in elliptic to oblong, often with a distinctive mucronate (pointed) tip. Having an opposite leave arrangement, *R. mucronata* flowers is small, white to yellowish flowers that grow in clusters (cymes) at the ends of branches.

Meanwhile its reproductive parts have five to six sepals and an equal number of petals, with numerous stamens and typically pollinated by wind and insect. The *R. mucronata* follows vivipary system where the seeds germinate while still attached to the parent tree. The propagules (seedlings) eventually drop into the water and are carried away by tides to take root in new locations.

Rhizophora mucronata is a robust mangrove species well-adapted to its intertidal habitat. Its unique root system, leathery leaves, and vivipary reproduction make it an essential component of coastal ecosystems, contributing to shoreline stability and providing vital habitats for diverse species.

Mangrove forests have specific anatomical traits that have been summed up by Tomlinson (1986). Mangrove wood is good for building and furniture-making because it is heavy, durable, and contains a lot of silica. The wood is a popular option for both indoor and outdoor applications because of its strong resistance to deterioration. Mangroves are also utilised for arts and crafts, fuel, and charcoal manufacture. Sapwood and heartwood are absent from *R. apiculata* wood, as evidenced by the macroscopic features of the twigs and branches. Oil mangrove branches and twigs have a simple pattern and a smooth touch. When exposed to light, cross sections made of wood have a rough texture and appear shiny. Fresh mangrove oil wood has a distinct scent and is categorised as medium to soft in hardness. Three bodily structures. *R. apiculata* twigs and branches define fuzzy borders between growth rings with radially arranged vasculature and diffuse porous porosity. Vessel groups exist in 2–6 cells or clusters and are partially solitary. There are 42% solitary vessels in the twigs and 45% in the branches. *R. apiculata's* twigs and twigs feature circular vessel outlines with perforated plates that contain fewer than 10 scalariform bars.

2.3 Reproduction

Mangroves procreate similar to terrestrial plants, pollination by insects and the wind results in blossoming. The seed stays affixed to the parent plant after pollination. According to Bhosale and Mulik (1991), there are four ways that mangroves can reproduce: viviparity, crypto viviparity, regular germination on soil, and vegetative reproduction. One special adaptation to shallow maritime settings is vivipary, which is the rapid and unabated growth of young while remaining attached to the parent plant (Thomas and Paul, 1996). For an entire year, true viviparous species stay affixed to their mother plant. Offspring of crypto viviparous parents only cling for one to two months (Bhosale and Mulik, 1991). Before being released from the parent tree, seedlings with viviparous reproductive patterns may be able to acquire some saline tolerance, according to S.M. Smith and Snedaker (1995a). Mangrove propagules must go through a mandatory dispersal phase a few weeks prior to the radicle lengthening in preparation for root growth. However, propagules can survive in seawater for several months if they do not come into touch with sediment (Clarke, 1993).

Mangrove breeding seasons can vary greatly throughout the range of the species and are dependent on local environmental factors. In northern tropical settings, the flowering to fruiting phase lasts two to three months; in southern temperate locations, it lasts up to ten months. Day length regulates flowering, while air temperature determines when fruit ripens. Inducing vegetative propagation in *Avicennia alba, A. officinalis, Sonneratia apetala, Xylocarpus granatum,* and *Rhizophora mangle* has been accomplished with success using the most recent method of air layering.

2.4 Previous Studies on Mangroves

According to Bryan-Brown (2020) found a steady loss in mangrove coverage in Indonesia, Malaysia, and Myanmar, with rates of 0.26%, 0.41%, and 0.70%, respectively. Several articles have been produced regarding Malaysian mangroves, including a study by Hong et al. (2017) which assessed carbon stock in mangrove forests in Peninsular Malaysia, a study by Chandra et al. (2015) which examined soil carbon storage in Sarawak mangroves, and a study by Rambok et al. (2010) which investigated soil chemical characteristics. Despite Sabah's extensive coverage of Malaysia's mangroves, there is a lack of available evidence regarding their significance as a carbon stock. Mangrove plants have varying carbon content potential, which can be determined by species-specific coefficients.

Global climate change has the potential to increase the amount of carbon dioxide (CO_2) released into the environment. Mangrove habitats contribute significantly to climate change mitigation by acting as carbon sinks, where carbon is absorbed and stored. Mangroves sequester carbon dioxide through the process of photosynthesis, Afterward, it is converted into carbs and stored in their biomass. Carbon will be absorbed and stored as a carbon reservoir both above and below the biosphere. Photosynthesis is used by plants to collect carbon from the atmosphere and transform it into organic compounds. Mangrove forests have the ability to decrease the amount of (CO_2) in the atmosphere by using sequestration processes to absorb carbon and store it as biomass.

The research conducted at the Anambas Islands Marine Tourism Park utilises the sampling approach to measure biomass without harvesting or hauling.

After measuring the height or diameter of trees, the allometric equation is used to calculate biomass. Use the line transect technique, for example, with a plot size of 10x10 metres. Data on the structure and content of the mangrove environment were collected within the tree category, with a specific focus on trees with a high breast diameter of more than 5 cm. This data collection was performed at each station using three replication plots. Nevertheless, during the carbon assessment study conducted in the densely populated delta of Kelantan, for sample purposes in DK, the inventory unit was partitioned into six circular plots, each having a radius of 6m. For each plot, inventory data such as species composition and diameter at breast height (DBH) were collected. The main mangrove species found in DK are *Avicennia marina* and *Rhizophora apiculata*. The sample trees were divided into their respective components: leaves, branches, main stems, above-ground bark, and underground root systems. Soil samples were collected from five different depths: 0-20 cm, 20-40 cm, 40-60 cm, 60-80 cm, and 80-100 cm. These samples were then dried in an oven until they reached a consistent mass at a temperature of 105 °C. Every specimen was measured and subjected to a drying process in an oven at a temperature of 80 °C for a duration of 3-4 days in order to eliminate any residual moisture. The carbon content of the sample was determined thereafter using the Walkley-Black chromic acid wet oxidation procedure. (Walkley and Black, 1934).

The approach is essentially identical to the one employed in the Mangrove Carbon Stock Estimation study conducted in Sulaman Lake Forest. A forest inventory was carried out to assess the diameter at breast height (DBH) of both living and dead trees situated along the transect line. Shovels, PVC pipes, scopes, and other sampling equipment are used to collect soil samples. To obtain composite soil samples for the analysis of soil physicochemical properties, an auger made of PVC tubing is employed. Four distinct depths were used to gather the samples: 0–15 cm, 15–30 cm, 30–50 cm, and 50–100 cm (Awang Besar et. al, 2020).

The collected data from the study on Anambas Islands Marine Tourism Park was converted into biomass levels on the ground using an allometric formula that takes into account the different mangrove species. This biomass was then converted into carbon stock using the formula (C = B X 0.47). The formula was used to further translate the carbon stock data and calculate the value of CO2 sequestration. (CO_2 sequestration = Cn x 3.67). The study conducted in the Kelantan Delta employs precise equations derived from Adame et al. (2017) in order to minimise inaccuracies. The equation for *Avicennia marina* is AGB = 0.251 ρ D2.46, while the equation for R. apiculate is AGB = 0.1709 ρ D2.516. The calculation of soil carbon mass for each sample depth interval is determined by multiplying the bulk density (g/cm) by the soil depth interval (cm) and the percentage of carbon. This is expressed by the formula Soil carbon = (t/ha) x bulk density (g/cm) x soil depth interval (cm) x % C. Additionally, the equation for the total carbon stock, adopted from Kauffman and Donato (2012), is also used. The total amount of carbon stored in the biomass of aboveground trees equals the total carbon stock (C treeAG), the amount of carbon held in subsurface tree biomass (C treeBG), and the carbon stored in the soil (Csoil).

The research study titled "Estimation of carbon stocks of mangroves in Tasik Sulaman Forest using the Allometric Equation for Rhizophora spp" conducted by Fromard et al. (1998) employed the equation W=0.128DBH2.60 to calculate the above-ground biomass of the mangroves. The diameter of the tree at breast height

(DBH) is the only parameter used in this calculation. The aboveground biomass results were subsequently transformed into aboveground carbon by applying a conversion factor of 0.5, based on the premise that the carbon content of a standing tree is 50% of its biomass (Houghton and Hackler, 2001). The biomass of roots was determined using a biomass comparison ratio of 3:1 (aboveground biomass to belowground biomass) established by Kusmana et al. (2018), and the carbon content of the roots is estimated to be 50% of their biomass.

CHAPTER 3

MATERIALS AND METHOD

3.1 Study area

The Delta Tumpat is located in Tumpat district. The Delta Tumpat spanned around 1,200 hectares and consists of 17 small islands, with 339.6 hectares of mangrove forest (Raudatu et. al, 2020). The delta is situated on the eastern coast of Peninsular Malaysia, bounded by latitude and longitude coordinates of 06º 11.00' N to 06º 13.00' N and 102º 10.00' E to 102º 14.00' E respectively. The research was specifically carried out in Pulau Tujuh, delta Tumpat Kelantan (6°12'04" N 102°10'15' E) as indicated in Figure 3.1.

Pulau Tujuh area of 6.29 ha in total. Generally, the climate is affected by the northeast and southeast monsoons, with an average temperature of 26.8ºC and an average relative humidity of 83.7% (Z. Nor Syahirah1 et. al, 2018). The area is along the border with Thailand that represents an amazing fusion of natural and cultural heritage. The region's vast coastline provides residence for a gigantic mangrove ecosystem, in which one can find all varieties of fauna, from fish and birds to crabs.

The area is covered with mangrove and non-mangrove tree species include *Rhizhophora mucronata*, *Nypa fruticans*, *Sonneratia ovata* and others as shown in Figure 3.2.

Figure 3.1: Location of the study area and sampling plots

Figure 3.2 Example of sampling sites

3.2 Materials

To determine the above-ground biomass (AGB) and carbon stock of mangrove tree species in the research area, it is necessary to estimate the diameter-at-breast height (DBH) using the DBH tape to measure the circumference of the mangrove tree. Meanwhile, the estimation method is used to measure the height of the tree. The Global Positioning System (GPS) is used to record the location and coordinates of the plots.

3.3 Method

3.3.1 Field Data Collection

The sampling plot was set at 5% of the study area. Eight 20x20 m plot was established and DBH and estimation of tree height were recorded. Species selected for this study was *Rhizophora mucronata*. Only trees with a diameter at breast height (DBH) exceeding 5 cm were measured.

Figure 3.3.1 Plot establishment at the study site

3.3.2 Data analysis

The aboveground biomass (AGB) of recoded data was analyzed following Adame et al. (2017). The AGB was calculated, and the determination of mangrove biomass was carried out using equations specific to each species. Wood density of *R.mucronata* was set at 0.814 adopted from Chave et al. (2009). The formula used for this study was expressed as in the Equation 1.

$$AGB = 0.1709\ \rho\ D^{2.516}$$ ....Equation 1

Where;

AGB = aboveground biomass

ρ = density

D= diameter

This approach facilitates a more accurate determination of mangrove biomass, contributing valuable insights to the understanding regarding the quantity of carbon stored.

In order to quantify the carbon stock in mangrove trees, a simple calculation involving the carbon content factor was applied. This approach involved dividing the biomass of the system by a set carbon content factor, usually set at 50% (Houghton and Hackler, 2001). The formula for this calculation was expressed as in the Equation 2.

Carbon stock = AGB x 0.5 .... Equation 2

Where;

AGB= above ground biomass

By using this method, a reliable estimate of the carbon stored and aboveground biomass in the mangroves of seven islands was obtained, contributing valuable data to the understanding of carbon sequestration. All data recorded in the field was transferred to the MS Excel for descriptive statistic calculation and ABG and carbon estimation.

CHAPTER 4

RESULTS AND DISSCUSION

The total area of Pulau Tujuh is 6.29 ha. The area is covered with mangrove and non-mangrove tree species include *Rhizhophora mucronata*, *Nypa fruticans, Sonneratia ovata* and others. From the eight plots surveyed, a total of 384 *R.mucronata* were measured. The mean diameter-at-breast height (DBH) and tree height were 12.38 cm and 10.09 m respectively. The tree density of *R.mucronata* at Pulau Tujuh is 122 trees/ha.

The above ground biomass of *R.mucronata* species were calculated following Adame et al. (2017) and Chave et al. (2001) for Wood density. Total aboveground biomass (AGB) of the study site was estimated at 767.90 t/ha. Meanwhile the total carbon stock of the area was 383.95 tC/ha. The average ABG of the study site is 95.9h/ha with Plot 6 shows the greatest number of trees allowing most of the biomass value which is 153.13 t/ha and carbon stock of 76.56 tC/ha. The lowest carbon stock recorded in this study was in Plot 8 where the total and total carbon stock were 55.50 t/ha and 27.75 tC/ha respectively.

Overall mean DBH for all plots is 12.38 cm. The highest DBH value was in Plot 2, with the mean DBH of 13.13cm and average tree height of 11.59m. Table 1 show the estimation of AGB and carbon stock of *R. mucronata* in Pulau Tujuh with mean DBH dan tree height of each plots surveyed.

Table 1 The estimation of total AGB and carbon stock of *R. mucronata* at the study area

Plot no.	**Number of Tree**	**Mean DBH (cm)**	**Mean height (m)**	**AGB (tonne)**	**Carbon Stock (tonne Carbon)**
1	64	12.05	9.68	127.68	63.84
2	27	13.13	11.59	66.28	33.14
3	55	12.15	9.19	106.96	53.43
4	47	12.28	11.31	72.61	36.30
5	49	12.86	8.96	111.30	55.65
6	73	12.57	9.65	153.13	76.56
7	44	11.26	9.44	74.45	37.22
8	25	12.73	10.87	55.50	27.75
Total				767.90	383.95

The result of this study was compared to several mangrove biomass and carbon studies especially by Adame et al. (2015), Rozainah et al. (2018) and Islam et al. (2021). Table 2 shows the comparison findings of carbon in different mangrove forests. From this study, the highest mean DBH was recorded by Rozainah et al. (2018) in Delta Kelantan at 47.0 cm that suggesting the presence of older or larger trees. Meanwhile the lowest mean DBH was recorded by Islam et al. (2021) in Setiu, Terengganu at 9.8 cm, which indicate the younger and smaller trees of particular area. In term of carbon, Pulau Tujuh exhibiting significantly lowest carbon stock compared to others. With an average AGB of 95.89 t/ha and carbon stock of 47.99 tC/ha the value is correlating with the low tree density of the area compared to study by Islam et al. (2021) which reflected a high biomass accumulation despite the smaller DBH.

Mangroves in Setiu, Terengganu shows the highest biomass and carbon stock, making it a significant carbon sink despite having smaller trees, possibly due to high tree density. Meanwhile largest tree sizes in Delta Tumpat study exposes on mature and potentially well-preserved mangrove forests. In this study, the carbon stock value only focuses on specific species of *R.mucronata*. Therefore, even though Pulau Tujuh also consider in the belt of Delta Tumpat it literally shows lowest tree density and biomass, which also could reflect on different ecological or anthropogenic influence that results in lower carbon sequestration. These differences have implications for carbon storage and the overall health of the mangrove ecosystems, emphasizing the need for targeted conservation and management practices tailored to each site's unique characteristics.

Table 2 comparison of mangrove forest in Pulau Tujuh with others.

ABG previous study	Mean DBH (cm)	Tree density (tree/ha)	AGB (t/ha)	Carbon stock (tC/ha)	Study site
Adame et al.,2015	11.0	1213	421.1	215.0	Chiapas, Mexico
Rozainah et al., 2018	47.00	1455	427.8	205.7	Delta Kelantan
Islam et al., 2021	9.80	1533	522.9	261.45	Setiu, Terengganu
Fikri	12.38	122	95.98	47.99	Pulau Tujuh

Although local climatic conditions are of paramount importance in shaping forest dynamics, which in turn affect aboveground biomass, factors such as temperature, solar radiation, rainfall patterns, and storm frequency directly influence tree growth rates, species composition, and overall forest structure. Komiyama et al. (2008). For example, areas with higher temperatures and solar radiation may allow for the growth of larger DBH measurements and AGB values. For instance, on Pulau Tujuh Island and Delta Tumpat, its position being near settlements and close to human activities may be high carbon factor in the study area. Besides these, the soil properties and nutrient status are also responsible for affecting tree growth and biomass accumulation.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This study analysed the biomass available in the mangrove forests within Pulau Tujuh Delta Tumpat. The carbon stock of Rhizophora mucronata was estimated in this study. By applying Adame et al (2017) carbon calculation, the total aboveground biomass of the area is recorded at 767.90 t/ha, and the total carbon stock associated with this value was obtained to be 383.95 tC/ha. The results show a clear picture regarding the importance of the mangrove forest at Pulau Tujuh with respect to carbon stock and in future it calls for effective management and preservation of the area.

5.2 Recommendations

Estimation of ABG and carbon stock of Pulau Tujuh could be enhancing by the following suggestions:

- Sampling intensities should consider rising above 5% of the study area. Increasing the sampling intensity will be able to have a better understanding of the AGB and carbon stock content in Pulau Tujuh. This could be done either by increasing the number of plots or by increasing the size of each plot, capturing the wider range of heterogeneity in the species, DBH, and height of trees. The enumeration of the number of trees with a smaller DBH size, for example, less than 5 cm in the measurement size, could provide an indication of the dynamics in the growth of young trees and their contribution to the overall biomass and carbon stock.

- Conduct comprehensive field survey with a sufficient number of sample plots spread across different forest types and conditions within Pulau Tujuh. Measure tree diameters, heights, and other relevant parameters.
- Establish permanent sample plots for long-term monitoring to track changes in biomass and carbon stock over time. This can provide insights into forest dynamics and the effects of environmental changes.
- Employ Geographic Information Systems (GIS) to analyze spatial patterns of biomass distribution across Pulau Tujuh. Identify areas of high and low biomass and understand the factors influencing these patterns. Integrate high-resolution satellite imagery from sources such as Landsat, Sentinel, or commercial satellites to monitor and estimate AGB over large area would also alternative cost-effective method for carbon calculation. In addition, if technology could help in estimating carbon, local personnel in biomass estimation techniques and the use of remote sensing and GIS tools to build local capacity for ongoing monitoring and management should be trained.
- Include assessments of biodiversity to ensure that biomass and carbon stock estimations are part of a holistic understanding of the ecosystem's health and functioning.

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