



**EVALUATING ABOVEGROUND BIOMASS AND  
CARBON STOCK OF *Hevea brasiliensis* AT  
KAMPUNG KULIM, LAKOTA, JELI,  
KELANTAN**

by

**NOOR SYAHIRAH BINTI MOHD SAFII**

A thesis submitted in fulfillment of the requirements for the degree of  
Bachelor of Applied Science (Natural Resources Science) with Honours

---

**FACULTY OF EARTH SCIENCE  
UNIVERSITI MALAYSIA KELANTAN**

2024

---

## DECLARATION

I declare that this thesis entitled Evaluating aboveground biomass and carbon stock of *Hevea Brasiliensis* at Kampung Kulim, Lakota, Jeli, 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.

Signature:



Name: NOOR SYAHIRAH BINTI MOHD SAFII

Date: 30 July 2024

UNIVERSITI  
MALAYSIA  
KELANTAN

FYP FSB

## ACKNOWLEDGEMENT

This thesis represents the culmination of years of effort and the contributions of numerous individuals and organization without whom this work would not have been possible.

I owe a debt of appreciation to my supervisor, Ts. Dr Mohd Sukhairi Bin Mat Rasat, whose knowledge, expertise and constant encouragement to me during this process. His guidance has greatly impacted my academic and professional development in addition to inspiring this research.

A special thank you goes out to my thesis colleagues, particularly Aishah Izzati, Siti Mariam and my colleagues, for their companionship, academic discussion and spiritual support. This academic journey has been beneficial of their friendship.

Personally, I want to express how appreciative I am to my family for their unwavering support, love and tolerance during this difficult process. To my late father, Mohd Safii bin Seman and my mother, Gayah binti Mamat for instilling in me a strong work ethic and a love of study. To my siblings, my dear brothers and sisters for their continuous encouragement and faith in my potential.

Lastly, I would want to thank all of the people who have helped with this thesis manner, no matter how big or small. Your encouragement, support and believe in me have been an inspiration to me all along.

Thank you all for being part of this journey.

## TABLE OF CONTENT

<b>TITLE</b>	i
<b>DECLARATION</b>	ii
<b>ACKNOWLEDGEMENT</b>	iii
<b>TABLE OF CONTENT</b>	iv
<b>LIST OF TABLES</b>	vi
<b>LIST OF FIGURES</b>	vii
<b>LIST OF ABBREVIATION</b>	viii
<b>LIST OF SYMBOLS</b>	ix
<b>ABSTRAK</b>	x
<b>ABSTRACT</b>	xi
<b>CHAPTER 1: INTRODUCTION</b>	1
1.1 Background of Study	1
1.2 Problem Statement	4
1.3 Objective	4
1.4 Scope of Study	5
1.5 Significant of Study	5
<b>CHAPTER 2: LITERATURE REVIEW</b>	6
2.1 <i>Hevea brasiliensis</i>	6
2.1.1 Morphology of <i>Hevea brasiliensis</i>	7
2.1.2 Taxonomy of <i>Hevea brasiliensis</i>	8
2.1.3 Impact of <i>Hevea brasiliensis</i> to Ecosystem Services	9
2.2 Sampling Plot	10
2.3 Aboveground Biomass and Carbon Stock	10

<b>CHAPTER 3: MATERIAL AND METHOD</b>	15
3.1 Study Area	15
3.2 Material	16
3.3 Method	17
3.3.1 Aboveground Biomass	18
3.3.2 Biomass Carbon Stock	19
3.3.3 Data Analysis	20
<b>CHAPTER 4: RESULT AND DISCUSSION</b>	22
4.1 Descriptive Analysis	22
4.1.1 DBH Classes and Mean DBH by Each Plot	22
4.1.2 Total AGB by Each Plot	23
4.1.3 Total Carbon Stock by Each Plot	24
4.2 Comparison of Aboveground Biomass and Carbon Stock of <i>Hevea brasiliensis</i> in Kampung Kulim with Another Research	25
<b>CHAPTER 5: CONCLUSION AND RECOMMENDATION</b>	27
5.1 Conclusion	27
5.2 Recommendation	27
<b>REFERENCES</b>	29
<b>APPENDIX A</b>	34
<b>APPENDIX B</b>	38

## LIST OF TABLES

No.	Title	Page
2.1	Summary of the parameters that need to be measured of each inventory compartment	10
2.2	Allometric equation of AGB	14
3.1	The coordinate of each plot	16
4.2	Comparison of Aboveground Biomass and Carbon Stock of <i>Hevea brasiliensis</i> in Kampung Kulim, Lakota, Jeli, Kelantan with Another Research.	25

## LIST OF FIGURES

No.	Title	Page
2.1	<i>Hevea brasiliensis</i> plantation	6
2.1	Morphology of <i>Hevea brasiliensis</i>	8
2.2	Taxonomy of <i>Hevea brasiliensis</i>	8
3.1	Location of study area	15
3.2	Sampling sites in Kampung Kulim	16
3.3	The inventory line of sampling plot	17
3.4	Research flowchart	18
4.1	DBH class and mean DBH by each plot	22
4.2	Total AGB by each plot	23
4.3	Total carbon stock by each plot	24

## LIST OF ABBREVIATION

IPCC	-	Intergovernmental Panel on Climate change
NASA	-	National Aeronautics and Space Administration
UNFCCC	-	United Nation Frameworks Convention on Climate Change
EPA	-	Environmental Protection Agency

UNIVERSITI  
MALAYSIA  
KELANTAN

## LIST OF SYMBOLS

CO <sub>2</sub>	- Carbon dioxide
GHGs	- Greenhouse gasses
CO	- Carbon monoxide
M	- Meter
Cm	- Centimeters
°	- Degree
°C	- Degree Celsius
AGB	- Aboveground biomass
DBH	- Diameter at breast height
H	- Tree height
Kg	- Kilogram
CH <sub>4</sub>	- Methane
%	- Percentage
CA	- Crown area
ρ	- Wood density
Mg C/ha	- Megagrams of carbon
α	- Slope coefficient
c	- Intercept
Km <sup>2</sup>	- Square kilometer
D	- Diameter
Kg/ha	- Kilogram per hectare
Mg/ha	- Megagrams per hectare

**MENILAI BIOJISIM DIATAS TANAH DAN STOK KARBON *Hevea brasiliensis* DI KAMPUNG KULIM, LAKOTA, JELI, KELANTAN**

**ABSTRAK**

Salah satu tanaman komersial yang paling signifikan dan sumber pengganti sumber daya biojisim adalah pokok getah. Menurut IPCC, salah satu gas rumah hijau yang bertanggungjawab atas pemanasan global adalah CO<sub>2</sub>. Untuk mengurangkan pelepasan karbon ianya perlu memaksimumkan penilaian kesan alam sekitar ladang getah berkenaan biojisim dan dinamik karbon. Kajian ini dijalankan untuk menilai biojisim di atas tanah dan stok karbon menggunakan persamaan alometrik. Kawasan kajian terletak di Kampung Kulim, Lakota, Jeli, Kelantan di Semenanjung Malaysia dengan jumlah 5 plot dan 116 pokok yang diukur pada plot berbentuk segi empat berukuran 25 x 20 meter. Diameter pada ketinggian dada (DBH) diukur menggunakan pita diameter, sementara biojisim di atas tanah (AGB) dan stok karbon dianggarkan menggunakan persamaan alometrik. Hasil kajian mencatatkan kelas DBH paling tinggi iaitu 10-15 cm (50 pokok) manakala jumlah AGB dan stok karbon yang direkodkan ialah 86.6 Mg/ha dan 43.30 Mg C/ha. Kajian ini dapat membantu menentukan jumlah karbon yang diserap dan meningkatkan pemahaman tentang dinamik karbon di kawasan tersebut.

**EVALUATING ABOVEGROUND BIOMASS AND CARBON STOCK OF  
*Hevea brasiliensis* AT KAMPUNG KULIM LAKOTA, JELI, KELANTAN**

**ABSTRACT**

One of the most significant commercial crops and a substitute source of biomass resources is the rubber tree. According to the IPCC, one of the greenhouse gases responsible for global warming is CO<sub>2</sub>. Reducing carbon emissions requires maximizing the evaluation of rubber plantation environmental impacts concerning biomass and carbon dynamics. This study was conducted to evaluating the aboveground biomass and carbon stock using allometric equation. The study area was in Kampung Kulim, Lakota, Jeli, Kelantan in Peninsular Malaysia with total 5 plots and 116 sample trees were measured for 25 x 20 meters in square shape. The diameter at breast height (DBH) measured using diameter tape, while aboveground biomass (AGB) and carbon stock were estimated using allometric equation. The results recorded the highest DBH class which is 10-15 cm (50 trees), the total of AGB and carbon stock is 86.6 Mg/ha and 43.30 Mg C/ha respectively. This study can help determine the amount of carbon sequestered and enhance comprehension of region's carbon dynamics.

UNIVERSITI  
MALAYSIA  
KELANTAN

# CHAPTER 1

## INTRODUCTION

### 1.1 Background of Study

The process by which gases in the atmosphere retain solar heat is known as the greenhouse effect. Warming is brought on by greenhouse gases (GHGs) such as carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>) and water vapour, which let sunlight enter the atmosphere but absorb infrared radiation that bounces back off the surface of the earth reported by IPCC (2013). Instead of a comfortable 15°C, the average temperature on Earth would be roughly -18°C without the greenhouse effect. Life cannot exist without the greenhouse effect as reported by NASA (2022). Nonetheless, human actions such as the burning of fossil fuels have raised the atmospheric concentration of GHGs, intensifying the greenhouse effect and causing global warming according to EPA (2022). According to IPCC (2014), water vapour is the most common GHGs, while human-caused emissions of CH<sub>4</sub> and CO<sub>2</sub> have increased radiative forcing and warming. Mitigating climate change can be achieved by lowering GHGs emissions from sources such as energy production, deforestation, agriculture, and transportation (UNFCCC, 2022).

According to Pan et al. (2011) trees absorb and store CO<sub>2</sub> photosynthesis, reducing emissions by 25%. Growing forests act as carbon sinks, sequestering carbon in plants and soils. Deforestation can reverse this effect, turning forests into sources of CO<sub>2</sub>. Maintaining and expanding forests is crucial for climate change mitigation, with the IPCC estimating that

stopping deforestation and planting new trees could provide over 20% of CO<sub>2</sub> reductions needed. Governments are promoting tree planting initiatives, but it may take decades for new forests to accumulate significant carbon stocks (IPCC, 2002).

The entire amount of living plant material above the soil surface in a given area is referred to as aboveground biomass, and it is usually expressed as dry weight per unit area. Stems, leaves, branches, and any other above-ground plant elements fall under this category. In forestry, carbon storage evaluations, and ecological research, aboveground biomass is a crucial parameter. For the purpose of evaluating carbon stocks, tracking vegetation changes over time, and comprehending ecosystem dynamics, aboveground biomass assessment is essential. Aboveground biomass can be estimated using a variety of techniques, including as modelling methodologies, remote sensing, and field observations (Chave et al., 2005).

Both aboveground and belowground biomass is included in biomass carbon stocks. All live plant material above the earth, such as stems, leaves, and seeds, is referred to as aboveground biomass. According to IPCC (2006), roots and other subterranean living tissue are examples of belowground biomass. Decomposing organic material litter, woody debris, and organic matter found in soil are examples of carbon stocks. While woody waste contains fallen dead wood, litter consists of things like twigs and fallen leaves. Organic material in varying states of decomposition is referred to as soil organic matter (Schlesinger et al., 2000). Carbonates that are found in mineral soils that are produced either by air CO<sub>2</sub> or by the weathering of carbonate rocks are referred to as soil inorganic carbon according to Lal (2004).

One of the most important aspects of comprehending the dynamics of carbon in ecosystems is the relationship between carbon stock and aboveground biomass. The biomass that is found above ground in plants is made up of their stems, leaves, and branches. This biomass includes carbon, and variations in aboveground biomass can have an effect on ecosystems carbon stocks.

Sequestration of carbon in aboveground biomass where carbon is stored by living plants through the process of photosynthesis. Plant tissues absorb CO<sub>2</sub>, mostly from aboveground biomass (Pan et al., 2011). Aboveground biomass in forests contributes significantly to the overall amount of carbon stored, making them important carbon reservoirs (Baccini et al., 2012). Meanwhile, land use changes that have an impact on aboveground carbon, deforestation, can have a big impact on aboveground biomass and, in turn, carbon stocks (Houghton et al., 2009). Consequently, aboveground biomass's contribution to climate change mitigation is by improving carbon sequestration, aboveground biomass management and conservation are critical to reducing global warming (Keith et al., 2009). Additionally, insights into the distribution and variations in aboveground biomass and carbon stocks across various ecosystems have been provided by global assessments of aboveground biomass and carbon stocks (Saatchi et al., 2011).

*Hevea brasiliensis* has been chosen to evaluate the aboveground biomass and carbon stock of fast-growing tree that can sequester a large amount of carbon during its growth. By acting as a carbon sink, the tree can help mitigate climate change, and understanding the aboveground biomass and carbon stock helps assess the tree's contribution (Pearson et al., 2017). By the

aboveground biomass provides insights into the impact of rubber plantations on biodiversity and ecosystem health. Then, could evaluate the impacts of transforming natural ecosystems into rubber plantations on the environment is made easier by analysing changes in aboveground biomass (Wilcove et al., 2013).

## 1.2 Problem Statement

Rubber plantations, predominantly composed of *Hevea brasiliensis*, play a crucial role in the global economy by supplying natural rubber. Understanding the aboveground biomass and carbon stock of these plantations is essential for effective carbon storage strategies and sustainable land management. However, there is a lack of comprehensive study that accurately assesses the biomass and carbon stock of *Hevea brasiliensis* in Kelantan, Malaysia.

The existing methodologies for evaluating aboveground biomass and carbon stock may be limited in precision and may not account for the diverse factors influencing these parameters in rubber plantations. Furthermore, the variability in age, management practices, and environmental conditions across different plantations further complicates the accurate estimation of biomass and carbon storage.

## 1.3 Objectives

- a. To quantify the aboveground biomass of *Hevea brasiliensis*.
- b. To determine carbon stock of *Hevea brasiliensis*.

#### 1.4 Scope of study

This study focussing on aboveground biomass and carbon stock founded in *Hevea brasiliensis*. The sample of *Hevea brasiliensis* was identified and obtained from rubber plantation in Kampung Kulim Lakota, Jeli Kelantan.

The study has been done on rubber trees that are only 20-30 years old with a range of diameter at breast height (DBH) between 10 cm to 38 cm. The study also done through a plot that is 20m x 25m on the study site.

#### 1.5 Significant of study

This study helps the public to learn more about carbon stock and aboveground biomass, especially related to *Hevea brasiliensis* since there is a lack of related research done in Malaysia, especially in Peninsular Malaysia.

In addition, among the importance of biomass evaluation studies on the ground and the carbon stock of *Hevea brasiliensis* trees include several aspects, including contributions to climate change mitigation, biological diversity and ecosystem services, sustainable land use planning, forest management and conservation, utilization of carbon credits, and contribution to research and development in the context of sustainable rubber agriculture.

## CHAPTER 2

### LITERATURE REVIEW

#### 2.1 *Hevea brasiliensis*

Known by most as the rubber tree, *Hevea brasiliensis* is a species indigenous to South America's Amazon rainforest. It is a member of the Euphorbiaceae family. The rubber tree holds significant economic value due to its latex, which serves as the main source of natural rubber (Priya et al., 2009). It features soft wood, a lot of bark, and tall, branching limbs. About thirty percent of the milky liquid (latex) that seeps from tree bark wounds is rubber. This rubber can be coagulated and processed into solid products like tyres (Britannica, 2021). Concentrated latex can also be used to make dipped products, like surgical gloves. Figure 2.1 show the *Hevea brasiliensis* plantation (Britannica, 2021).

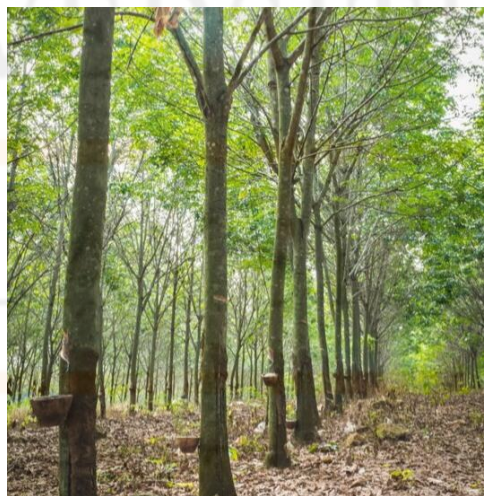


Figure 2.1: *Hevea brasiliensis* plantation (Britannica, 2021)

### 2.1.1 Morphology of *Hevea brasiliensis*

The *Hevea brasiliensis* tree can reach heights of over 40 metres and a diameter of over 1 metre in its straight, cylindrical trunk (Priyadarshan, 2011). According to Rao and Vijayakumar (1992), the tree has trifoliate, spirally arranged leaves that are made up of three elliptic to oblong leaflets that are 10–25 cm long and 4–10 cm wide. The petiole is 8–15 cm long. The leaflets have a lighter green underside and a glossy green upper surface. During the dry season, the leaves become yellow and fall off. The tiny, pale yellow flowers are up to 20 cm long and grouped in pendulous axillary panicles.

The male and female flowers grow separately on the same tree, indicating that the flowers are monoecious. The female flowers have a non-functioning calyx and corolla, a single pistil with a 3-celled ovary, and a nectary, whereas the male flowers have a 5-lobed calyx, 5 petals, and 10 stamens. When the fruits are fully developed, they split apart to reveal small, globose to ovoid, pale brown seeds. The fruits are three-lobed capsules with a diameter of 2-3 cm (Priyadarshan, 2011). The Figure 2.2 show the morphology of *Hevea brasiliensis* which is aboveground and belowground of the tree (Plant World, 2021).

MALAYSIA

KELANTAN

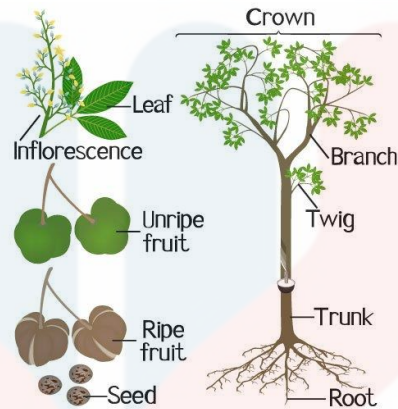


Figure 2.2: Morphology of *Hevea Brasiliensis* (Plant World, 2021)

### 2.1.2 Taxonomy of *Hevea brasiliensis*

Taxonomy is the scientific classification and categorization of organisms based on shared characteristics. Kingdom, phylum, class, order, family, genus, and species are among the taxonomic ranks, ranging from largest to most specific. Figure 2.3 shows the taxonomy of *Hevea brasiliensis* according to Forestry Images (2022).

**Kingdom:** Plantae

**Phylum:** Magnoliophyta

**Class:** Magnoliopsida

**Subclass:** Rosidae

**Order:** Euphorbiales

**Family:** Euphorbiaceae

**Genus:** *Hevea*

**Species:** *Hevea brasiliensis* (Willd. ex A. Juss.) Müll. Arg.

Figure 2.3: Taxonomy of *Hevea brasiliensis*

### 2.1.3 Impact of *Hevea brasiliensis* to Ecosystem Services

There are a few impacts of *Hevea brasiliensis* to the ecosystem services such as provisioning services. Natural rubber is produced by rubber trees and is a valuable industrial product. Large-scale rubber plantations may make less space available for natural ecosystems or other crops (Margono et al., 2012). Next, *Hevea brasiliensis* could be serve as regulating service. Though they store more carbon than agriculture areas, rubber plantations may impair sequestration and storage of carbon when compared to native forests (Li et al., 2008). They can also impact water cycling, with higher water usage and reduced groundwater recharge compared to native vegetation (Guardiola-Claramonte et al., 2008).

Then, this species should play a role as supporting services. The habitat of native plant and animal species is reduced when forests are converted to rubber plantations. Compared to the wild woods they replace, plantations contain significantly less biodiversity (Beukema et al., 2007). Lastly, cultural services. For thousands of smallholder farmers, rubber tapping generates revenue that supports their lives and local economies. Big plantations, however, can have a detrimental effect on the way of life and culture of the area.

## 2.2 Sampling Plot

The DBH measurement for every plot is determined by the class of tree size. Measuring is limited to trees that satisfy the requirements for every plot listed in the Table 2.1 below (Jemali & Majid, 2023).

Table 2.1: Summary of the parameters that need to be measured of each inventory compartment

Compartment inventory	Size (m)	Width		Inventory intensity (%)	Tree size class	Explanation
		(m <sup>2</sup> )	(ha)			
Main	50 x 20	1000	0.1000	10.00	DBH > 45cm DBH > 30 cm-45cm	Big tree Small tree
Second	25 x 20	500	0.0500	5.00	DBH >15cm – 30 cm	Jaras wood (large)
Third	10 x 10	100	1.00	1.00	DBH > 5cm – 15cm	Jaras wood (small)
Fourth	5 x 5	25	0.25	0.25	Height >1.5 m DBH < 5 cm	Sapling
Fifth	2 x 2	4	0.04	0.04	Height > 15 cm- 1.5 m	Seedlings

## 2.3 Aboveground Biomass and Carbon Stock

Rubber plantations have been expanding into sub-optimal environments in continental South-East Asia for the last decade. The carbon sequestration potential of rubber trees depends on suitable allometric equations and biomass-to-carbon conversion factor. Most equations are age-, elevation-, or clone-specific, giving uncertain results at the landscape level. Currently, none of the allometric equations consider environmental factors for pan-tropical usage. A study of 30 rubber trees with a root profile of up to 2 meters was conducted, and 882 trees were measured non-destructively in 27

plots in mountainous South Western China. Allometric equations for aboveground biomass estimations considering diameter at breast height, tree height, and wood density were superior to other equations. A simpler model with similar performance can be used if tree-specific wood density is not available (Xueqing et al., 2017).

Tree biomass could also be modelled using allometric equations, that link easily measurable tree parameters, such as diameter at breast height (DBH), tree height (H), crown area (CA) and wood density ( $\rho$ ), with biomass through linear or non-linear model fitting (Picard et al., 2012).

Based on study investigating tree stand for rubber tree aboveground biomass and carbon stock estimation by Iqbal et al. (2020) rubber plantation is a crucial economic crop and an alternative for biomass resources, as CO<sub>2</sub> is a GHGs causing global warming. To reduce carbon emissions, it is essential to assess the environmental effects of rubber plantation related to biomass and carbon dynamics. The study aimed to estimate above-ground biomass and carbon sequestration using two different allometric equations and analysed the relationship between biomass and predictors, height and age group, using statistical model non-linear regression. The study was conducted in Felda Lubuk Merbau, Peninsular Malaysia, with 195 sample trees measured in rectangular shapes. The average estimated aboveground biomass is 296.8 kg/tree of Dey et al. (1996), while Shorrocks et al. (1965) has a higher estimated aboveground biomass and carbon sequestration in allometric equations.

Statistical tests using non-linear regression showed robust relationships between the predictors, with high  $R^2$  values for height and age group. The amount of aboveground biomass is peaked at age 10 (ten), as it follows the optimum physical growth of height within this age group. The age group, which is not included in previous general biomass allometric equations, affects the cycle of biomass estimation and relates to the physical growth and development of rubber tree structures, such as trunk diameter and tree canopy, which contribute to changes in estimated aboveground biomass and carbon sequestration.

Meanwhile, allometric biomass equations for rubber tree components were derived in the form of power functions. Such allometric models are widely used in studies of tree biomass, including in vast majority of European studies. Regression techniques have been widely used in biomass studies (Crow & Schlaegel, 1988).

Tree biomass is primarily a function of DBH and it is relatively insensitive to tree height (Payandeh, 1981). Most published European biomass equations are based on DBH (Zianis et al., 2005). In rubber tree stands measurement of height can be difficult due to closed canopies.

Height was a poor predictor of rubberwood biomass. On the contrary, DBH described best the allometric relationship and was also easier to be measured than tree height. Height and other parts such as crown length and volume are not easy to measure in the field. To avoid defects and scars from rubber tapping, diameter has been measured in some studies at heights of 1.2, 1.5 and 1.7 m. Tapping height depends on the age of trees and, in old trees, it

can be over 1.7 m. Thus, they used DBH (1.3 m), which is used in forestry as a standard (Hytonen et al., 2018).

According to Bridhikitti, A. (2017), allometric equations created by Brown (1997) and modified by Basuki et al. (2009) were used to estimate the above-ground biomass (AGB) for forest and Para rubber trees based on tree diameter at breast height (DBH). The formula is as follows:  $AGB = \exp[c + \alpha \ln(DBH)]$ , where DBH is expressed in centimetres,  $c$  is the intercept, and  $\alpha$  is the slope coefficient. AGB represents above-ground biomass per tree in kg. The tropical forest in this study had a slope coefficient ( $\alpha$ ) of 2.32 and an intercept ( $c$ ) of -1.996 (Brown, 1997). In the work of Basuki et al. (2009), the aboveground biomass for deciduous forest was estimated from the mixed species model ( $c = -1.201$ ,  $\alpha = 2.196$ ), and the biomass for para rubber was from the commercial species model ( $c = -1.498$ ,  $\alpha = 2.234$ ). Table 2.2 below show the allometric equation of aboveground biomass.

Table 2.2: Allometric equation of AGB

Allometric equation	Source	Study site
1. $AGB = \exp [c + \alpha \ln(DBH)]$ , aboveground biomass in kg/tree, DBH is in cm, $c = -1.498$ $\alpha = 2.234$	Developed by Brown (1997), modified by Basuki et al. (2009)	Thailand
2. Aboveground biomass (kg) Stem = $0.313 \times (DBH^2 \times H)^{0.9773}$	Kato et al., 1978	Malaysia
3. Aboveground biomass = $0.11 * (\rho D^2 H)^{0.916}$  AGB = Aboveground tree biomass (kg) $\rho$ = Wood density (g/cm <sup>3</sup> ) D = Diameter at breast height (cm) H = Tree height (m)	Kurniawan et al., 2018	Thailand
Aboveground biomass stem $W_s = 0.0396 \times (D^2 \times H)^{0.9326}$	Ogawa et al., 1965	Thailand
4. $\ln(\text{Stem AGB}) =$ $-2.01 + 2.41 \times \ln(DBH)$	Aholoukpe et al., 2013	Malaysia
5. Stem AGB = $0.0483 \times (DBH)^{2.4173}$	Wattana et al., 2013	Thailand
6. Aboveground biomass = $0.15 \times (DBH)^{2.45}$	Hytönen et al. (2019)	Thailand

## CHAPTER 3

### MATERIAL AND METHOD

#### 3.1 Study Area

Kelantan is a state in Peninsular Malaysia with an area of 15,040 km<sup>2</sup> meanwhile Jeli is the third largest district in the state of Kelantan, where Jeli occupies an area of 128,020.56 hectares, or 1,280.21 km<sup>2</sup>. Kampung Kulim is situated in Lakota, Jeli with geographical coordinates are 5° 44' 30" North, 101° 51' 30" East. Figure 3.1 below show the location of study area.

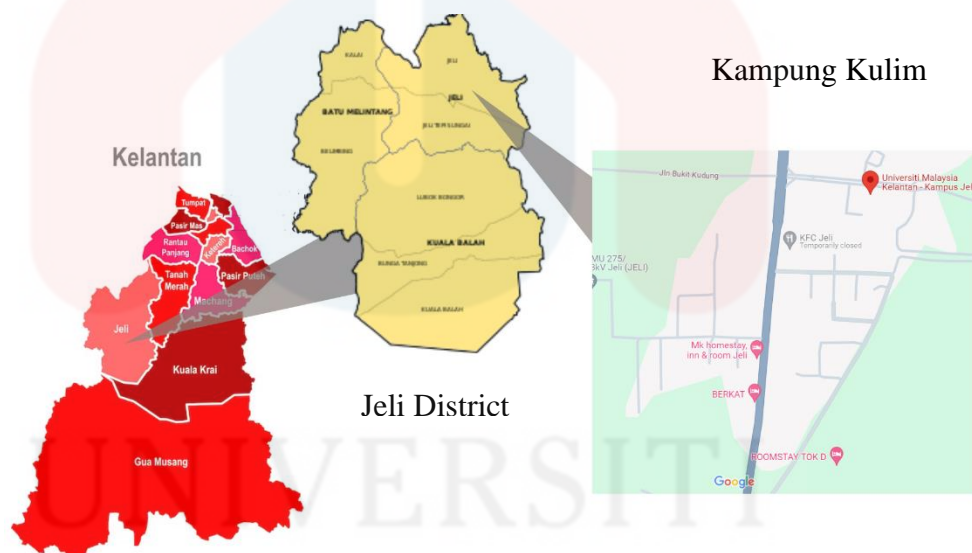


Figure 3.1: Location of study area

There are 5 plots has been setting up at Kampung Kulim, Lakota. Table 3.1 shows the coordinates by each plots of this study meanwhile Figure 3.2 shows the sampling sites.

Table 3.1: The coordinate of each plot

Plot	Coordinate
A	5°44'29"N 101°51'31"E
B	5°44'30"N 101°51'31"E
C	5°44'29"N 101°51'29"E
D	5°44'30"N 101°51'30"E
E	5°44'30"N 101°51'31"E



Figure 3.2: Sampling sites of Kampung Kulim

### 3.2 Material

In this study, the aboveground stem biomass and carbon stock of *Hevea brasiliensis* was determined using field diameter at breast height (DBH) measurements and allometric models. Then, *Hevea brasiliensis* collected at age 20 to 30 years old.

### 3.3 Method

A sampling plot with an area of 20m x 25m with 5 plots equals to 2,500 km<sup>3</sup> has been used to collect the data based on the previous study that has mentioned in Section 2.2, Chapter 2. It is because most DBH of the *Hevea brasiliensis* measured 15 cm and above. DBH measuring tape and raffia rope are two of the tools that been used. The sampling method is systematic random sampling. Randomly sample the required number of subjects from each stratum in a way that reflects the stratum's share of the total population. Then, combine the random samples from each stratum into a final sample for the study. Figure 3.3 shows the inventory line of sampling plot meanwhile Figure 3.4 below shows the research flowchart throughout the study.

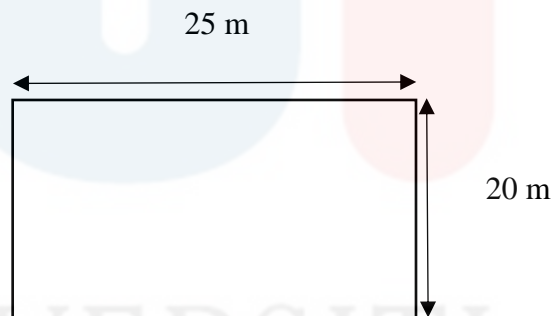
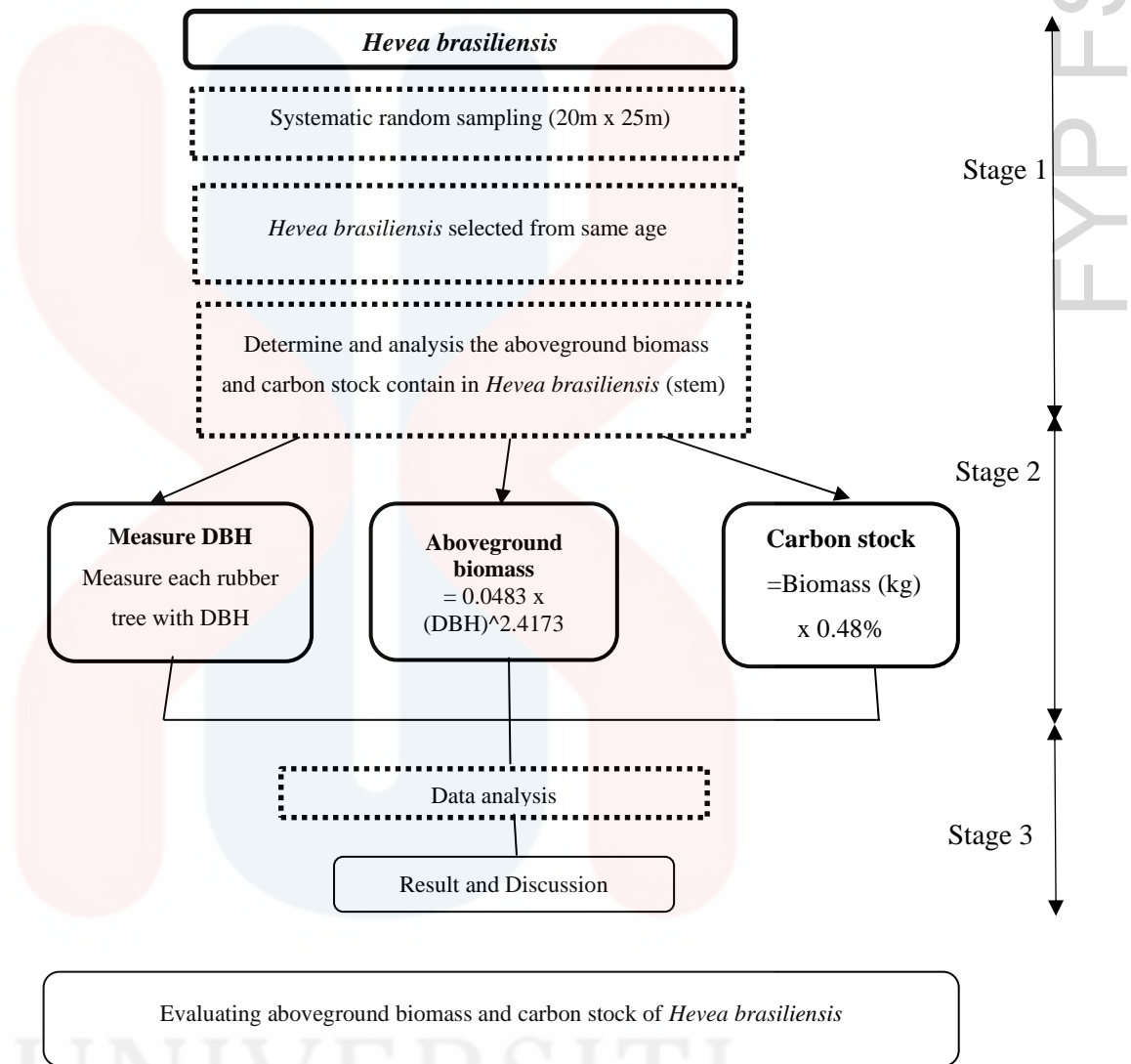


Figure 3.3: The inventory line of sampling plot

## Research Flowchart



Stage 1: Material preparation  
 Stage 2: Biomass allometric model will be use in this study  
 Stage 3: Analysis, evaluation, result and discussion

Figure 3.4: Research Flowchart

### 3.3.1 Aboveground Biomass

Next, Allometric model has been applied to evaluate aboveground biomass and carbon stock. The aboveground biomass of *Hevea brasiliensis* was estimated in a number of ways, one of which is frequently used: the allometric equation. DBH, height, or both observable characteristics are connected to a plant's biomass using allometric equations. To evaluate aboveground biomass and carbon stock of *Hevea brasiliensis* biomass allometric model are used to complete this study.

The rubber trees' total aboveground biomass from the sample has been determined. Allometric equations unique to Malaysia that are based on measurements like tree diameter and height will be utilized to calculate total biomass. The estimated aboveground biomass of each tree sampled was added to calculate total biomass (in kg).

The DBH of each rubber tree sampled has been measured in centimeters (cm). The diameter of the tree trunk measured at a standard height of 1.3 meters above the ground in order to calculate DBH. The DBH of the rubber tree can be determined by having the circumference of the tree trunk at breast height measured with calipers or a DBH measuring tape, and then calculating the diameter.

The allometric model shown by Equation (3.1) by Hytönen et al. (2019) has been applied to this study to estimate aboveground biomass. An allometric equation specifically designed for *Hevea brasiliensis* and specific to Thailand has been used to estimate aboveground biomass based on DBH. This is because the study site Kampung Kulim, Jeli borders the neighboring country which is Thailand due to certain factors. This equation also use to

estimate aboveground biomass of stem *Hevea brasiliensis* in Thailand based on previous study.

Calculating the equation aboveground biomass = 0.15 x (DBH<sup>2.45</sup>) requires mathematical study. To illustrate this, we'll use a fictitious dataset.

First, construct Linear Regression Sums

$$\sum x = 35.388$$

$$\sum y = 64.012$$

$$\sum x^2 = 126.793$$

$$\sum y^2 = 415.321$$

$$\sum xy = 227.985$$

$$n = 10$$

Next, calculate slope (B) and intercept (A)

$$B = (n * \sum xy - \sum x * \sum y) / (n * \sum x^2 - (\sum x)^2)$$

$$= (10 * 227.9852 - 35.3884 * 64.0121) / (10 * 126.7928 - 35.3884^2)$$

$$= (2279.852 - 2265.2155) / (1267.928 - 1252.3385)$$

$$= 14.6365 / 5.9895$$

$$= 2.4500$$

$$A = (\sum y - B * \sum x) / n$$

$$= (64.0121 - 2.4500 * 35.3884) / 10$$

$$= (64.0121 - 86.7016) / 10$$

$$= -22.6895 / 10$$

$$= -1.8971$$

Next, create the linear equation.

$$\ln(\text{Biomass}) = 2.4500 * \ln(\text{DBH}) - 1.8971$$

Then, convert back to power function biomass and calculate coefficients.

$$= e^{-1.8971} * \text{DBH}^{2.4500}$$

$$a = e^{-1.8971} = 0.15$$

$$b = 2.4500 = 2.45$$

So,

$$\text{aboveground biomass} = 0.15 x (\text{DBH}^{2.45}) \quad (3.1)$$

Where:

- 0.15: Applying regression analysis to determine the coefficient that best describe the relationship and reflects the specifics growth characteristics and wood density of *Hevea brasiliensis* in the studied region.
- DBH: standard measure of a tree's diameter taken at 1.3 meters aboveground level.
- 2.45: Represents the non- linear relationship between DBH and AGB, and determined empirically through regression analysis of field data and reflects how biomass scales with tree size.

### 3.3.2 Biomass Carbon Stock

The total biomass multiplied by the carbon fraction for rubber trees, which is 0.48, to convert to carbon stock as shown by Equation (3.2) by Hytönen et al. (2019) for calculating the carbon stock.

$$\text{Carbon Stock (kg)} = \text{AGB(kg)} x 0.50 (\text{Carbon Fraction}) \quad (3.2)$$

**RESULT AND DISCUSSION**

**4.1 Descriptive statistics**

Descriptive statistic was used to analyze the recorded data. The method has been used for mean of DBH, Aboveground Biomass and Carbon Stock.

**4.1.1 DBH classes and mean of DBH**

Figure 4.1 below shows (a)DBH classes and (b) mean of DBH by each plot at Kampung Kulim, Lakota, Jeli, Kelantan.

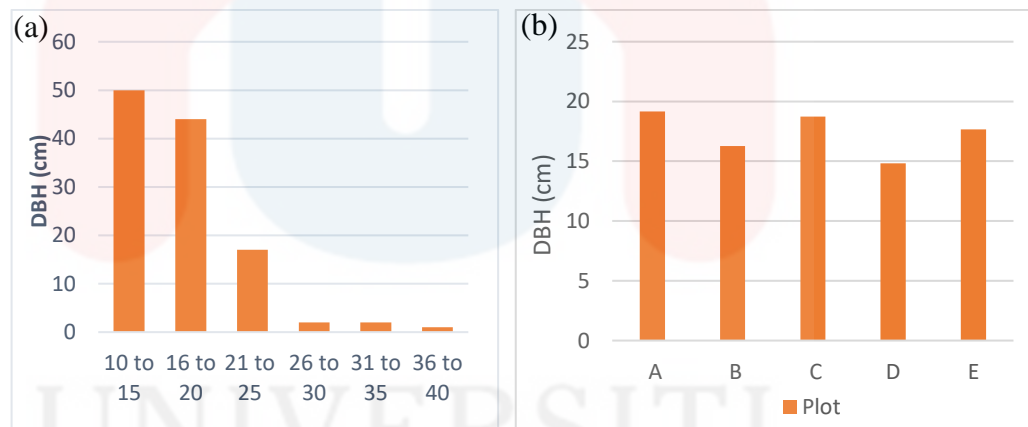


Figure 4.1: (a) DBH class of each tree and (b) mean DBH by each plot

Different distribution patterns among the plots are shown by Figure 4.1 (a) in analyzing the DBH classes for the trees in Kampung Kulim, Lakota, Jeli, Kelantan. Six ranges are used to classify the DBH classes. According to statistics, 50 and 44 trees, belong to the DBH classes of 10-15 cm and 16-20 cm, which contain the majority of trees. this implies that smaller trees represent the majority of the forest in this location. With just 17 trees in the 21-25 cm class and only 2 trees in each of the bigger DBH classes which is

26-30 cm and 31-35 cm. there are less and fewer trees as the DBH class rises. There is also only one tree in 36-40 cm class.

According to the statistics in Figure 4.1 (b), Plot B has the lowest mean DBH, indicating possible difficulties or increased competition, whereas Plot A has the greatest mean DBH, indicating more favourable growing circumstances. The DBH values of Plots C and E are comparable, but Plot D has the lowest mean DBH, indicating less ideal growing circumstances or younger trees. These differences demonstrate the variability of the forest stand, which is crucial for informing forest management decisions and identifying regions in need of specific strategies.

#### 4.1.2 Total of AGB by each plot

Figure 4.2 below shows total AGB by each plot at Kampung Kulim, Lakota, Jeli, Kelantan.

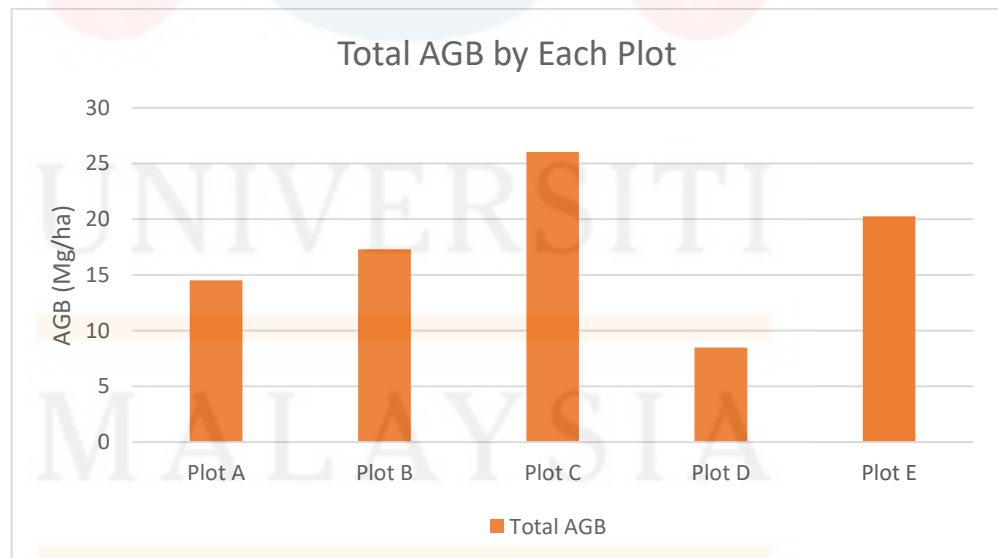


Figure 4.2: Total AGB by each plot

Variations in biomass accumulation are shown by AGB analysis conducted on various plots in Kampung Kulim, Lakota, Jeli, Kelantan. The

following are the plots' overall AGB values, the top plot which is Plot C, has 26.039 Mg/ha, the lowest, Plot D, has 8.495 Mg/ha and Plot E, has 20.26 Mg/ha. Plot A has 14.51 Mg/ha and Plot B has 17.296 Mg/ha.

The differences in AGB between the plots provide insight on Kampung Kulim's forest's biological variability. In comparison to the other plots, Plot C had greater AGB implies a larger or more mature stand of trees, which may indicate better growth circumstances or less disturbance. On the other hand, Plot D's lower AGB suggests higher disturbance levels, a smaller tree cover, or younger vegetation. The middle plots, A, B and E show a moderate growth of biomass.

#### 4.1.3 Total carbon stock by each plot

Figure 4.3 below shows total carbon stock by each plot at Kampung Kulim, Lakota, Jeli, Kelantan.

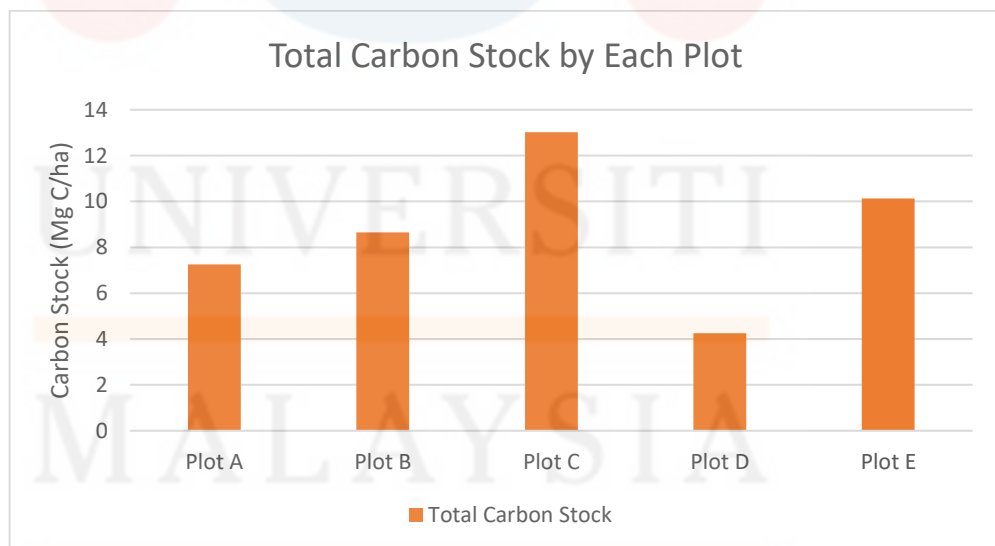


Figure 4.3: Total carbon stock by each plot

Different amounts of carbon storing are shown by analyzing the total carbon stock across plots in Kampung Kulim, Lakota, Jeli, Kelantan. The total

carbon stock values as follows, Plot C has the largest carbon stock at 13.020 Mg C/ha, Plot D has the lowest at 4.247 Mg C/ha, Plot E has 10.130 Mg C/ha and Plot A has 7.255 Mg C/ha, Plot B has 8.648 Mg C/ha. This distribution shows how the biomass of the trees in each plot stores carbon differently.

Important information on the forest's function in storing carbon in Kampung Kulim is provided by the data on total carbon stocks. Plot C has the largest carbon store because of its larger biomass, which is mostly responsible for storing carbon and may attributed to older or more closely spaced trees. The lowest carbon stock in Plot D, on the other hand, would point to a less developed or thick forest stand, which is the result of recent disturbances or unfavorable growth circumstances.

#### 4.2 Comparison of Aboveground Biomass and Carbon Stock of *Hevea brasiliensis* in Kampung Kulim, Lakota, Jeli Kelantan with Another Research.

To complete this study, comparison of DBH, AGB and carbon stock has been done between another two-study area which is Felda Lubuk Merbau, Alor Setar Kedah and Songkhla Province, Southern Thailand. Table 4.2 shows the comparison of AGB and carbon stock by each area.

Table 4.2: Comparison of aboveground biomass and carbon stock of *Hevea brasiliensis* in Kampung Kulim, Lakota, Jeli Kelantan with another research.

	This study	Iqbal et al.	Titeesang et al
Year	2024	2020	2021
Area	Kampung Kulim, Lakota Jeli Kelantan	Felda Lubuk Merbau, Alor Setar, Kedah	Songkhla Province, Southern Thailand
DBH	>10cm	>10cm	>5cm
AGB	86.6 Mg/ha	148 Mg/ha	82.1 Mg/ha

		196.7 Mg/ha	
Carbon stock	43.30 Mg C/ha	34.88 Mg C/ha 41.53 Mg C/ha	38.6 Mg C/ha

According to research investigating tree stand parameter for rubber tree aboveground biomass and carbon stock estimation by (Iqbal et al., 2020), using two distinct allometric equations, the aboveground biomass and carbon sequestration were estimated in this study meanwhile this research only use one allometric equation.

Additionally, it used statistical model non-linear regression to examine the link between the biomass and the two predictors, namely height and age group. 195 sample trees were measured over 30 x 30 meters rectangular area in Felda Lubuk Merbau, Peninsular Malaysia. There were total of 8 sample plots in the research area. Plots were allocated at random to trees in the age groups of 5, 10,15 and 20 years. Meanwhile in this study 80 sample tree were measured in 25 x 20 meter in 5 sample plots in the tree age 20-30 years.

Using the equations from Dey et al. (1965), the average estimated AGB is 148.4 Mg/ha and 196.7 Mg/ha, respectively. The carbon stock from each equation is 34.88 Mg C/ha and 41.53 Mg C/ha. The Shorrocks et al. (1965) equation produced a greater result for the anticipated AGB and carbon sequestration when compare to other equation.

According to the research spatial assessment of para rubber (*Hevea brasiliensis*) aboveground biomass potentials in Songkhla Province, Southern Thailand by Titseesang et al., (2021), *Hevea brasiliensis* are estimated to have an average aboveground biomass density of 82.1 Mg/ha. This figure is based

on comprehensive field measurements and remote sensing methods that calculate the total biomass in the rubber plantation.

Meanwhile, a carbon fraction of the biomass is used to calculate the potential carbon stock. It's commonly assumed that 47% of biomass in rubber trees is made up of carbon. Thus, the carbon stock is almost the same as  $82.1 \text{ Mg/ha} \times 0.47$ , or about  $38.6 \text{ Mg C/ha}$ , if the aboveground biomass density is  $82.1 \text{ Mg/ha}$ . But the study makes this simpler by taking the biomass density as the potential carbon stock because of similar.

## CHAPTER 5

### CONCLUSION AND RECOMMENDATION

#### 5.1 Conclusion

This study successfully quantified the aboveground biomass and determine the carbon stock of *Hevea brasiliensis* at Kampung Kulim, Lakota, Jeli. The rubber plantations several plots under study exhibit difference in the mean DBH, AGB and carbon stock. The plot with the best growing circumstances was DBH class 10-15 cm which had the greatest values for DBH which is 50 trees, meanwhile Plot C show the highest total of AGB (130.197 Mg/ha) and carbon stock (65.099 Mg C/ha). The lowest class of DBH was 36-40 cm present only one tree, meanwhile Plot D which is 42.474 Mg/ha and carbon stock 21.237 Mg C/ha plot D had the lowest values, indicating either suboptimal growing factors or increased tree competition.

#### 5.2 Recommendation

Further research should be done to determine the specific causes of the differences in DBH, AGB and carbon stock between the plots, including tree density, soil fertility water availability and management techniques. By taking care of these issues, the plantation as a whole may be able to increase biomass and store more carbon while also improving growing conditions. To improve the statistical power of the analysis and maybe find any significant changes, if any, increase the sample size or think about adding more sampling sites inside the rubber plantation. Examine site-specific management

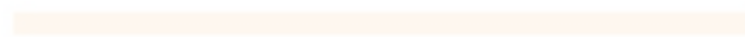
techniques to improve the rubber trees capacity to develop and sequester carbon, particularly in plots with lower DBH, AGB and carbon stock values such as plot D.



UNIVERSITI



MALAYSIA



KELANTAN

## REFERENCES

- Aholoukpe, H., Dubos, B., Flori, A., Deleporte, P., Amadji, G., Chotte, J. L., & Blavet, D. (2013). *Estimating aboveground biomass of oil palm: Allometric equations for estimating frond biomass*. *Forest Ecology and Management*, 292, 122-129.
- Baccini, A. G. S. J., Goetz, S. J., Walker, W. S., Laporte, N. T., Sun, M., Sulla-Menashe, D., ... & Houghton, R. (2012). *Estimated carbon dioxide emissions from tropical deforestation improved by carbon-density maps*. *Nature climate change*, 2(3), 182-185.
- Basuki, T. M., van Laake, P. E., Skidmore, A. K., & Hussin, Y. A. (2009). Allometric equations for estimating the above-ground biomass in tropical lowland Dipterocarp forests. *Forest Ecology and Management*, 257(8), 1684-1694. <https://doi.org/10.1016/j.foreco.2009.01.027>
- Bridhikitti, A. (2017). *Soil and biomass carbon stocks in forest and agricultural lands in tropical climates*. *Songklanakarin Journal of Science & Technology*, 39(6).
- Britannica, T. Editors of Encyclopaedia (2021, May 28). *rubber tree*. *Encyclopedia Britannica*. <https://www.britannica.com/plant/rubber-tree>
- Beukema, H., Danielsen, F., Vincent, G., Hardiwinoto, S., & van Andel, J. (2007). *Plant and bird diversity in rubber agroforests in the lowlands of Sumatra, Indonesia*. *Agroforestry Systems*, 70, 217-242.
- Bugwood Network. (2022). Rubber tree (*Hevea brasiliensis*) in forest plantation. <https://www.forestryimages.org/browse/subinfo.cfm?sub=21340>
- Brown, S. (1997). *Estimating biomass and biomass change of tropical forests: a primer*. Food and Agriculture Organization of the United Nations. Retrieved from <http://www.fao.org/3/w4095e/w4095e00.htm>
- Chave, J., Andalo, C., Brown, S., Cairns, M. A., Chambers, J. Q., Eamus, D., ... & Yamakura, T. (2005). *Tree allometry and improved estimation of carbon stocks and balance in tropical forests*. *Oecologia*, 145, 87-99.
- Crow, T. R., & Schlaegel, B. E. (1988). A guide to using regression equations for estimating tree biomass. *Northern Journal of Applied Forestry*, 5(1), 15-22. <https://doi.org/10.1093/njaf/5.1.15>
- Dey, S. K., Nair, P. K. R., & Pritchett, W. L. (1996). Evaluation of growth and biomass production of eight multipurpose tree species in Kerala, India. *Agroforestry Systems*, 34(2), 153-165. <https://doi.org/10.1007/BF00148156>
- Everitt, B. S., & Skrondal, A. (2010). *The Cambridge dictionary of statistics*. Cambridge University Press.
- Forestry Images. (n.d.). Rubber tree plantation aboveground biomass data from destructive sampling studies [Reference list].from <https://www.forestryimages.org/browse/subinfo.cfm?sub=21340#references>
- Guardiola-Claramonte, M., Troch, P. A., Ziegler, A. D., Giambelluca, T. W., Durcik, M., Vogler, J. B., & Nullet, M. A. (2008). *Hydrologic effects of the expansion*

- of rubber (Hevea brasiliensis) in Montane Mainland Southeast Asia.* *Ecohydrology*, 1(4), 361-373.
- Houghton, R. A., Hall, F., Goetz, S. J., & Imhoff, M. L. (2009). "Carbon emissions from land use and land-cover change." *Biogeosciences*, 6(12), 2247-2257.
- Hoy, W. K., & Adams, C. M. (2015). *Quantitative research in education: A primer*. Sage Publications.
- Hytönen, J., Nurmi, J., Kaakkurivaara, N., & Kaakkurivaara, T. (2019). Rubber Tree (*Hevea brasiliensis*) Biomass, Nutrient Content, and Heating Values in Southern Thailand. *Forests*, 10(8), 638. <https://doi.org/10.3390/f10080638>
- IPCC (2002). *Climate Change 2001 Synthesis Report*. Cambridge University Press. Retrieved from <https://www.ipcc.ch/report/ar4/syr/>
- Intergovernmental Panel on Climate Change. (2006). *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Retrieved from [https://www.ipcc.ch/site/assets/uploads/2018/03/GPG\\_LULUCF\\_FULLEN.pdf](https://www.ipcc.ch/site/assets/uploads/2018/03/GPG_LULUCF_FULLEN.pdf)
- IPCC (2013). *Climate Change 2013: The Physical Science Basis*. <https://www.ipcc.ch/report/ar5/wg1/>
- IPCC (2014). *Climate Change 2014 Synthesis Report*. <https://www.ipcc.ch/report/ar5/syr/>
- IPCC (2022). *Climate Change 2022: Mitigation of Climate Change*. <https://www.ipcc.ch/report/ar6/wg3/>
- Iqbal, P. A., Wahab, R., Abdu, A., Jani, A., Harun, J., & Saidin, S. (2020). Investigating tree stand parameter for rubber tree aboveground biomass and carbon stock estimation. *Journal of Tropical Forest Science*, 32(3), 318-330. <https://doi.org/10.26525/jtfs32.3.318>
- Jemali, N.J.N., Majid, S. A., (2023) *Bab 10: Teknik Inventori Hutan*. In Hamzah, A. S. M. A., Fauzi, N., & Jemali, N.J.N., *Teknik Kerja Lapangan Dalam Sains Sumber Asli* (page 89), Location: Penerbit UMK.
- Kato, R., Tacho, S., & Siteo, A. (1978). Allometric equations for estimating aboveground biomass in tropical rainforests. *Journal of Forestry Research*, 5(2), 32-36.
- Keith, H., Mackey, B. G., & Lindenmayer, D. B. (2009). *Re-evaluation of forest biomass carbon stocks and lessons from the world's most carbon-dense forests*. *Proceedings of the National Academy of Sciences*, 106(28), 11635-11640.
- Kurniawan et al. 2018. *Forest Ecology and Management* <https://www.sciencedirect.com/science/article/pii/S0378112718301240>
- Kurniawan, D., Tata, H. L., Maryani, E., & Rahayu, S. (2018). Allometric models for estimating the aboveground biomass of secondary forests in tropical lowland.

- Journal of Forestry Research, 29(3), 797-805. <https://doi.org/10.1007/s11676-018-0576-3>
- Lal, R. (2004). Soil carbon sequestration impacts on global climate change and food security. *Science*, 304(5677), 1623-1627. Retrieved from <https://www.science.org/doi/10.1126/science.1097396>
- Li, H., Ma, Y., Aide, T. M., & Liu, W. (2008). *Past, present and future land-use in Xishuangbanna, China and the implications for carbon dynamics*. *Forest Ecology and Management*, 255(1), 16-27.
- Margono, B. A., Turubanova, S., Zhuravleva, I., Potapov, P., Tyukavina, A., Baccini, A., ... & Hansen, M. C. (2012). *Mapping and monitoring deforestation and forest degradation in Sumatra (Indonesia) using Landsat time series data sets from 1990 to 2010*. *Environmental Research Letters*, 7(3), 034010.
- Margono, B. A., Potapov, P. V., Turubanova, S., Stolle, F., & Hansen, M. C. (2012). Primary forest cover loss in Indonesia over 2000-2012. *Nature Climate Change*, 4(9), 730-735. Retrieved from <https://www.nature.com/articles/nclimate2277>
- NASA. (2022). *Causes of Climate Change*. NASA Climate Change and Global Warming. <https://climate.nasa.gov/causes/>
- Ogawa, H., Yoda, K., Ogino, K., & Kira, T. (1965). Comparative ecological studies on three main types of forest vegetation in Thailand. *Nature and Life in Southeast Asia*, 4, 49-80.
- Ong, R. C., Vongkaluang, C., & Klein, J. (2019). Aboveground biomass and carbon stocks of rubber (*Hevea brasiliensis*) plantations in Southeast Asia. *Journal of Environmental Management*, 240, 10-18.  
doi:10.1016/j.jenvman.2019.03.013
- Pan, Y., Birdsey, R. A., Fang, J., Houghton, R., Kauppi, P. E., Kurz, W. A., ... & Ciais, P. (2011). *A large and persistent carbon sink in the world's forests*. *Science*, 333(6045), 988-993.
- Payandeh, B. (1981). Choosing regression models for biomass prediction. *Forest Chronology*, 57(5), 229-232. <https://doi.org/10.5558/tfc57229-5>
- Pearson, T. R. H., Brown, S., Murray, L., & Sidman, G. (2017). *Greenhouse gas emissions from tropical forest degradation: an underestimated source*. *Carbon Balance and Management*, 12(1), 5.
- Picard, N., Saint-André, L., & Henry, M. (2012). *Manual for building tree volume and biomass allometric equations: From field measurement to prediction*. Food and Agricultural Organization of the United Nations and Centre de Coopération Internationale en Recherche Agronomique pour le Développement. Retrieved from <https://www.fao.org/sustainable-forest-management/toolbox/tools/tool-detail/en/c/218049/>.

- Plant World. (2021). *Parts of Rubber Tree (Hevea brasiliensis) Plant*. Design Bundles. <https://designbundles.net/plant-world/1196752-parts-of-rubber-tree-hevea-brasiliensis-plant>
- Priya, P., Venkatachalam, P., & Thulaseedharan, A. (2009). *Rubber (Hevea brasiliensis Muell. Arg.) - Recent Advances and Future Prospects*. Journal of Plantation Crops, 37(3), 191–243.
- Priyadarshan, P. M. (2011). *Biology of Hevea rubber* (pp. 1-6). Wallingford, UK: CABI.
- Rao, P., & Vijayakumar, K. (1992). *Structure and development of the latex system in Hevea brasiliensis*. Journal of Biosciences, 17(3), 295-313.
- Saatchi, S. S., Harris, N. L., Brown, S., Lefsky, M., Mitchard, E. T., Salas, W., ... & Petronelli, P. (2011). *Benchmark map of forest carbon stocks in tropical regions across three continents*. Proceedings of the National Academy of Sciences, 108(24), 9899-9904.
- Schlesinger, W. H., & Andrews, J. A. (2000). Soil respiration and the global carbon cycle. Biogeochemistry, 48(1), 7-20. Retrieved from <https://www.jstor.org/stable/2641104>
- Shorrocks, V. M., & Young, D. J. (1965). Tree growth and rubber yield in *Hevea brasiliensis*. The Journal of Agricultural Science, 65(2), 185-191. <https://doi.org/10.1017/S0021859600015481>
- Titseesang, T., Okpara, K. E., & Techato, K. (2021). Spatial assessment of Para rubber (*Hevea brasiliensis*) above ground biomass potentials in Songkhla Province, Southern Thailand. Sustainability, 13(16), 9344. <https://doi.org/10.3390/su13169344>
- United Nations Framework Convention on Climate Change (UNFCCC). (2022). *What Do We Do*. UNFCCC. <https://unfccc.int/about-us/about-the-secretariat/what-do-we-do>
- U.S. Environmental Protection Agency. (2022). Climate Change. Retrieved from <https://www.epa.gov/climate-change>
- Watthana, S., & Vannarong, N. (2013). *Allometric models for estimating rubber wood biomass of Hevea brasiliensis*. Journal of the Faculty of Agriculture and Technology, Yasothon Rajabhat University.
- Wilcove, D. S., Giam, X., Edwards, D. P., Fisher, B., & Koh, L. P. (2013). *Navjot's nightmare revisited: logging, agriculture, and biodiversity in Southeast Asia*. Trends in Ecology & Evolution, 28(9), 531-540.
- Xueqing, L., Ping, Z., Juxiu, L., Hong, Z., Jianping, C., & Tao, S. (2017). Allometric equations for estimating the aboveground biomass of rubber trees (*Hevea brasiliensis*) in mountainous regions of southwestern China. Forest Ecosystems, 4(1), 1-13. Retrieved from <https://forestecosyst.springeropen.com/articles/10.1186/s40663-017-0112-9>

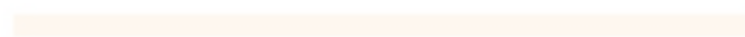
Zianis, D., Mencuccini, M., Scarascia-Mugnozza, G., & Montero, G. (2005). Allometric equations for estimating biomass and carbon stock in the European Union's forests. European Commission. <https://publications.jrc.ec.europa.eu/repository/handle/JRC29961>



UNIVERSITI



MALAYSIA



KELANTAN

## APPENDIX A

Table A.1: Raw data of collected data by each plot

### Plot A

<b>Bil</b>	<b>DBH(cm)</b>	<b>AGB (kg)</b>	<b>Carbon stock (Mg)</b>	<b>AGB (Mg/ha)</b>	<b>Carbon stock (Mg C/ha)</b>
1	15	114.160	57.080	0.457	0.228
2	20.8	254.300	127.15	1.017	0.509
3	17.5	166.546	83.273	0.666	0.333
4	20.4	242.485	121.243	0.970	0.485
5	19.5	217.108	108.554	0.868	0.434
6	20.5	245.408	122.704	0.982	0.491
7	18.9	201.105	100.552	0.804	0.402
8	15.8	129.659	64.829	0.519	0.259
9	33.1	793.725	396.862	3.175	1.587
10	15.2	117.926	58.963	0.472	0.236
11	21.6	278.935	139.467	1.116	0.558
12	15.3	119.835	59.918	0.479	0.240
13	18.4	188.319	94.160	0.753	0.377
14	19.5	217.108	108.554	0.868	0.434
15	15.5	123.710	61.855	0.495	0.247
16	19.5	217.108	108.554	0.868	0.434
<b>Sub total</b>	306.5	3627.337	1813.718	14.51	7.255

### Plot B

<b>Bil</b>	<b>DBH</b>	<b>AGB (kg)</b>	<b>Carbon stock (Mg)</b>	<b>AGB (Mg/ha)</b>	<b>Carbon stock (Mg C/ha)</b>
1	23	325.330	162.665	1.301	0.651
2	13.3	85.021	42.511	0.340	0.170
3	19	203.722	101.861	0.815	0.407
4	16.3	139.943	69.971	0.560	0.280
5	17.1	157.374	78.687	0.629	0.315
6	13	80.399	40.200	0.322	0.161
7	14.4	103.295	51.648	0.413	0.207
8	18.8	198.508	99.254	0.794	0.397
9	19.5	217.108	108.554	0.868	0.434
10	15.2	117.926	58.963	0.472	0.236
11	13.4	86.596	43.298	0.346	0.173
12	12.9	78.893	39.446	0.316	0.158
13	12.5	73.033	36.517	0.292	0.146
14	15.3	119.835	59.918	0.479	0.240
15	14	96.406	48.203	0.386	0.193
16	20.5	245.408	122.704	0.982	0.491
17	13.9	94.728	47.364	0.379	0.189

18	18.4	188.319	94.160	0.753	0.377
19	17.2	159.638	79.819	0.639	0.319
20	12.5	73.033	36.517	0.292	0.146
21	12.7	75.929	37.965	0.304	0.152
22	14.5	105.061	52.531	0.420	0.210
23	18.3	185.822	92.911	0.743	0.372
24	16.1	135.773	67.887	0.543	0.272
25	14.8	110.467	55.233	0.442	0.221
26	25.1	402.988	201.494	1.612	0.806
27	13.6	89.797	44.898	0.359	0.180
28	19.3	211.693	105.847	0.847	0.423
29	17.3	161.921	80.961	0.648	0.324
<b>Sub total</b>	471.9	4323.967	2161.984	17.296	8.648

### Plot C

<b>Bil</b>	<b>DBH (cm)</b>	<b>AGB (kg)</b>	<b>Carbon stock (Mg)</b>	<b>AGB (Mg/ha)</b>	<b>Carbon stock (Mg C/ha)</b>
1	10	42.276	21.138	0.169	0.085
2	10	42.276	21.138	0.169	0.085
3	11	53.395	26.698	0.214	0.107
4	13.2	83.464	41.732	0.334	0.167
5	13.5	88.188	44.094	0.353	0.176
6	14.4	103.295	51.648	0.413	0.207
7	14.5	105.061	52.531	0.420	0.210
8	14.5	105.061	52.531	0.420	0.210
9	16	133.717	66.858	0.535	0.267
10	16.5	144.187	72.094	0.577	0.288
11	17.3	161.921	80.961	0.648	0.324
12	17.9	176.028	88.014	0.704	0.352
13	18	178.447	89.223	0.714	0.357
14	18	178.447	89.223	0.714	0.357
15	18.1	180.886	90.443	0.724	0.362
16	18.2	183.344	91.672	0.733	0.367
17	18.5	190.837	95.418	0.763	0.382
18	18.6	193.374	96.687	0.773	0.387
19	19.3	211.693	105.847	0.847	0.423
20	21	260.333	130.166	1.041	0.521
21	21.4	272.650	136.325	1.091	0.545
22	21.5	275.782	137.891	1.103	0.552
23	22.5	308.275	154.138	1.233	0.617
24	23.8	353.757	176.878	1.415	0.708
25	24	361.084	180.542	1.444	0.722
26	24.2	368.501	184.251	1.474	0.737
27	31	675.970	337.985	2.704	1.352
28	37.5	1077.626	538.813	4.311	2.155

<b>Sub total</b>	524.4	6509.873	3254.936	26.039	13.020
------------------	-------	----------	----------	--------	--------

**Plot D**

<b>Bil</b>	<b>DBH (cm)</b>	<b>AGB (kg)</b>	<b>Carbon stock (Mg)</b>	<b>AGB (Mg/ha)</b>	<b>Carbon stock (Mg C/ha)</b>
1	13.2	83.464	41.732	0.334	0.167
2	16.5	144.187	72.094	0.577	0.288
3	24.4	376.007	188.004	1.504	0.752
4	10	42.276	21.138	0.169	0.085
5	13.7	91.423	45.712	0.366	0.183
6	10.5	47.644	23.822	0.191	0.095
7	17.2	159.638	79.819	0.639	0.319
8	17.1	157.374	78.687	0.629	0.315
9	11.3	57.034	28.517	0.228	0.114
10	14	96.406	48.203	0.386	0.193
11	13.4	86.596	43.298	0.346	0.173
12	13.3	85.021	42.511	0.340	0.170
13	12.8	77.403	38.701	0.310	0.155
14	14	96.406	48.203	0.386	0.193
15	10.1	43.319	21.660	0.173	0.087
16	21.5	275.782	137.891	1.103	0.552
17	19	203.722	101.861	0.815	0.407
<b>Sub total</b>	252	2123.701	1061.851	8.495	4.247

**Plot E**

<b>Bil</b>	<b>DBH (cm)</b>	<b>AGB (kg)</b>	<b>Carbon stock (Mg)</b>	<b>AGB (Mg/ha)</b>	<b>Carbon stock (Mg C/ha)</b>
1	11	53.395	26.698	0.214	0.107
2	11.5	59.539	29.769	0.238	0.119
3	12	66.082	33.041	0.264	0.132
4	12	66.082	33.041	0.264	0.132
5	12.3	70.204	35.102	0.281	0.140
6	13.5	88.188	44.094	0.353	0.176
7	13.6	89.797	44.898	0.359	0.180
8	14.5	105.061	52.531	0.420	0.210
9	14.7	108.647	54.324	0.435	0.217
10	14.9	112.305	56.152	0.449	0.225
11	15.6	125.674	62.837	0.503	0.251
12	16	133.717	66.858	0.535	0.267
13	16	133.717	66.858	0.535	0.267
14	16.6	146.338	73.169	0.585	0.293
15	17.4	164.224	82.112	0.657	0.328
16	18	178.447	89.223	0.714	0.357

17	18.1	180.886	90.443	0.724	0.362
18	19.4	214.390	107.195	0.858	0.429
19	19.6	219.846	109.923	0.879	0.440
20	21.5	275.782	137.891	1.103	0.552
21	22.5	308.275	154.138	1.233	0.617
22	23.5	342.932	171.466	1.372	0.686
23	24	361.084	180.542	1.444	0.722
24	24.1	364.782	182.391	1.459	0.730
25	27	481.873	240.936	1.927	0.964
26	29.8	613.651	306.825	2.455	1.227
<b>Sub total</b>	459.1	5064.916	2532.458	20.26	10.130
<b>Total</b>	<b>2013.9</b>	<b>19117.336</b>	<b>10824.947</b>	<b>86.6</b>	<b>43.3</b>

**APPENDIX B**



Picture C.1: The pictures of during plotting and data collection.