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ABOVEGROUND BIOMASS AND CARBON DENSITY OF MANGROVE FOREST IN PENGKALAN KUBUR, KELANTAN

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ABOVEGROUND BIOMASS AND CARBON DENSITY OF MANGROVE FOREST IN PENGKALAN KUBUR, KELANTAN

by

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A report submitted in fulfillment of the requirements for the degree of Bachelor of Applied Science (Sustainable Science) with Honours

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2017

DECLARATION

I declare that this thesis entitled “title of the thesis”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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Date : ________________________________

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LIST OF ABBREVIATIONS

FAO	Food of Agriculture Organization
sq mi	square kilometers
mm	millimeter
AGB	aboveground biomass
CO2	carbon dioxide
i.e.	id est
e.g.	exempli gratia
ha	hectare
spp.	species
cm	centimeter
CO	carbon monoxide
CH4	methane
DBH	diameter at breast height
m	meter
kg	kilogram
kgC	kilogram Carbon

LIST OF SYMBOLS

≥	more than or equal to
>	more than
$	United States Dollar
%	percent
=	equal to
+	addition
–	subtraction
x	multiplication
÷	division
/	division slash
( )	parentheses
º	degree
*	multiplication

Aboveground Biomass And Carbon Density Of Mangrove Forest In Pengkalan Kubur, Kelantan

ABSTRACT

Mangroves are small trees that grow in coastal saline which are found in the tropical and subtropical tidal areas. The study area is the mangrove forest in Pengkalan Kubur located in the district of Tumpat, Kelantan. A good management practices through this study helps to face the constraints in the mangrove forest of Pengkalan Kubur, which are lack of laws and regulations, financial barriers and lack of awareness from the community living nearby. Besides, there is also no estimation of aboveground biomass (AGB) and carbon density value in this area. This study was conducted to determine the aboveground biomass of the mangrove trees in Pengkalan Kubur and to estimate the carbon density of the mangrove forest in the study area. All the trees with diameter at breast height more than 5 cm were measured. Hypsometer was used to get the tree height measurement. Allometric relationship used for estimating AGB was based on the canopy diameter (CD) and tree height (H). The total aboveground biomass for the ten plots from A to J was 791.52 kg and the total aboveground biomass per hectare was 1583.04 kg/ha. Meanwhile, the total carbon density for the ten plots was 395.76 kgC and the total carbon density per hectare was 791.52 kgC/ha. Based on the results, the highest aboveground biomass was from the plot E, due to the higher presence of the trees with large diameter at breast height of more than 16-21 cm diameter with proportions of 66%. The study showed that the mangrove forest was being degraded because of the anthropogenic activities and the environmental sustainability was not being practised in the study area. Hence, it is hoped that the future study will find an effective way to improve the environmental sustainability by having a good management practices.

Biojisim Atas Tanah Dan Ketumpatan Karbon Hutan Paya Bakau Di Pengkalan Kubur, Kelantan

ABSTRAK

Bakau adalah pokok-pokok kecil yang tumbuh di pantai air masin yang terdapat di kawasan pasang surut tropika dan subtropika. Kawasan kajian ialah hutan bakau di Pengkalan Kubur yang terletak di daerah Tumpat, Kelantan. Amalan pengurusan yang baik melalui kajian ini membantu untuk menghadapi kekangan hutan paya bakau di Pengkalan Kubur, yang kurangnya undang-undang dan peraturan-peraturan, halangan kewangan dan kurangnya kesedaran daripada masyarakat yang tinggal berhampiran. Malah, tiada juga anggaran biojisim atas tanah (AGB) dan nilai ketumpatan karbon di kawasan ini. Kajian ini dijalankan untuk menentukan biojisim atas tanah pokok bakau di Pengkalan Kubur dan untuk menganggarkan kepadatan karbon hutan bakau di kawasan kajian. Semua pokok dengan diameter pada paras dada lebih daripada 5 cm diukur. Hypsometer telah digunakan untuk mendapatkan ukuran ketinggian pokok. Hubungan allometrik digunakan untuk menganggarkan biojisim atas tanah berdasarkan garis pusat kanopi (CD) dan ketinggian pokok (H). Jumlah biojisim atas tanah untuk sepuluh plot dari A ke J ialah 791,52 kg dan jumlah biojisim atas tanah sehektar ialah 1583,04 kg / ha. Sementara itu, jumlah ketumpatan karbon untuk sepuluh plot ialah 395,76 kgC dan jumlah ketumpatan karbon setiap hektar ialah 791,52 kgC / ha. Berdasarkan keputusan, biojisim atas tanah yang tertinggi ialah dari plot E, disebabkan oleh kehadiran lebih banyak pokok-pokok dengan diameter pada paras dada yang besar melebihi daripada 16-21 cm diameter dengan perkadaran 66%. Kajian ini menunjukkan bahawa hutan bakau tersebut sedang dimusnahkan kerana aktiviti-aktiviti antropogenik dan kemampanan alam sekitar tidak diamalkan di kawasan kajian. Oleh itu, adalah diharapkan bahawa kajian pada masa hadapan akan menemui cara yang berkesan untuk meningkatkan kemampanan alam sekitar dengan mempunyai amalan pengurusan yang baik.

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Mangroves are shrubs or small trees that grow in coastal saline or brackish water (Giri et al., 2011). The term is also used for tropical coastal vegetation consisting of such species. Mangroves occur worldwide in the tropics and subtropics, mainly between latitudes 25° N and 25° S (Giri et al., 2011). The mangrove biome, known as mangal, is a saline forest or shrubland natural surroundings portrayed by depositional beach, which fine silts present with high natural substances gathered in the regions shielded from high-vitality wave activity.

Mangrove swamps are found in tropical and subtropical tidal areas. Areas where mangal occurs include estuaries and marine shorelines (World Vegetation, 2008). Of the recognized 110 mangrove species, only about 54 species in 20 genera from 16 families constitute the "true mangroves", species that occur almost exclusively in mangrove habitats (Hogarth & Peter, 1999). Demonstrating convergent evolution, many of these species found similar solutions to the tropical conditions of variable salinity, tidal range (inundation), anaerobic soils and intense sunlight. Plant biodiversity is generally low in a given mangal (World Vegetation, 2008).

The greatest biodiversity occurs in the mangal of New Guinea, Indonesia and Malaysia. On the Malayan Peninsula, mangroves cover an estimated 1,089.7 square kilometres (420.7 sq mi), while most of the remaining 5,320 square kilometres (2,054 sq mi) mangroves in Malaysia are on the island of Borneo (Augustin & Sean, 2014). During the past decades, however, the situation with regard to the mangrove forests has been deteriorating because of increased demand for land to be allocated to food and industrial production and rural and/or urban settlements (Blasco et al., 2001; Dahdouh-Guebas et al., 2005b; Duke et al., 2007; FAO, 2007).

The mangrove forest in Pengkalan Kubur with the longitude and latitude of (06º14’05.18”N 102º05’58.42”E) is located in the district of Tumpat, Kelantan in the northernmost of Peninsular Malaysia bordering to Thailand. It is having its northeast monsoon and southeast monsoon that influence the climate in Kelantan with the mean annual air temperature of 28.0ºC in May and 25.5ºC in January. The relative humidity average is 82% and the annual rainfall average recorded is from 2750-3000 mm. In 1999, the rainfall recorded is 2467 mm per year, where the daily rainfall is 148 mm, which is suitable for the growth of mangrove. The soil in Pengkalan Kubur is made up of sand, silt and clay. The elevation for the study area ranges from 11 m above the sea level.

1.2 PROBLEM STATEMENT

Mangrove forests have regularly been seen as inefficient and rancid, thus, cut off to make spaces for farming areas, urban settlements and infrastructures, for example, harbors and industrial sites. Currently it becomes more serious as it is cleared for visitor advancements and shrimp aquacultures have likewise occurred. These clearings are the main reasons of the mangrove cut off in the world.

Mangrove trees are utilized for development wood, wood chip, firewood, production of pulp, charcoal generation and fodder for animals. Collecting of mangrove trees have occurred for quite a long time, in some parts of the world it is no more economical and sustainable, destructed the eventual fate of the woods.

Moreover, stream changes to make dams and watering systems diminished the quantity of water achieving the mangrove woods, changing the water level of salinity and the mangroves will not survive. Besides, the increased in soil erosion because of the land area deforestation will greatly accelerate the production of silt in the streams.

In addition, the worldwide overfishing crisis confronting the world's oceans has given a big effect to the world. The ecology balance of food chains and also the mangrove fish community have been altered. It gives impact to the destruction of coral reefs too as coral reefs act in providing the primary barrier against the strong waves and currents (Oswell, 2016).

Based on the problems stated, the most things to give full attention in sustainability management is mangrove swamp as one of the most unique natural ecosystem to act as a carbon sequestration or carbon storage. Once the disturbance occurred in mangrove, it may cause bad implications and cost a high maintenance. A good management practices through this study may help to face the constraints in mangrove forests in Pengkalan Kubur which are lack of laws and regulations, financial barriers and lack of awareness from the community living nearby.

The mangrove area in Pengkalan Kubur placed under the management of local authority of Forestry Department of Kelantan state. The agency does not have specific laws to protect the mangrove forest of Pengkalan Kubur from being destructed as no special attention is given to the area. Thus, the agency should implement new laws to make sure that the mangrove area is protected and preserved. The financial barrier is another factor that contributes to the constrain faced by the Forestry Department. The agency does not have specific budget allocated for the management of mangrove forest as it costs high price to cover the area. The community in Pengkalan Kubur also does not have exposure to the importances of mangrove forest as they did not have awareness among themselves.

Indeed, there is no estimation of aboveground biomass (AGB) and carbon density in this area. The presence of many trees in the mangrove forest can increase the evapotranspiration and photosynthesis process. This phenomenon can give good effects with high amount of carbon that can be absorbed by tree (Arnfield & John, 2003). This study can help to know the value of aboveground biomass and carbon density that are stored in the mangrove trees in this area.

1.3 OBJECTIVES

1. To determine the tree aboveground biomass of the mangrove in Pengkalan Kubur, Kelantan.

2. To estimate the tree carbon density of the mangrove forest in the study area.

1.4 SIGNIFICANCE OF STUDY

This study will provide useful information about the value of aboveground biomass and carbon density that are stored in the mangrove forest in Pengkalan Kubur. Thus, the data can be used as a guideline for the government to take further action in good environmental management practices. The presence of trees in the mangrove forest help in reducing climate change and global warming effects with high amount of carbon dioxide that are absorbed by trees during photosynthesis process. Furthermore, the result of this study can also be used for further research. Hence, it is hoped that the future study will find an effective way to improve the environmental sustainability.

CHAPTER 2

LITERATURE REVIEW

2.1 MANGROVE SWAMP ECOSYSTEM

Mangroves are defined as plants, such as trees, shrubs, palms and ferns, growing within the inter-tidal region of coastal and estuarine environments throughout the tropical and sub-tropical areas of the world. Mangroves can also include the plants, the associated forest communities, and the abiotic factors, which form the mangrove ecosystem. For instance, the term 'mangrove' can be used as an adjective, i.e. 'mangrove tree' or 'mangrove fauna'. Sometimes, the term 'mangal' is used interchangeably with 'mangrove' to refer to the biological components. According to Mc Nae (1968), however, he proposed that mangal should only refer to the forest community, while mangroves refer to the individual plant species.

Other terms for mangrove forests are tidal forests, coastal woodlands, walking forests in the sea, root of the sea, oceanic rain forests, tropical swamps or 'manggi-manggi' i.e. 'above the soil'. Mangroves are also classified as a wetland ecosystem. Besides plant life, estuaries, creeks, lagoons, mudflats, and islands are included in the mangrove landscapes.

Mangrove plants are grouped into three types, which are major elements or true mangroves or mangrove exclusive, minor elements or mangrove non-exclusive, and mangrove associates. True mangroves are mainly restricted to intertidal zone between high water levels of neap and spring tides. These plants are morphological adapted to survive in extreme conditions of the coastal areas (e.g. leathery leaves, vivipary germination, and aerial roots).

Minor elements are species that tolerate some degree of salinity. They are found in a mangrove habitat but are not restricted to it. Mangrove flora associates are all other biota that includes grasses, epiphytes, pteridophytes, bryophytes, and parasitic plants (Malaysia Mangrove, 2011).

2.2 MANGROVE DISTRIBUTION IN MALAYSIA

Mangrove forest is the overwhelming seaside vegetation group in tropical Asia, with the Malay-Indonesian locale as its focal point of dissemination. Malaysia has 645, 852 ha or 2% of its aggregate area territory that ranks third after Indonesia and Australia. Out of the aggregate mangrove forests in Malaysia, Sabah covers 57%, followed by Sarawak 26% and Peninsular Malaysia 17%. In Peninsular Malaysia, a sum of 86,454 ha of mangrove territories were gazetted as forest reserved, where Perak is the biggest region (47.8%), trailed by Johor (20.6%), Selangor (17.3%) and Kedah (9.2%).

It was evaluated that somewhere around 1980 and 1990, 12% of the nation's mangrove areas have vanished. While in Johor, mangrove forests have diminished around 46% from year 1955 to 1998. The mangrove biological system in the Indo-Malaysian area is the most abundance with 48 selective mangrove species compared with other mangrove locales around the world.

Table 2.1: The area in hectares (ha) of forest reserves mangroves and state land mangroves distribution in Malaysia.

State	Forest Reserve Mangroves (ha)	State Land Mangroves (ha)	Total area (ha)
Johor	17,029	8,050	25,079
Kedah	7,949	-	7,949
Kelantan	-	-	-
Melaka	338	100	438
Negeri Sembilan	540	727	1,267
Pahang	2,483	8,990	11,473
Penang	451	-	451
Perak	43,502	-	43,502
Perlis	-	-	-
Selangor	15,090	-	15,090
Terengganu	1,295	-	1,295
Sabah	317,423	49,927	367,350
Sarawak	34,992	133,000	167,992
Total	441,092	200,794	641,886

(Source: Abd Shukor, 2004)

2.3 SPECIALIZED ROOT SYSTEM IN MANGROVE

The main plant species forming the mangrove biological community have aerial roots, normally prop roots or stilt roots, for instance is *Rhizhophora spp*. Stilt roots function to provide anchor for the plants and in air circulation, because of the fact that the mangrove mud has a tendency to be anaerobic. *Rhizophora spp*. or known as red mangroves have prop roots plummeting from the trunks and branches, giving a steady support. The other mangrove species, include the white mangroves, *Avicennia marina* (*A. marina*) acquire balance with a broad arrangement of shallow, underground "cable roots" that transmit out from the focal trunk, pneumatophores stretch out from these roots.

Breathing roots are extraordinary vertical roots, known as pneumatophores, structured from lateral roots in the mud, projecting above the soil, for instance are *Avicennia* and *Sonneratia*, allowing some oxygen to reach the oxygen-starved submerged roots. The thickness, size and the number of pneumatophores differ per tree. The colours are green and they contain chlorophyll.

In addition, stilt roots are the fundamental organs for breathing particularly when the high tide. They are common in numerous types of species of *Rhizophora* and *Avicennia* (*Avicennia marina* and *Avicennia offficinalis*). The stilt roots of *Rhizophora mucronata* have numerous little pores or lenticels, where at low tide permit oxygen to diffuse into the plant and down to the underground roots by open entries called aerenchyma. In *Brugeira* and *Ceriops*, they get to be emptied and malfunctional after some stage. Air circulation happens additionally through lenticels in the bark of mangrove species, for instance, types of *Rhizophora*.

2.4 INTRINSIC VALUES OF MANGROVE

Mangrove forests provide protection and shelter against extreme weather events, such as storm winds and floods, as well as tsunamis. Mangroves absorb and disperse tidal surges associated with these events, as indicated by Hirashi and Harada (2003), a mangrove can reduce the destructive force of a tsunami by up to 90%. It acts as a coastal resilience to the environment.

Table 2.2: The diversity of mangrove trees family in Peninsular Malaysia.

Diversity (Family)	**Distribution**	**Sources**
Araneidae	Tioman, Pulai-Johor, around Malaysia	Song *et al.* (2002)
Clubionidae	Tioman	Not in all-new record
Lycosidae	Tioman	Not in all-new record
Oxyopidae	Morib	Not in Platnick
Pholcidae	Morib, cosmopolitan	All present
Pisauridae	Tioman, Morib	Not in all-new record
Psechridae	Morib	All present
Salticidae	Morib	Not in all-new record
Tetragnatidae	Sabah, Morib, Tioman, around Malaysia	Song *et al.* (2002)
Theridiidae	Tioman, around Malaysia	Song *et al.* (2002)

Besides, mangrove forests are rich in biodiversity providing a habitat for wide varieties of animal and plant species. They are dynamic areas, rich in food. Live and decaying mangrove leaves and roots provide nutrients that nourish plankton, algae, fish and shellfish. Many of the fish caught commercially in tropical regions reproduce and spend time in the mangroves as juveniles or adults.

Traditional economic activities vary from fishing and gathering of crustaceans to usages of the trees for timber or tannin production. Research by Barbier (2007) concluded that the economic annual value of just one hectare of mangrove forest (by adding the values of collected wood and non-wood forest products, fishery, nursery and coastal protection against storms) is $12,392.

Next, to economic value, mangroves also bear great cultural significance for communities, such as the *Concheras* (shellfish-gatherers) in South America, as their identity is strongly related to the ecosystem they live in. Mangrove forests also act as a carbon storage. Storage of carbon in mangroves takes place through accumulation in living biomass and through burial in sediment deposits. Mangroves rival the sequestration potential of rainforests (Wetlands International, 2014).

2.5 THREATS TO MANGROVE FOREST

By a wide margin, the main danger to the world's mangrove forest is the quickly growing shrimp aquaculture industry. Mangroves are cleared to make space for human-made lakes that are densely supplied with shrimps. Nearby residents are left with a crushed scene that cannot be used for cultivating and harvesting, fishing and lots of them are compelled to move away.

Tourism is another blasting industry and an essential factor of economic growth. Sadly, during visiting, they climb, drive, or explore into once-remote territories, they carry with them waste, vapor, lights, and different aggravations that can harm mangroves and the encompassing biological systems.

Besides, mangrove areas have been annihilated to be cleared for paddy fields, rubber plantations, palm oil ranches, and many different types of farming. Agriculturists frequently utilize composts and chemicals, and overflow containing these contaminations stream the into water supplies. Regardless of their resilience, mangroves can only endure just a little of modern and rural contaminations without passing on.

Development of coastal area takes numerous structures, from ports and docks to lodgings, marinas, golf courses, swimming pools and many more. In a meantime, contaminations that go with advancement can harm a single tree or an entire tracts of mangroves. With structures come individuals, crowd, rubbish, and waste, that will eventually bring destruction and pollution to the natural environment.

On the other hand, slashing down the mangroves for charcoal and timber production is crucial for the cottage industry. The wood is utilized for building materials, fencing, and fuel. It additionally yields high amount and quality charcoal. Places where fishing has decreased beneath the subsistence levels, numerous individuals have swung to charcoal generation for their business, which advances the cycle of environmental loss and fishery decrease. This will lead to the species extinction of certain organisms as well.

2.6 ZONATION IN MANGROVE

Mangal along a tropical bay characteristically shows zonation. A very broad and general distinction would be the proximal zone or front mangroves. This zone is towards water front, subject to regular tidal effect where intensity of soil accumulation and inundation is a continuous process. Main species with these features are *Rhizophora apiculata* and *Rhizophora mucronata*. On rocky and coral reef substrata, *Avicennia Spp*, *Sonneratia Caseolaris* are found. Both *Avicennia* and *Sonneratia* produce pneumatophores (www.mangroves.godrej.com).

Next is the middle zones or mid mangroves. Above the *Rhizophora* or *Avicennia* line luxuriant group of *Bruguiera gymnorrhiza, B. Cylindrica, Lumnitzera racemosa, L. littoralis, Ceriops tagal* and *Aegiceras corniculatum* occur. *Ceriops* and *Bruguiera* develop a strong hold fast in the form of knee roots or bent roots as a special adoption for supporting the erect bole. The third one is distal zone or back mangroves. Towards island area mangroves like *Excoecaris agallocha, Heritiera littoralis* and *Xylocarnus spp* occur. Both *Heritiera* and *Xylocarpus* produce buttresses. Generally the salinity is on lower side in this zone occurring towards hill sides where run off of fresh water is for a prolonged period (www.mangroves.godrej.com).

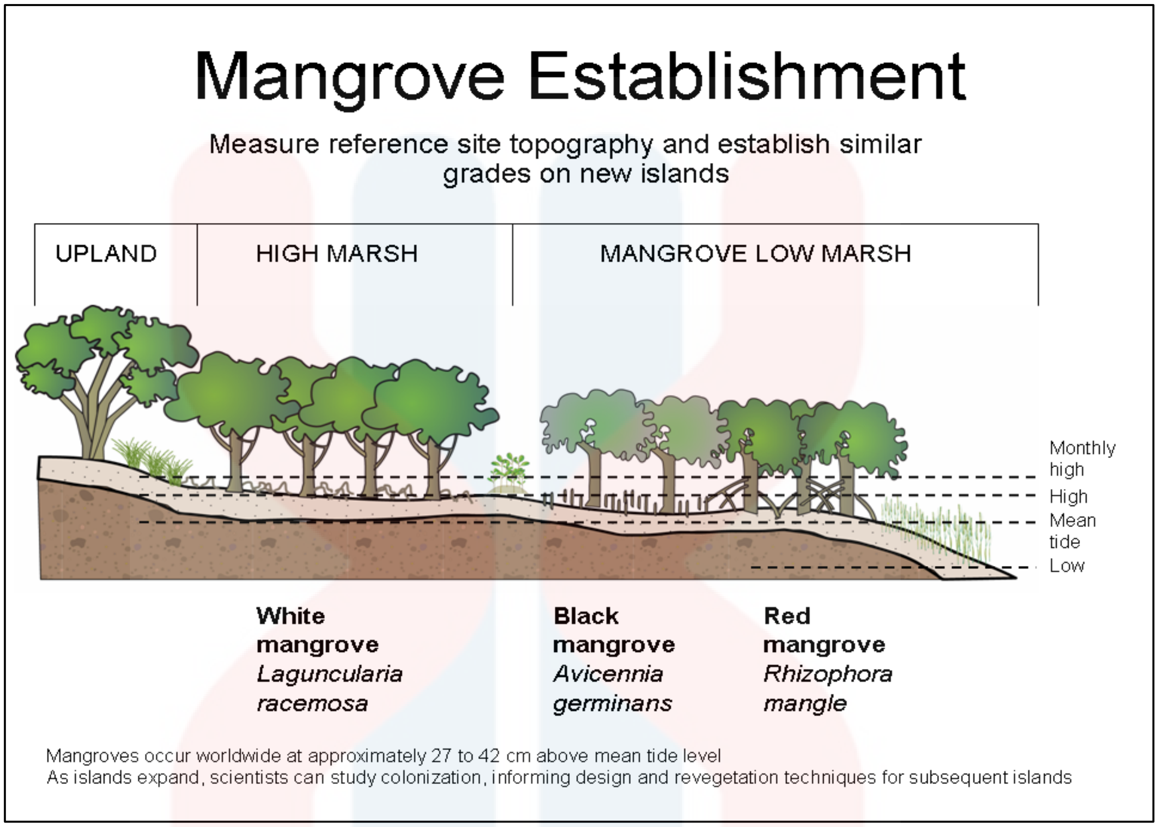


Figure 2.1: The zonation of mangrove.

2.7 BIOMASS OF MANGROVE

Fuelwood, fibre and raw material of food are example of source of biomass which is linked to vegetation structure which can influence biodiversity. Biomass can be defined as the magnitude and rate of autotrophic respiration and biomass density that determine the amount of carbon released to the atmosphere as CO_2, CO and CH_4 through burning and decay when ecosystems are disturbed by human activities or natural disaster. According to Dahlquist (2013), it is approximately 13% of all primary energy of biomass have been used.

Biomass also commonly includes the mass of living animals and plants, for example shrubs, grasses, trees, herbs, dead plant and microbes. Belowground components (roots, rhizomes, and microbes in soil) and aboveground material also embrace in biomass. According to Davidson and Janssens (2006), in the soil organic matter, it holds more carbon and the carbon in soils is physically and chemically protected and not easily oxidized. Mostly aboveground biomass is exposed to fire, land conversion and logging. It will simply release the carbon that hold in biomass to the atmosphere.

The change in mangrove biomass will affect the change of carbon density in the ecosystem. According to Jayakumar and Vashum, (2012), there are five carbon pools of mangrove ecosystem related to biomass which are soil organic matter, above ground biomass, below ground biomass, woody debris and the dead mass of litter. The aboveground biomass of a tree contributes to the main portion of the carbon pool, whereas below-ground biomass plays important role in carbon cycle by transferring and storing carbon in the soil.

There are two methods of field measurement that can be used to determine the aboveground biomass (AGB). Firstly is destructive method which also known as the harvest and direct method (Brown, 1997). Destructive methods consist of immediately determining fresh weight of the tree after it is cutted down at the study site.

The weight of different components of the harvested tree such as tree trunk, leaves and branches are determined after they are oven dried. Estimation of biomass using this method is accurate and limited to the areas that have high value of tree species and tree sample size. Referring to Montes (2000), the other reason is this method is also not relevant for degraded mangrove that contained threaten and valuable species.

Secondly is the non-destructive method in determining the AGB tree biomass. This method can be applied in ecosystem that has rare and protected tree species because the biomass can be estimated without harvesting the tree (Montes, 2000). Besides, this method can preserve and conserve the natural landscape. According to Ravindranath and Ostwald (2008), non-destructive method was applied by measuring the diameter at breast height, height of the tree, volume of the tree and wood density.

2.8 CARBON DENSITY OF MANGROVE

The term 'carbon density' as it applies to the area of carbon dioxide can be defined as the amount of carbon per unit area of an ecosystem, based on climatic conditions, topography, vegetative-cover type and amount, soils, and maturity of the vegetative stands (Mark, 2005).

Determining the biomass of mangrove is a useful way of providing estimates of the density of carbon. The density of biomass in a mangrove is the difference between production through photosynthesis. Thus, it is a useful measure for assessing changes in mangrove structure. The changes are brought about by natural succession, human activities such as silviculture, harvesting, and degradation, and natural impacts by wildfire and climate change. Biomass density is also a useful variable for comparing structural and functional attributes of mangrove ecosystems across environmental conditions (Forestry Department, 2004).

Biomass density also provide the means for calculating the amount of carbon dioxide that can be removed from the atmosphere by regrowing mangroves because they establish the rates of biomass production and the upper bounds for carbon sequestering. Many countries see mangroves as a means of mitigating greenhouse gas emissions, particularly carbon dioxide, a major greenhouse gas and the one fixed during photosynthesis (Brown *et al*., 1996).

Table 2.3: The biomass carbon density between Asia and worldwide.

Region	**Forest area (mill. ha)**	**Carbon density in living biomass ($MtCO_2$)**			**Growing density in 2005**
	2005	1990	2000	2005	(million m^3)
Africa	63,5412	241,267	228,067	222,933	64,957
Asia	571,577	150,700	130,533	119,533	47,111
Europe	1001,394	154,000	158,033	160,967	107,264
N.America	705,849	150,333	153,633	155,467	78,582
Oceania	206,254	42,533	41,800	41,800	7,361
S.America	831,540	358,233	345,400	335,500	128,944
World	3,952,026	1,097,067	1,057,467	1,036,200	434,219

(Source: IPCC, 2007)

2.9 ALLOMETRIC EQUATIONS

There are some methods that can be used to determine the biomass carbon density. According to Brown *et al*., (1997), he stated that tree stand allometric equations are developed by calculating the relationship from field measurement of the tree parameter such as diameter of the trunk, tree height, and diameter at breast height (DBH), tree species, age, crown density and also bioclimatic variable. However, many biomass estimates are based on the Kato's *et al*., (1978) equation. The regression model were developed from the equation $y = 0.2544 \times (DBH)^{2.3684}$ which is in the form $Y = a (DBH)^{b}$. Those equations were suitable for the DBH above 10 cm. The equation need to be derived according to suitable parameter and species of the tree.

According to Brown *et al*., (1989), the equation only estimates the biomass of live trees and not the fallen litters and the standing dead trees. The allometric equation that developed shows relationship between the stem diameter at breast height, leaf, stem and total root biomass. In addition, their research also showed correlation of allometric relationships between the tree height and tree biomass. There are many studies that develop an allometric equation. The carbon density then will be estimated from the allometric equation of forest biomass.

Generally, 50% of the aboveground biomass is assumed as the carbon concentration of the different parts of a tree (Brown, 1986; Whittaker & Linkens, 1973). According to Mac Dicken (1997), the result of repeated measurement of DBH and height can estimate the biomass change of the above ground and below ground components in allometric equation. The biomass estimation of the forest can be calculated by using any of the methods or in arrangement of the methods that had been stated. Method that will be applied must be suitable with the area, forest type and tree species (Jayakumar & Vashum, 2012).

There are many equations developed by the previous researchers in order to determine the AGB. Table 2.4 shows the equations from other researchers to calculate the AGB of mangrove forest.

Table 2.4: The equations of AGB.

DBH(cm)	Model: AGB	Country	Source
5-130	exp(-2.134 + 2.530 x ln(DBH)	Global	Brown, *et al*., (1989)
0.11–28.7	exp(-2.489 + 2.43 x ln(DBH)	Malaysia	Kenzo, *et al*., (2009)
5≥	exp ((2.62 x ln(DBH))-2.30)	Indonesia	Yamakura, *et al*., (1986)
5≥	exp ((2.196 x ln(DBH))-1.201)	Indonesia	Basuki, *et. al*., (2009)

In this study, the allometric relationship used for estimating AGB of different morphology mangrove trees is based on the canopy diameter (CD) and tree height (H). By comparing the correlation between AGB and CD^2*H, it is shown that the equation, in the form of $AGB=a(CD^2*H)^b$ is very suitable for estimation of AGB of multi-stemmed mangrove trees, and is not suitable for single-stemmed mangrove trees, but may be applied to those mangrove trees between multi-stemmed and single-stemmed in morphology (Fu and Wu, 2011).

CHAPTER 3

MATERIALS AND METHODS

3.1 STUDY AREA

The chosen study area was the mangrove of Pengkalan Kubur (06º14'05.18"N 102º05'58.42"E). It was located in the district of Tumpat, Kelantan in the northernmost of Peninsular Malaysia bordering to Thailand. The northeast monsoon and southeast monsoon influenced the climate in Kelantan with the mean annual air temperature of 28.0ºC in May and 25.5ºC in January. The relative humidity average is 82% and the annual rainfall average recorded is from 2750-3000 mm. In 1999, the rainfall recorded is 2467 mm per year, where the daily rainfall is 148 mm, which is suitable for the growth of mangrove. The soil in Pengkalan Kubur is made up of sand, silt and clay. The elevation for the study area ranges from 11 m above the sea level.

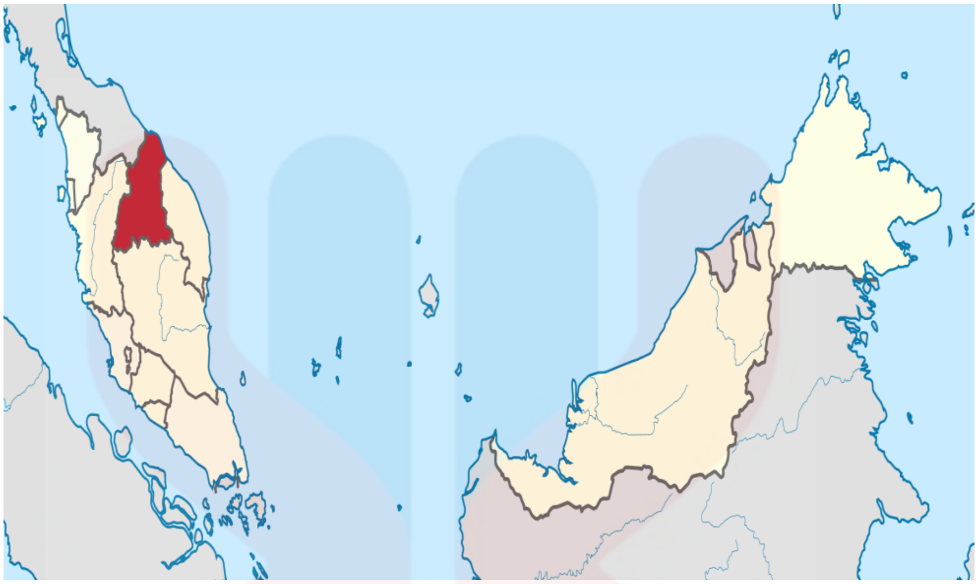


Figure 3.1: Location of Kelantan in Malaysia via Google.com.

Figure 3.2: Location of Tumpat district in Kelantan map via Google Image.

Figure 3.3: Location of Pengkalan Kubur mangrove forest in Tumpat via Google Earth.

3.2 MATERIALS

The site area was plotted using the red tape to mark the study area. The selected area was measured using the measuring tape. All the trees that have the diameter at breast height, or dbh more than 5 cm were measured using the measuring tape. The hypsometer was used to estimate the tree height.

3.3 METHODS

3.3.1 Sampling Plot

The area of the study was 0.5 ha. The area of the subplot design was measured as 25 m x 20 m as shown in the Figure 3.4. Ten subplots were established and marked by using the red tape. All the trees with the diameter breast height, or dbh more than 5 cm were measured. Trees that had the dbh less than 5 cm were not counted. The measured trees were tagged and the leaves samples were taken to the herbarium for species identification. All the specimens were deposited in UMK herbarium.

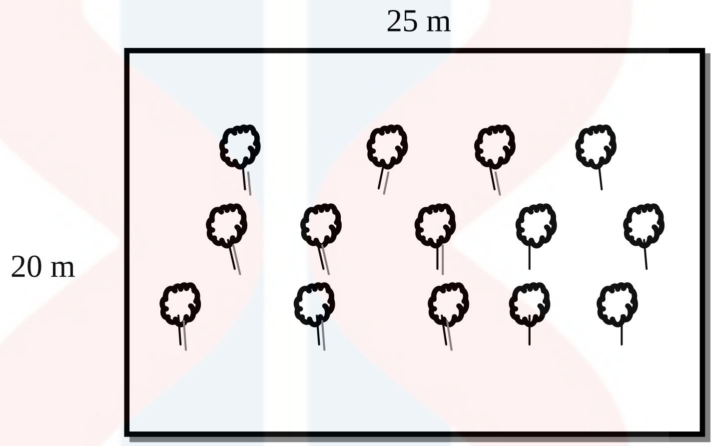


Figure 3.4: Plot of the area.

3.3.2 Diameter Measurement

DBH is the diameter that measured at the breast height level usually 1.3 m from ground level surface. There was diverse numbers of tree in Pengkalan Kubur mangrove forest that consists of tree trunks growing normal and abnormal.

Some of the trunks in the study area were multi-trunk, trunks were split at dbh level, and trunks were forks below dbh level and leaning trunks. DBH for the normal trunks were measured at 1.3m from aboveground, while for the abnormal trunks must follow the measurement as shown in the Figure 3.5.

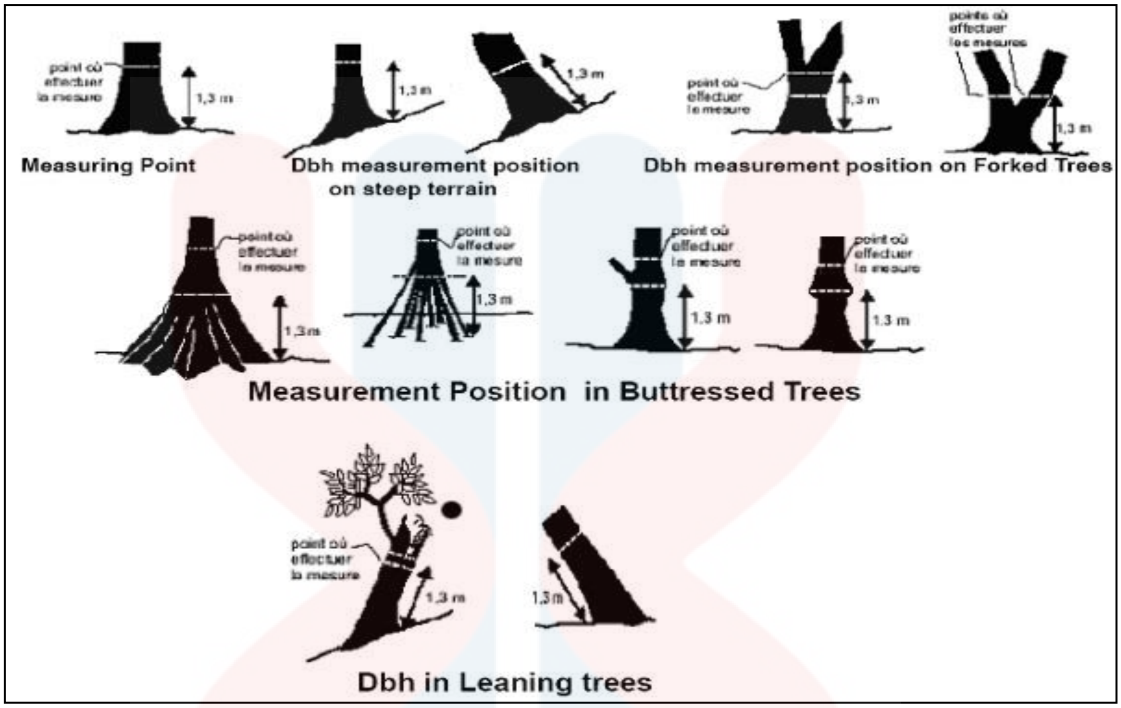
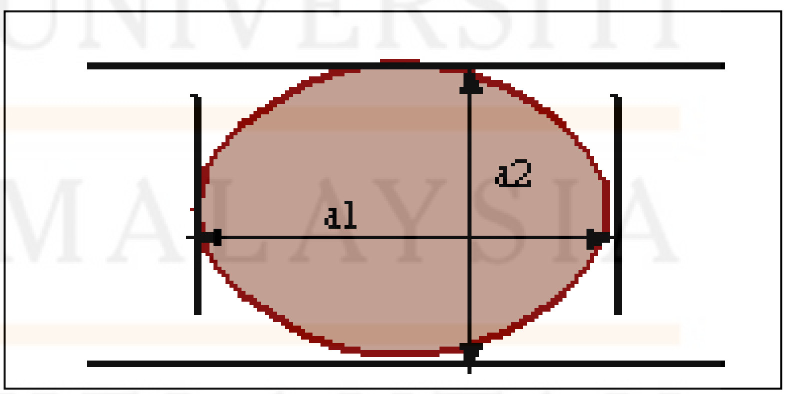


Figure 3.5: Measurement for abnormal tree trunks. (Source: Forestry Nepal, 2015)

The dbh measurement of the tree trunk was measured using the measuring tape. Then, allometric relationship is used for estimating AGB of different morphology of mangrove trees which is based on the canopy diameter (CD) and the tree height (H).



$$d = (d1 + d2) / 2$$

Figure 3.6: Diameter calculation.

Figure 3.7: Measuring tape.

3.3.3 Tree Height Measurement

In order to get the tree height measurement, hypsometer is the tool that could be used to estimate the tree height. This tool helps in getting the accurate reading height of tree. It could determine the angle from eye to base and top of the tree height.

Figure 3.8: Nikon hypsometer.

The linear distance and horizontal distances (D) were determined by point the hypsometer target at top height of tree and eye level. The angle a^o was displayed at the hypsometer screen. Then, hypsometer target was focused at eye level and base level. The angle b^o was displayed at the hypsometer screen. Total heights (A+B) were calculated by using the equation in Figure 3.9.

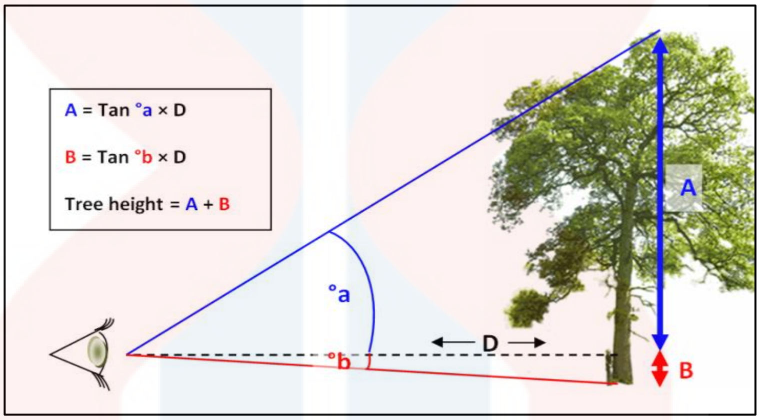


Figure 3.9: Tree height measurement by using hypsometer.

3.3.4 Aboveground Tree Biomass (AGB) and Carbon Density Estimation

The estimation of dbh and height of the tree were measured on each of the tree species in Pengkalan Kubur mangrove forest. In this study, allometric relationship used for estimating AGB of different morphology of mangrove trees is based on the canopy diameter (CD) and the tree height (H). By comparing the correlation between AGB and CD^2*H, it shows that the regression equation, in the form of $AGB=a(CD^2*H)^b$, is very suitable for estimation of AGB of multi-stemmed mangrove trees, and is not suitable for single-stemmed mangrove trees, but may be applied to those mangrove trees between multi-stemmed and single-stemmed in morphology (Fu and Wu, 2011).

Carbon density can be determined by estimating the AGB calculation and times with 0.5. Fifty percent of the biomass was assumed as the carbon density of the tree (Brown, 1986; Whittaker & Linkens, 1973).

3.3.5 Analysis Methodology

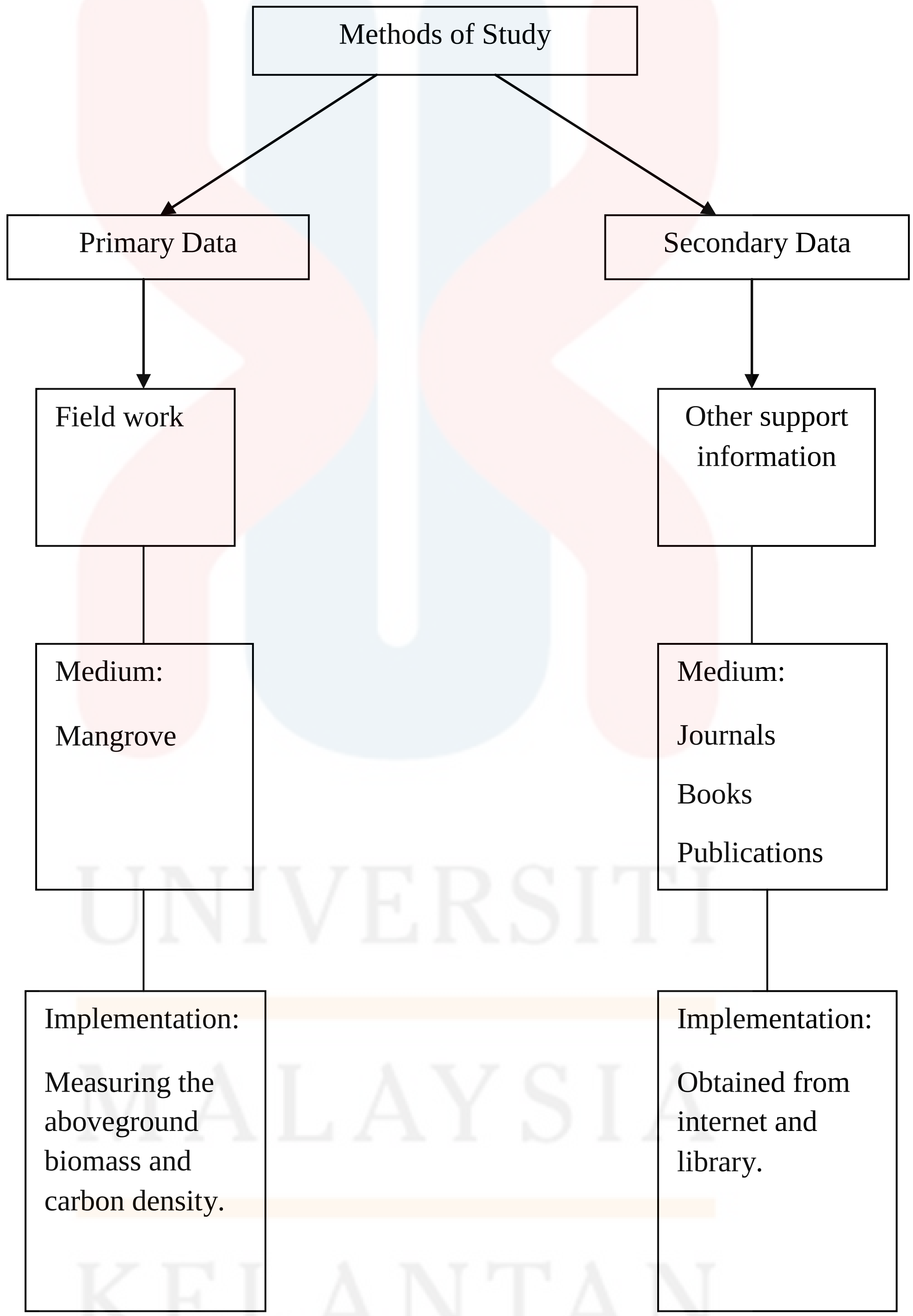


Figure 3.10: Research flow chart.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Aboveground Biomass (AGB) and Carbon Density in the Study Area

From this study, Table 4.1 shows the value of biomass and carbon density at plot A to J. The total AGB for the ten plots was 791.52 kg and the total AGB per hectare was 1583.04 kg/ha. The value was calculated by dividing the total sum of AGB with 0.5 ha.

Table 4.1: AGB and carbon density at plot A to J.

Plot	Area (ha)	AGB (kg)	Carbon density (kgC)
A	0.05	79.28	39.64
B	0.05	66.40	33.20
C	0.05	71.64	35.82
D	0.05	62.74	31.37
E	0.05	110.03	55.02
F	0.05	67.84	33.92
G	0.05	71.01	35.51
H	0.05	85.34	42.67
I	0.05	97.14	48.57
J	0.05	80.10	40.05
Total	0.5	791.52	395.76
Total per hectare		1583.04 kg/ha	791.52 kgC/ha

Meanwhile, the total carbon density for the plots was 395.76 kgC and the total carbon density per hectare was 791.52 kgC/ha. The total amount of carbon density was divided by total area in hectare.

The standing mangrove biomass in Pengkalan Kubur is significant and hence carbon stockpiling where the vegetation remains. The size of the trees contributes the most to the high biomass for a given species, though the density of the trees is also a factor. .

The density of the wood is also one of the factors in biomass and carbon storage, as the heavier timbered species is being better stores for a comparable size. The carbon store builds after some time as the forest and the trees develop, generally in a young forest.

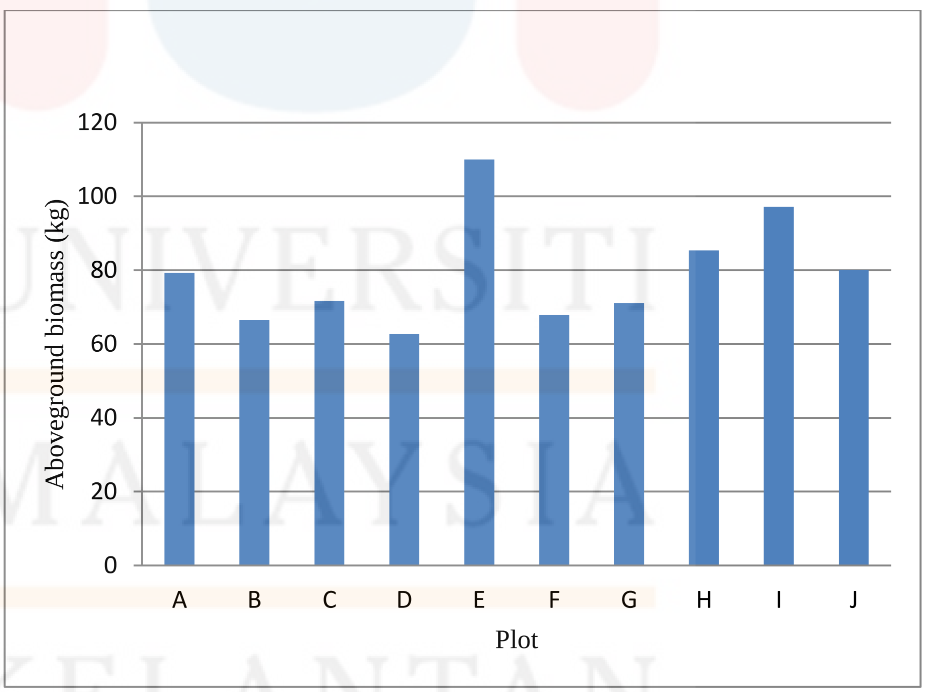


Figure 4.1: Graph of aboveground biomass of the plot A to J.

Figure 4.1 shows that the aboveground biomass in mangrove forest varied among the selected ten plots ranges from 62.74 kg to 110.03 kg. The overall contribution of living mangrove trees to the total aboveground biomass for all the ten plots was found to be moderate.

The highest value of aboveground biomass estimation was obtained in the plot E which was 110.03 kg and the lowest aboveground biomass was recorded in the plot D that was 62.74 kg.

Bushes and trees form the majority of aboveground biomass in the mangrove woods, in which the total biomass of a stand differing significantly, relying upon the soil and climate. In the case of mangrove vegetation, the frequency and the period of tidal inundation are the factors.

Besides, the factors are contributed by the age of the forest and its constituent trees. This is because the older forest has larger diversity and higher biomass. The most ideal approach to expand the biomass is by allowing trees to develop to the maximal size.

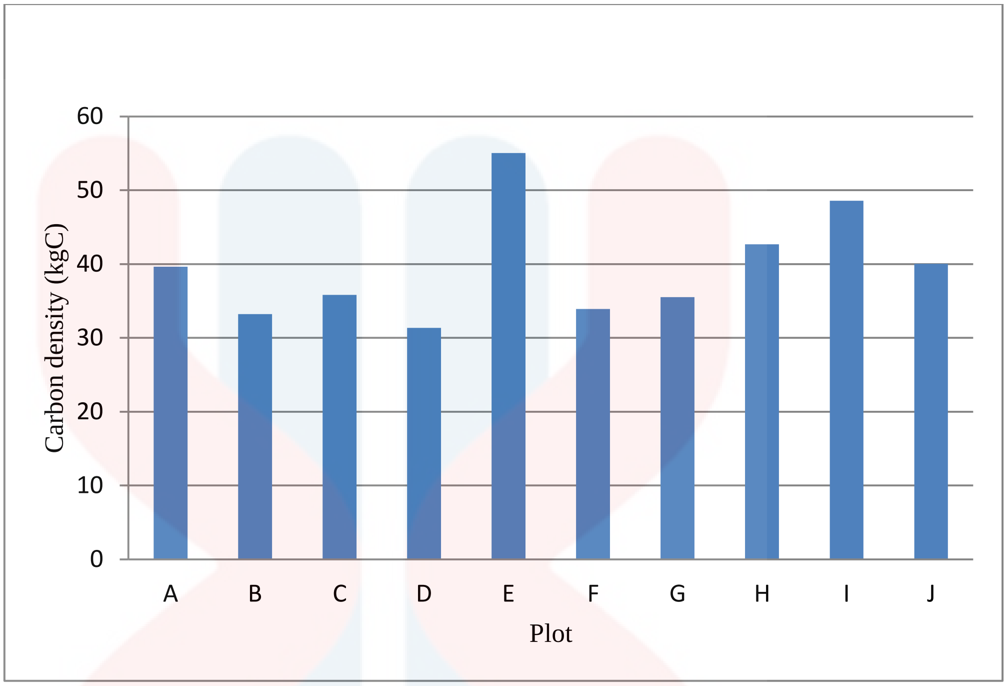


Figure 4.2: Graph of carbon density of the plot A to J.

Figure 4.2 shows the value of carbon density obtained among the ten plots ranges from 31.37 kgC to 55.02 kgC. The value was calculated by multiplying the aboveground biomass of the selected plots with 0.5.

Fifty percent of the biomass was assumed as the carbon density of the tree (Brown, 1986; Whittaker & Linkens, 1973). The highest value of carbon density was obtained in the plot E which was 55.02 kgC and the lowest carbon density estimation was recorded in the plot D that was 31.37 kgC.

Atmospheric carbon dioxide (CO_2) derived by all the carbon in biomass by means of the plant development. The carbon is returned to the environment in the form of carbon dioxide, or sometimes methane (CH_4), in the case of rotting by the degradation of woods cover and the smoldering or decaying of cut biomass.

Regardless of some changes over every day, thus, forests are a standing store of sequestered environmental carbon. A portion of the turnover separates to return to the environment, however different parts of the productivity enter the chains of food or are stored in the soil. Hence, soil carbon could be stable for a long time.

The ecosystem of a mangrove, as an example of the sedimentary environment could ease the biomass burial and in some cases, it forms peat because of the confined biomass breakdown especially in the wet soil. The main reason of the increasing of the carbon emission is because of the disruption and the removal of forest of the naturally-functioning wetland. It is because of the soil carbon is being oxidized to the environment.

4.2 Aboveground Biomass (AGB) Distribution between Diameter Classes

From the results in Table 4.2, the highest aboveground biomass in plot E was due to the higher presence of the trees with large dbh of more than 16-21 cm of diameter with proportions of 66%. Table 4.2 indicates that the high aboveground biomass for each plot was attained in different dbh classes.

Table 4.2: The aboveground biomass distribution between diameter classes.

AGB (kg/ha)	Average Height (cm)	Diameter (cm)						Total
		7-9	10-12	13-15	16-18	19-21	22-24	
A	4.7	2.87	27.84	13.54	16.56	18.47	0	79.28
B	4.8	2.87	3.18	17.68	16.55	19.11	7.01	66.4
C	4.7	0	13.52	12.74	31.69	6.37	7.32	71.64
D	5.0	0	7.32	17.84	15.93	6.69	14.96	62.74
E	4.8	2.87	10.34	17.2	21.65	50.96	7.01	110.03
F	5.0	0	10.5	21.82	10.04	25.48	0	67.84
G	4.9	0	10.98	24.68	15.92	12.42	7.01	71.01
H	4.9	0	10.66	16.88	0	43.47	14.33	85.34
I	5.0	0	0	17.84	27.38	38.06	13.86	97.14
J	5.0	0	3.82	22.14	0	32.17	21.97	80.1

The relationship between the size of trees and their biomass is not linear. This means that as the diameter and height of the tree increases, its biomass increases in a disproportionally greater way.

A common mangrove tree may increase in dry biomass by more noteworthy than 5 times with each multiplying of its trunk diameter of which about half is carbon. This implies a forest of thin trees, regardless of the possibility that firmly stuffed, may have just a small amount of the biomass of a forest of more extensive separated substantial trees.

The diameter distribution of mangrove trees is the most simple yet informative for depicting the properties of a stand of trees (Bailey & Dell, 1973). Studies have demonstrated that dbh is the most reliable variable for biomass estimation (Schroeder et al., 1997, Popescu, 2007).

The use of dbh alone for aboveground biomass estimation is a common and it is one of the universally used predators, because it shows a high correlation with all the tree biomass components and it is also easy to obtain accurately (Zianis, 2008).

CHAPTER 5

CONCLUSION

5.1 CONCLUSION

Overall, the study plots and direct observation carried out have achieved both of the objectives that have been stated in the study which were to determine the above ground biomass of the mangrove and to estimate the tree carbon density of the mangrove forest in the study area.

Allometric relationship for estimating AGB of different morphology of mangrove trees based on the canopy diameter (CD) and tree height (H) were studied. Equation, in the form of $AGB=a(CD^2*H)^b$, is very suitable for estimation of AGB of multi-stemmed mangrove trees such as *Nypa Fruticans*.

The total aboveground biomass for the ten plots from A to J was 791.52 kg and the total aboveground biomass per hectare was 1583.04 kg/ha. Meanwhile, the total carbon density for the ten plots was 395.76 kgC and the total carbon density per hectare was 791.52 kgC/ha.

The aboveground biomass distribution between different diameter classes shows that dbh is the most reliable variable for the biomass estimation. The use of dbh for aboveground biomass estimation is very common and indeed, it is one of the all around utilized predators.

The density of the trees and their size are the essential determinants of stand biomass. The wood thickness of the tree additionally influences the carbon substance of the plants and thus, that of the remain of vegetation.

Based on the observation, most environmental degradation and mangrove disappearance are caused by the anthropogenic activities. A comparative assessment based on the tree height and the dbh have been undertaken, looking at both the aboveground biomass and the carbon density. The study shows that the mangrove forest is being degraded and the environmental sustainability is not being practised in the study area.

5.2 RECOMMENDATIONS

Clearly human impacts on the mangrove forest quality, for example, deforestation has substantialy affect the biomass and carbon stockpiling capability of the forest. The presence of trees in the mangrove forest help in reducing climate change and global warming effects with high amount of carbon dioxide that is being absorbed by trees during photosynthesis process.

To increase the level of biomass and subseqent carbon stockpiling inside the mangrove forests in Pengkalan Kubur, actions to secure the woods will be very beneficial. Assurance, protection, recovery and reclamation of the forest is critical for reducing the climate change and will give extensive monetary advantages to Pengkalan Kubur.

There are several recommendations suggested for this study. The government has to find ways to establish a good management practices by implementing specific laws and regulations to protect the mangrove forest of Pengkalan Kubur from being destructed as no special attention is given to the area.

Besides, the community in Pengkalan Kubur also shoud be given an exposure to the importances of mangrove forest as they do not have awareness among themselves. Campaigns or events should be organized which involve the community at all age. The community can be sensitized by celebrating special days like World Environmental's Day or Global Mangrove's Day to help them practising sustainability in their daily life.

Moreover, the environmental study should be also included in school curriculum and be taught at all programmes in the university. The early education is important to give awareness during childhood because they will get used to environmental practices.

Last but not least, future management research shoud be conducted in Pengkalan Kubur mangrove forest area to develop a conservation and preservation area in increasing the value of forest aboveground biomass and lowering the carbon density of the study area. The environment sustainability of the mangrove forest should be taken a good care for the sake of future generation. This study can be a reference for future research.

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Appendix A

Figure A.1: The view along the river of mangrove forest in Pengkalan Kubur.

Figure A.2: The multi-trunk of a nypa tree.

Figure A.3: The leaves of *Nypa Fruticans*.

Figure A.4: The nypa trees were being measured by using tape.