EVALUATING ABOVEGROUND BIOMASS AND CARBON STOCK OF *Shorea platyclados, Agathis borneensis* AND *Gymnostoma sumatranum* IN COMPARTMENT 5 GUNUNG SIKU FOREST RESERVE, CAMERON HIGHLAND

by

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DECLARATION

I declare that this thesis entitled "Evaluating Aboveground Biomass and Carbon Stock of *Shorea platyclados*, *Agathis borneensis* and *Gymnostoma sumatranum* in Compartment 5 Gunung Siku Forest Reserve, Cameron Highland" 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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Evaluating Aboveground Biomass and Carbon Stock of *Shorea platyclados*, *Agathis borneensis* and *Gymnostoma sumatranum* in Compartment 5 Gunung Siku Forest Reserve, Cameron Highland

ABSTRACT

Global climate change such as increasing greenhouse emission is often related with deforestation. Forest is most important that link with global climate change where trees absorbed carbon dioxide (CO2) in atmosphere and help to regulate climate. A study was conducted in Gunung Siku Forest Reserve, Cameron Highland. A reforestation site which had been planted with two hundred and fifty saplings of *Shorea platyclados*, *Agathis borneensis* and *Gymnostoma sumatranum* since February 2015. Data collections were done every six month. In this study, these three species were measured and their aboveground biomass (AGB) and carbon stock were determined subsequently. *Gymnostoma sumatranum* showed the most changes in growth performance which was 0.44% increase in diameter compared to *Shorea platyclados* and *Agathis borneensis* were 0.35% and 0.08% respectively. The first, second and third objectives were achieved in which all the three species showed increasing in growth performance. For these three species, total amount for AGB per hectare (ha) were 602.74 kg/ha on February 2016 and 1074.56 kg/ha on August 2016. The total amount of carbon stock per hectare (ha) on February and August 2016 were 301.37 kgC/ ha and 537.26 kgC/ha respectively. This showed the steady increase of AGB and carbon stock in this reforestation area. The planting of non-native tree species in the area would possibly boost the increment in growth area as well as AGB and carbon stock.

Menilai Biomass Permukaan Tanah dan Stok Karbon *Shorea platyclados*, *Agathis borneensis* dan *Gymnostoma sumatranum* di Kompatment 5 Hutan Simpan Gunung Siku, Cameron Highland

ABSTRAK

Perubahan iklim global seperti peningkatan pelepasan rumah hijau sering berkait dengan penebangan hutan. Hutan adalah penting dimana mengandungi pautan yang berkait rapat dengan perubahan iklim global seperti pokok-pokok menyerap karbon dioksida (CO2) dalam atmosfera dan membantu mengawal iklim. Satu kajian telah dijalankan di Hutan Simpan Gunung Siku, Cameron Highland. Kawasan penanaman semula hutan yang telah ditanam dengan *Shorea platyclados*, *Agathis borneensis* dan *Gymnostoma sumatranum* yang berjumlah dua ratus lima puluh anak pokok sejak Februari 2015. Koleksi data dilakukan setiap enam bulan. Dalam kajian ini, ketiga-tiga spesies telah diukur dan kemudiaanya, biojisim permukaan tanah (AGB) dan stok karbon ditentukan. *Gymnostoma sumatranum* menunjukkan perubahan yang paling bagus dalam pertumbuhan prestasi iaitu peningkatan 0.44% diameter berbanding *Shorea platyclados* dan *Agathis borneensis* masing-masing adalah 0.35% dan 0.08%. Dalam objektif pertama, kedua dan ketiga telah dicapai dimana ketiga-tiga spesies menunjukkan peningkatan dalam prestasi pertumbuhan. Bagi ketiga-tiga spesies, jumlah untuk AGB per hektar (ha) adalah 602.74 kg/ha pada Februari 2016 dan 1074.56 kg/ha pada Ogos 2016. Jumlah untuk stok karbon per hektar (ha) pada bulan Februari dan Ogos 2016 masing masing ialah 301.37 kgC/ha dan 537.26 kgC/ha. Ini menunjukkan peningkatan yang stabil daripada AGB dan stok karbon di kawasan penanaman semula hutan ini. Penanaman spesies pokok bukan asli di kawasan itu mungkin akan meningkatkan kenaikan di kawasan pertumbuhan serta AGB dan stok karbon.

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REDD+	-	Reducing emissions from deforestation and forest degradation in developing countries; and others roles of conservation, sustainable management of forest and enhancement of forest carbon stocks
REDD	-	Reducing emissions from deforestation and degradation
UNFCCC	-	United Nations Framework Convention on Climate Change
FFPRI	-	Forest and Forest Products Research Institute
FRIM	-	Forest Research Institute Malaysia
IPCC	-	Intergovernmental Panel on Climate Change
NRE	-	Ministry of Natural Resources and Environment
FDPM	-	Forestry Department Peninsular Malaysia
PADDD	-	Protected Area Downgrading, Downsizing and Degazettement
GPS	-	Positioning system devices
IUCN	-	International Union for Conservation of Nature

LIST OF SYMBOLS

CO_2	-	Carbon dioxide
%	-	Percentage
m	-	Meter
NO_2	-	Nitrogen dioxide
CO	-	Carbon monoxide
SO_2	-	Sulphur dioxide
mil	-	Million
ha	-	Hectare
Pg	-	Petagrams
>	-	More than
<	-	Less than
cm	-	Centimetre
ºC	-	Degree celcius
º	-	Degree
ht	-	Height
ABG	-	Aboveground biomass
Mg	-	Megagram
Mha	-	Mega hectare
Mha $year^{-1}$	-	Mega hectare per year
Mg C ha^{-1}	-	Megagram of carbon per year
Tg C $year^{-1}$	-	Teragrams of carbon per year

D	-	Diameter at breast height
exp	-	Exponential function
e	-	Mathematical constant
kg	-	Kilogram
ln	-	Lorne
h	-	Tree height
Mg dry weight	-	Megagram in dry weight
Kg dry weight	-	Kilogram in dry weight

CHAPTER 1

INTRODUCTION

1.1 Background of study

Global climate change like increasing greenhouse emission is commonly related with deforestation. It is affected due to the rising in temperature and changing pattern of rain leads to the changes of landscape. Forest is most important that link with global climate change where trees absorbed carbon dioxide (CO_2) in atmosphere and help to regulate climate. Deforestation in tropical forest is one of the main reasons for increased carbon dioxide emission occurred (Aisyah et al., 2015; Berenguer et al., 2014).

Among the greenhouse gases, carbon dioxide (CO_2) is the major gas that released into the atmosphere compared to other gases such as methane and carbon monoxide (Houghton, 2005) but small amount of carbon in the biomass that held initially by forest is stored in long-lasting structure. Tropical deforestation and degradation accounts for 15-25% emission of global greenhouse every year caused by the changes of unprecedented in land cover and land use (Houghton, 2005; Malhi et al., 2000).

Anthropogenic activity such as logging, mining and conversion of forest into agriculture lands is the major source of deforestation (Kurnianto et al., 2014; Addo-Fordjour et al., 2013). Deforestation of the tropical forest leads to the negative environmental problem such as soil erosion and landslide. One of early effect by deforestation is carbon that originally held in forest released in slow rates to the atmosphere (Houghton, 2005) through burning of trees or clear cutting.

Forest globally in tropical country undergoing the highest rates in changes due to the human disturbance activity which is their biomass and carbon content are influences in carbon cycle. Most of previous studies on aboveground biomass of tropical forest have been conducted in the Brazilian Amazon and Southeast Asia. In addition, the previous studies of aboveground biomass in tropical forest was conducted in Africa (Goetzs et al., 2010).

Tropical forests play main role as a carbon sink and an origin of global carbon cycling (Seo et al., 2015; van der Heijden at al., 2015; Ngo et al., 2013). About 50% of carbon from the biomass of forest that provides approximate of the carbon pools in forest vegetation (Brown, 1992). Total carbon stored in both aboveground biomass and the top 1 m of the soil is about 50% in tropical forest for worldwide (Dixon et al., 1994). Somehow the factor such as age of stand, species composition and topography are influence the biomass of a forest. About 85% of the global aboveground carbon is covered by forests (Tan et al., 2009).

Changes of carbon stocks in living biomass of trees within a certain time after the planting be abandoned is the amount result of growth of existing trees with the addition of adoption of new trees after minus mortality (Prach et al., 2011; Lebrija-Trejos at al., 2010). The carbon degradation stock in tropical forest depending on the type of damage or disturbance such as logging and mining, intensity and frequency of disorder events, and a period of ago since their events (Aragao et al., 2014; Barlow et al., 2012). The rapid growth of species in the early stages of succession causing the higher rate of aboveground production, higher rate of carbon stock and nutrients release from deforestation and land uses (Navarro et al., 2013).

Deforestation leads to the global climate change occurs where emission of greenhouse gases is especially carbon dioxide (CO_2) and the others such as nitrogen dioxide (NO_2), carbon monoxide (CO) and sulphur dioxide (SO_2). Increasing temperature in atmosphere is the major effect now days. Malaysia take effort in mitigate climate change started in 2010 (Niiyama et al., 2010) through Reducing emissions from deforestation and forest degradation in developing countries and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries (REDD+) under the United Nations Framework Convention on Climate Change (UNFCCC). This project purposed by Forest and Forest Products Research Institute (FFPRI) and Forest Research Institute Malaysia (FRIM) through Intergovernmental Panel on Climate Change (IPCC) because of they are more experienced in monitoring the deforestation. REDD+ is the mitigation strategies to reduce and try to balance the level of emission of greenhouse gases at atmosphere that leads to the global climate change.

Therefore, the evaluation must be performed regularly to monitor the changing of the natural tropical forest caused by anthropogenic activities, the changing of carbon stock and the emission of greenhouse gases. As the result, replanting tree in deforestation area is the one of method to reduce the carbon emission in order to rehabilitation the forest.

1.2 Problem statement

Deforestation that occurred for agriculture activities lead to the soil erosion and compaction because there is no plant covers. *Shorea platyclados, Agathis borneensis* and *Gymnostoma sumatranum* is not the original trees in Gunung Siku Forest Reserve, Cameron Highland. Thus, the performance of growth rate of these tree species is undetectable because it has been planted in highland area by government for reforestation project. Most of these tree species are found in lowland forest area which grows with higher rate, extensive. Crop cultivation activity was caused the deterioration of soil quality, nutrient depletion and organic matter losses. It is probably effected the growth performance rate of these tree species subsequently. In addition, the studies on highland tropical forest in Malaysia are scarce. There is limited source of the information about the previous study of highland tropical forest in Malaysia.

1.3 Objectives

The objectives are:

1. To measure the growth of sapling species, *Shorea platyclados, Agathis borneensis* and *Gymnostoma sumatranum* in deforested area.
2. To measure the aboveground biomass of sapling species, *Shorea platyclados*, *Agathis borneensis* and *Gymnostoma sumatranum* in deforested area.
3. To analyse carbon stock in each three species, *Shorea platyclados*, *Agathis borneensis* and *Gymnostoma sumatranum* planted in deforested area.

CHAPTER 2

LITERATURE REVIEW

2.1 Deforestation

Deforestation is the permanent destruction of tropical forests to make the deforested area as for other uses. Destruction of tropical forest by anthropogenic activities and natural process itself obviously increase the emission of greenhouse gases at the atmosphere that surely leads to the increasing of global climate change. Deforested area is degraded and deforested by anthropogenic activities such as logging, agriculture and mining. There are two ways of deforestation which are burning trees and clear cutting. The planting at deforested land can lead to the reducing of soil quality which is the sensitive ecological components of tropical forest are not be able to be a buffer from farming activities. Consequently, the severe downturn in soil quality possibly leads to the eternal indignity for productivity land (Islam et al., 2000). This will effect to physical topography such as soil erosion, flood and drought because there are no plant cover in the tropical forest. The agriculture plants such as coffee, cabbage, and wheat that replace the trees are actually not able to hold the soil and it also make soil more badly.

Deforestation is one of the biggest factors of carbon dioxide emission that spread out around world. The deforestation contributes up to 20-25% of carbon dioxide global (Penman et al., 2003). There are two factors that are determined in emissions of carbon from tropical deforestation which are rates of land-use change including harvest and per hectare changes in carbon stocks by deforestation (Houghton, 2005). The rate of deforestation is still high in other countries such as Indonesia but low for several countries such as Canada and Russia which there is a gap in year between 2000 and 2010 where global annual net loss of forest was 5.2 mil ha year^{-1} compared to year between 1981 and 1990 was 15.4 mil ha year^{-1} of global annual net loss of forest (Food and Agriculture Organization of United Nations, 2010).

The issues of deforestation in Malaysia has been discussed since 1970s (Aisyah et al., 2015). In Malaysia, the forested land has been cleared to make way for rubber and oil palm plantations (Repetto, 1988). However, most of these deforestation studies focus only on lowland tropical forest. The reducing of emission from deforestation can be clearly in benefit based on the statistical bounded estimates of carbon emission (Table 1) (Harris et al., 2012). Indigenous trees planting that has benefit such as timber, food and medical product is the one of the successful method for rehabilitation of tropical rain forest (Hattori et al., 2013). There are several studies of deforestation in Malaysia (Table 2).

Table 1: Top carbon emitter from forest cover loss by region, 2000-2005

Region	Country	Forest area 2000 (Mha)	Gross forest cover loss, 2000-2005 (Mha $year^{-1}$)	Average forest cover density (Mg C ha^{-1})	Carbon emissions, 2000-2005 (Tg C $year^{-1}$)
Latin America and Caribbean	Brazil	458	3292	116	340
	Colombia	63	137	138	14
	Bolivia*	61	129	90	11
	Argentina*	49	437	24	10
	Venezuela*	49	115	134	9
Sub-Saharan Africa	Democratic	167	203	128	23
	Republic of the				
	Congo	34	196	42	9
	Mozambique*	23	149	45	7
	Tanzania	29	134	43	7
	Zambia	26	54	142	7
	Cameroon				
Asia	Indonesia	107	701	155	105
	Malaysia	**22**	**233**	**179**	**41**
	Myanmar	33	186	155	29
	India	42	206	104	18
	Thailand	17	134	126	16

*Emission estimates (at 90% confidence) include potential emission values of zero in the uncertainty range

Source by Harris et al., (2012)

Table 2: Previous study on deforestation in Malaysia

No.	Title	Area	Year	Author
1.	Gender impact of large-scale deforestation and oil palm plantations among indigenous groups in Sarawak, Malaysia	Sarawak	2015	Yong et al.
2.	Deforestation analysis in Selangor, Malaysia between 1989 and 2011	Selangor	2015	Aisyah et al.
3.	Assessing carbon pools in dipterocarp forests of Peninsular Malaysia	Pahang	2015	Omar et al.
4.	Tropical deforestation and carbon emissions from protected area downgrading, downsizing, and degazettement (PADDD)	Malaysia and Peru	2015	Forrest et al.
5.	Impact of long-term forest enrichment planting on the biological status of soil in a deforested dipterocarp Forest in Perak,Malaysia	Perak	2012	Karam et al.
6.	Exploring land use changes and the role of palm oil production in Indonesia and Malaysia	Indonesia and Malaysia	2011	Wicke et al.
7.	Land use trends analysis using spot-5 images and its effect on the landscape of Cameron Highland, Malaysia	Pahang	2003	Ismail et al.
8.	Soil physical properties and preferential flow pathways in tropical rain forest, Bukit Tarek, Peninsular Malaysia	Selangor	1997	Noguchi et al.

2.2 Afforestation

There are several hydrological functions that implement by tropical forest including flood diminution and maintaining dry season and rainfall patterns. Forest in developing countries is replaced with alternative use land due to the demand of increasing population and development activity. Most of developing countries such as Malaysia were looking way to preserve and conserve biodiversity in their tropical forest. The one of ways of many countries used are reforestation and afforestation where it is important in restocks the native flora and fauna.

The important of differences element such as natural regeneration, survival of fallen seed and artificial regeneration, and also growth of seedlings planted has to be made for reclamation of forest land where a planting of species that not suitable is not beneficial for forest (Haibara et al., 1989). In 21st century, forests are tend to have dramatic changes in type, overall performance growth and development (Lawson et al., 2014). There are several negative impact that has been made by human activity that affecting reforestation efforts such as decreased in rainfall patterns, increased temperatures, and continued drought (Pawson et al., 2013).

Deforestation is the one of activities by human to meet the demand of human population. It is identify as agricultural expansion such as the production of commercial industry such as rubber, palm oil, cattle, soybean, coffee, and cocoa (DeFries et al., 2010). The expansion of rubber in the early to mid-20th century and oil palm from 1960s onwards leading deforestation in Peninsular Malaysia (Abdullah et al., 2008). Afforestation effort is made in way to reduce the deforestation in tropical forest in Malaysia. However, there is lacking information due to the limited studies about afforestation effort in Malaysia.

The famous between the measures designed to address climate change by switch forest-management practices is the “Reducing Emissions from Deforestation and Degradation” scheme (REDD) which it is an approach to reducing greenhouse gas emissions through avoiding deforestation and forest degradation, the conservation and sustainable management of forests and through the enhancement of forest carbon stocks (Zahar et al., 2013). One of the ways that Malaysia does is replanting the species of plant to rehabilitation the land forest in order to restore flora and fauna and also to mitigate the emission of greenhouse gases.

2.3 Aboveground biomass

There is an important in knowing reason the amount of biomass stock in tropical forest. The first reason is biomass data is a basic in order to evaluate the productivity, structure, and conditions of forests (Bruce et al., 2011). The other reason is biomass measurements are effective in estimate the amount of carbon sequestration by forest (Ketterings et al., 2001). The distribution of biomass is essential because the emissions of carbon from deforestation are determined by the biomass of the deforested forest but not necessarily by the average biomass for a region (Houghton, 2005). In addition, the biomass of tropical forest is influence by several factor such as topography, external interference, species composition, surrounding environment and age of stand (Chaturvedi et al., 2013).

Some of tropical forests in Malaysia are almost converted to the secondary forest due to the disturbance from human such as agriculture, logging and mining. The ability of secondary forest in storing biomass may be changes due to the changing of tropical forest ecosystem that caused by human disturbance (Addo-Fordjour et al., 2013), also the changing biomass stock in primary forest may happen from time to time because of several factors that show the changes in forest composition (Chave et al., 2009). There are two common ways to estimate biomass of tree in tropical forests which are collecting the whole part of plant and then measure biomass by their dry weight, and the other way is using of allometric equations to estimate biomass of plants (Addo-Fordjour et al., 2013).

Allometric equation is more preferable in estimate biomass of plant in order to avoid disturbance to trees. The important step in analyse the carbon dynamics and account of carbon dioxide emission from deforestation to the atmosphere is the measuring aboveground biomass (Gonzalez et al., 2013; Houghton et al., 2003; Brown et al., 1995). Allometric equation is a method that effectively used to determined aboveground biomass (Riofrío et al., 2015). However, the selection of the allometric equation is the biggest error occurs in measuring biomass and carbon (Fonseca et al., 2012). There are several studies about aboveground biomass in Malaysia (Table 3) and the measuring aboveground biomass as below (Table 4).

Table 3: Previous study on aboveground biomass in Malaysia

No.	Method	dbh	Area	Year	Author
1.	The differences of allometric equations are used to estimating total above-ground biomass (kg) for mixed species. Total biomass = c + αD Total biomass = c + αL Total biomass = c + αD + βL $(\text{Total biomass})^{0.9}$ = c + αD Total biomass = c + αD^2 Log10 (total biomass) = c + α(log10 D) Log10 (total biomass) = c + α(log10 D)+ β(log10 L) *equation number; D: liana diameter; L:liana length.	<5c cm & >30cm	National Park, Penang	2013	Addo-Fordjour et al.
2.	Linear allometric equation. (Y=aXb), (1/Y=1/ aXb + 1/Ymax) All regressions are significant ($P < 0.01$) * Y= height; X= dbh; a=1.61; b=1.00; Ymax=69	>5cm	Pasoh Forest Reserve, Negeri Sembilan	2010	Niiyama et al.
3.	Allometric equation is used: $y = ax^b$ *y=biomass; x=dbh (cm) or H (m) or dbh^2 x H (cm^2 m); a and b= coefficients estimated by regression *dbh= diameter at breast height (cm); H= height of tree	>3cm	Niah Forest Reserve, Sarawak	2010	Kenzo et al.
4.	Allometric equation is used: $y = ax^b$ *y=biomass; x=dbh (cm) or H (m) or dbh^2 x H (cm^2 m); a and b= coefficients estimated by regression *dbh= diameter at breast height (cm); H= height of tree	>5cm	Lambir hill National Park, Sarawak	2009	Kenzo et al.
5.	Estimation of aboveground biomass as a function of diameter and wood specific gravity. $Y = \rho \times \exp(-1.499 + 2.148 \ln(D) + 0.207 [\ln(D)]^2 - 0.0281 [\ln(D)]^3\}$, where ρ = wood density (g cm^{-3}); D= diameter	>10cm	Gunung Palung National Park, Sabah	2008	Paoli et al.
6.	Allometric equation for aboveground biomass. ln Y = -2.17 + 1.02 ln(dbh)2 + 0.39 ln(h) *dbh= diameter at breast height (cm); h= height of tree	>3cm	Niah River Watershed, Sarawak	2006	Jepsen et al.

Table 4: Previous study on method for measuring aboveground biomass

NO.	Parameter	Method	Area	Year	Author
1.	Dbh Height of tree Aboveground biomass Carbon stok	Stratified random selection. DBH>10cm is measured and converted to aboveground biomass. AGB= $e^{-2.134=2.53\times\ln(dbh)}$ Using positioning system (GPS) devices	Sabah	2015	Seo et al.
2.	Dbh Height of tree Aboveground biomass Carbon stock	DBH >10cm & DBH>2.5cm & H is measured AGB= $exp\left(-2.172+0.868\ \times\ \ln(DBH^2\times H)+\frac{0.0939}{2}\right)$ AGB = kg dry weight, DBH = diameter at breast height 1.3m above ground level (cm), H = tree height (m)	Mexico	2013	Orihuela Belmontea et al.
3.	Dbh Height of tree Aboveground biomass Carbon stock	DBH and ht is measured, spp is identified&tagged. AGB= $\rho\ \times exp(-1.499+2.148\ln(dbh)+0.207(\ln(dbh))^2-0.0281(\ln(dbh))^3)$ ρ = wood specific gravity, dbh = diameter at breast height (cm), AGB = aboveground biomass (kg dry mass)	Singapore	2013	Ngo et al.
4.	Dbh Height of tree Basal area Aboveground biomass Carbon stock	D ≥1cm & D≥10cm measured by meter tape, counted & labelled. D more than ≥1cm dbh are recorded & convert to basal area to get AGB. Equation AGB for D<5: AGB= $\frac{(exp(4.9375+1.0583\ln(D^2))1.14)}{10^6}$ AGB = aboveground biomass (Mg dry weight), D = diameter at breast height 1.3 m above level	Southern Mexico	1999	Hughes et al.
5.	Dbh Height of tree Aboveground biomass	AGB = 0.3210(dbh)exp(1.3925), DBH = 0.3 to < 5 cm dbh = diameter at breast height (cm), AGB = aboveground biomass (kg dry mass)	Southeastern Puerto Rico	1992	Weaver et al.

2.4 Carbon

Tropical forest in worldwide build the biggest pool of biomass carbon stock which are put up more than half planet's terrestrial biodiversity and a third of its terrestrial global (Richard et al., 2011; Beer et al., 2010). There are five main primary in carbon components of tropical forest that plays their roles in terms to balance the carbon cycle in atmosphere (Table 5). Trees components which are aboveground biomass, belowground biomass, deadwood and litter are stored carbon in forest about 98% and the balance of carbon is stored by the soils (Omar et al., 2015).

Apart from that, tropical forest also determine a country's carbon storage for the reducing emissions from deforestation and degradation (REDD) scheme (Gibbs et al., 2007). The measures of forest conservation, sustainable management of forests, and increase forest carbon stocks are encompasses in enlarge this scheme whereby the new version as REDD +. The result of any modification to forest either in productivity or dynamics may lead to adverse global impact such as increasing in greenhouse gases and increasing temperature in atmospheric (Schnitzer et al., 2014). The tropical forest is an effectively indicator of the system for carbon stock and mitigation of global climate change especially in reduce greenhouse gases from deforestation because about 50% from total biomass of the plant consist carbon (Chapin III et al., 2002; Chave et al., 2001).

In the other hand, a secondary tropical forest is the main role in global carbon cycle due to the speed in increasing of growing nature and atmospheric carbon accumulation. Due to the increased in size of tropical secondary forests, the improvement forest carbon stocks should be considered as a major component in the future negotiations of REDD+ (Edwards et al., 2010) which stock data are not only required but also estimation of carbon accumulation rates (Orihuela-Belmonte et al., 2013).

Pan et al. (2011) state that tropical secondary forest worldwide may sequester between 1.57 and 1.72 Pg of carbon each year. Tree community composition, disturbance history, successional stage, climate, and soil fertility are the factors that influence in differentiation carbon stock among tropical forest (Ngo et al., 2013). Furthermore, the other factors such as age (Shimamoto et al., 2014; Orihuela-Belmonte et al., 2013), life history and biotic interaction also play their role in effect the pattern of growth where they influence the carbon accumulation.

Table 5: The main primary in carbon components tropical forest

Carbon components	Definition
Aboveground biomass	All living thing biomass above the soil including stem, stump, branches, bark, seeds and foliage
Belowground biomass	All biomass of live roots streaming. Fine roots of less than (suggested) 2mm diameter are sometimes excluded because they often cannot be distinguished empirically from soil organic matter or litter.
Deadwood	Dead wood includes wood not contained in the litter either standing, lying on the ground or in the soil, wood lying on the surface, dead roots and stumps larger than or equal to 10 cm in diameter or any other diameter used by the country includes dead roots to usually 2mm diameter.
Litter	Non-living biomass with a diameter less than a minimum diameter chosen by the country (for example 10 cm), lying dead, in various states of decomposition above the mineral or organic soil. This includes litter, fumic, and humic layers. Live fine roots also (of less than the suggested diameter limit for below-ground biomass) are included in litter where they cannot be distinguished from it empirically.
Soils	Organic matter in mineral and organic soils including peat to a specified depth chosen by the country and applied consistently through the time series. Live fine roots of less than the suggested diameter limit for below-ground biomass are included with soil organic matter where they cannot be distinguished from it empirically.

Source by http://www.fao.org/

2.5 Growth

Understanding tree growth as a function of the size of the tree is important for ecology and management of various applications. Tree growth is an increasing all the part of the tree through times (Weiskittel et al., 2011). Trees growth has a characteristic which is the outcome between the reaction of genes and environment somehow this outcome is not being same for each individual of trees. It is because genes is main role in control the trees growth mechanism whereby they plays their role in term of respond the mechanism in environment and make to use for tree growth. The dimension of height and diameter is often used in measuring because they have strongly related to wood volume and biomass which is easy to measures (Bowman et al., 2013).

Determining factor that limit the growth is important, and forest inventory plots remains is the main source of many long term but very complex growth information (Eitzel et al., 2013). Besides, tree growth rates partly to estimate the mortality growth (Das et al., 2007) and then the stock of energy, water, and nutrients that has been measured in isolation process or in soil type has tough in limitation of the tree growth in tropical forest (He et al., 2000). The basic of regrowth strategy, maximum size and the association species with specific edaphic and climate condition are defined to the resources of limitation of tree growth at different temporal and spatial scales, and the different growth rates and the reaction of functional groups (Baker et al., 2003).

Tree growth affected by several abiotic factors, including the climate (Brown et al., 1989), soil characteristics (DeWalt et al., 2004; Laurance et al., 1999), and topography (Alves et al., 2010; Laumonier et al., 2010). The pattern of tree growth is strongly affected also by the tree age, life history, and biotic interactions such as predation (van Breugel et al., 2012). Then, the differences in biomass accumulation, the final of estimation that limits of species distribution and the guarding of carbon balance in ecosystem may cause by the different growth patterns among the different ecological groups (Baker et al., 2003). The carbon absorbed by forest is determined by the diameter of the tree. The trees that have diameter greater than 10 cm at breast height has the largest carbon content (approximately 95 %) of biomass in tropical forests (Chave et al., 2006).

2.6 Tree species

Shorea platyclados as shown in figure below (Figure 1) is from Dipterocarpaceae family and belong to genus *Shorea*. It consist of 500 species around the tropical forest area (Ashton, 1982). According to Symington, (2004) this species can be found in hilly area at Sumatra, Peninsular Malaysia and Borneo and also in a highland with elevation 700 m (Javed et al., 2014). According to International Union for Conservation of Nature (IUCN) red list, this species which some of subpopulation are found in primary forest reserve whereby they get the protection and conservation. This is because *Shorea platyclados* is endangered species.

Figure 1: *Shorea platycados* planted

Agathis borneensis as shown in figure below (Figure 2) is Araucariaceae family. This species is cover lowland to highland area up to 1200 m above sea level of tropical rainforests in Australia and Southeast Asia such as Malaysia (Wilf et al., 2014). This species is existed in some protected areas in Malaysia that only cover a small area of global population (Farjon, 2013). This is because *Agathis borneensis* is the endangered species in the world. The disturbance of *Agathis borneensis* give clearly appearing in harmful effect on carbon balance, biodiversity, and ecosystem structure and function (Wilf et al., 2014).

Figure 2: *Agathis borneensis* planted

Gymnostoma sumatranum as shown in figure below (Figure 3) belong to Casuarinaceae family. This species can be found at the elevation to higher of 200 m to 1400 m above sea level (Antony et al., 2015). Casuarinaceae family is a successful species (Dommergues et al., 1990) because of their nitrogen-fixing nodules (Antony et al., 2013) that found in ultramafic soil. In addition, the concentration of foliar potassium in *Gymnostoma sumatranum* is quiet high, despite the soil has low in potassium supply (Antony et al., 2013) where it help for other plant around them in order to get more nutrient for their growth.

Figure 3: *Gymnostama sumatranum* planted

CHAPTER 3

METHODOLOGY

3.1 Study Area

The study area covers a disturb area in Gunung Siku Forest Reserve, Cameron Highland in Compartment 5 which cover about 2.5 hectare (ha). The elevation of Gunung Siku is 1916 metres above sea level with 4°35'49.92" latitude,_101°23'48.47" longitude (Figure 4). The temperature in Cameron Highland has ranged from a minimum of 14º C to a maximum of 28º C with dry season from February to April where temperature rise and cold season is from December to February where temperature may drop to 10 ºC (Figure 5) in particular area. Cameron Highland has a steep slope 66% of the area are more than 20º degree (Ismail et al., 2003) in which the characteristic of Cameron Highland topography is rugged ground (Razak et al., 2011). There are two types of soils in the Cameron Highlands that derived by parent materials which are acid intrusive that cover most of the area and a small part from schist, phyllite, slate and limestone (Abdullah et al., 2001). According to staff of Pahang Forestry Department, the original plants in Cameron Highland were *Cinnamomum porrectum, Symingtonia populnea*, *Garcinia cowa* and *Eugenia grata*. This area was deforested due for land cultivation activity that increases rapidly in Cameron Highland. Vegetables, fruits and flower plantation were agriculture development that established in Gunung Siku Forest Reserve, Cameron Highland.

Map of Gunung Siku Forest Reserve, Cameron Highland

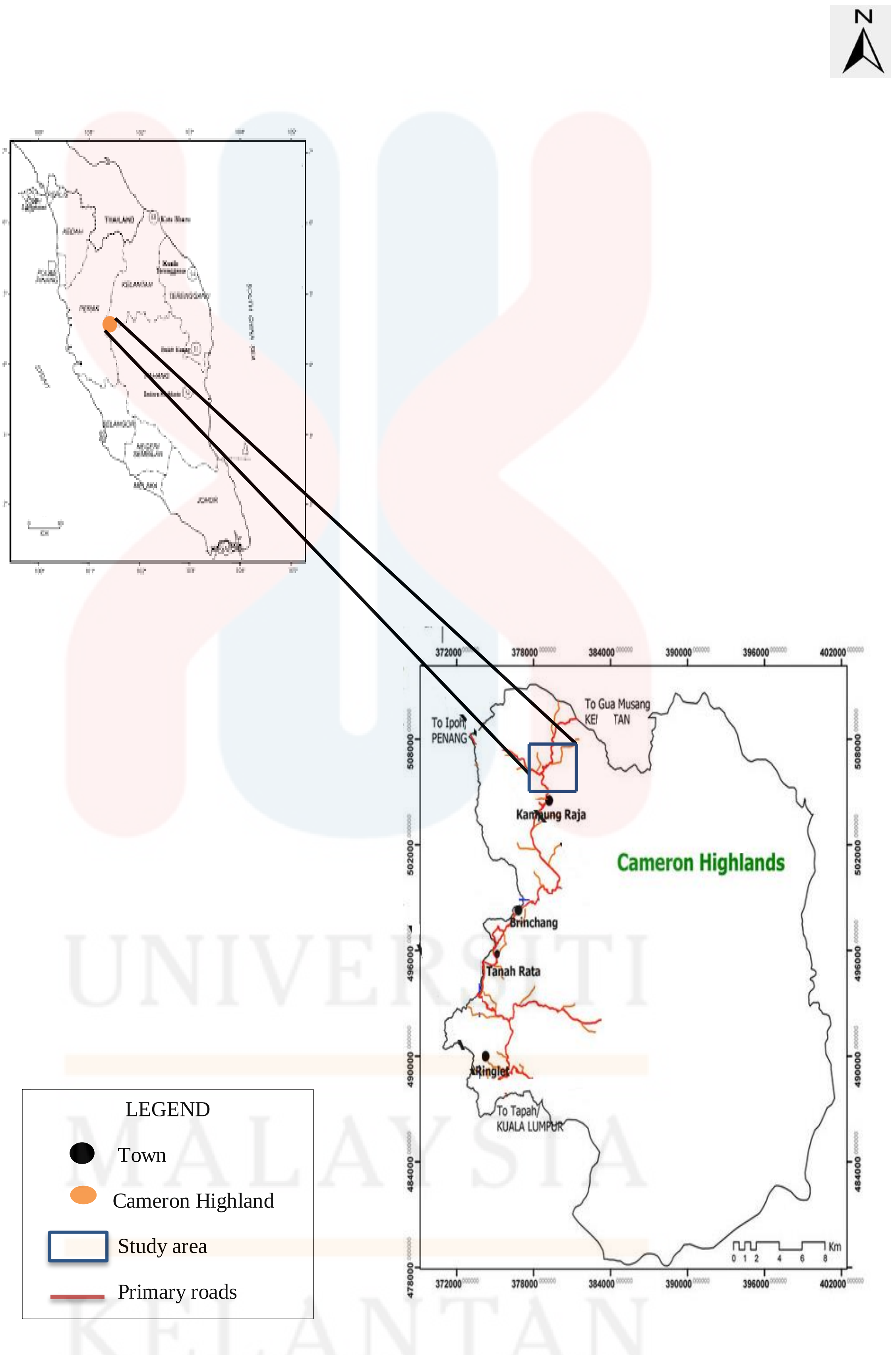

Figure 4: Location of Gunung Siku Forest Reserve, Cameron Highland

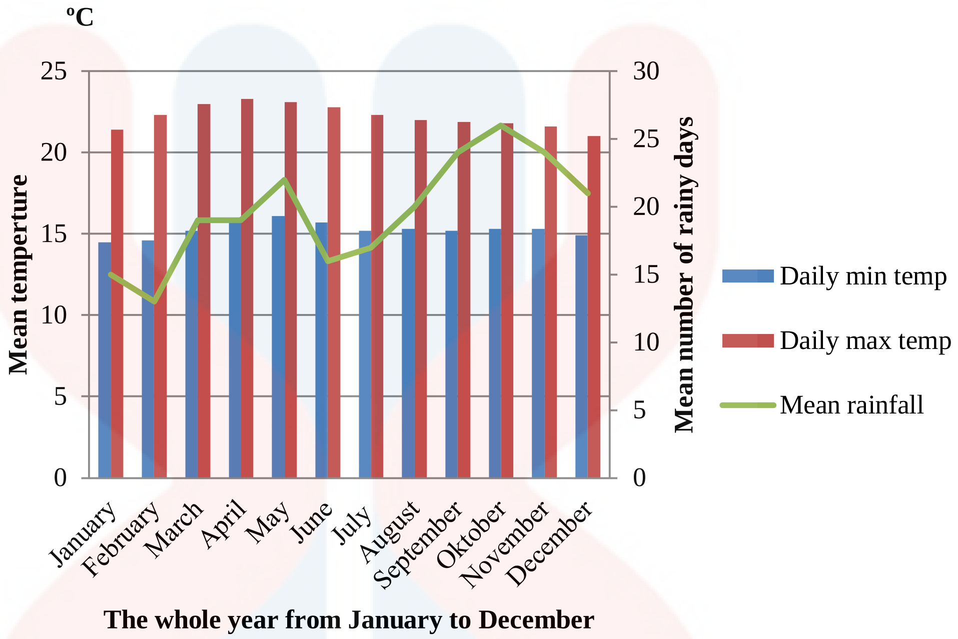

Figure 5: Mean temperature ºC and rainfall against a year

Source by http://cameronhighlands.com/weather/

The deforestation occurred in Compartment 5 Gunung Siku Forest Reserve, Cameron Highland in the end of year 2013 whereby illegal crop cultivation activities was the essential caused. The government lead by Forestry Department Peninsular Malaysia with the enforcement from Pahang Forestry Department has taken this illegal land clearly matter seriously. They took tough action to shut down any illegal from operators that related to the department justification. The main plantation was cabbage (Figure 6) due to those illegal crop cultivation activities. Government and NGO agencies such as Forest Research Institute Malaysia (FRIM), Ministry of Natural Resources and Environment (NRE), Forestry Department Peninsular Malaysia (FDPM), Malaysian Nature Society (MNS), Pertubuhan Pelindung Khazanah Alam Malaysia (PEKA), Regional Environmental Awarenes Cameron Highland

(REACH) and Pahang Forestry Department had come to gathered in 'Greening of Cameron Highland' programme in support of the reforestation effort especially in Gunung Siku Forest Reserve, Cameron Highland (Start et al., 2015).

The reforestation activity at Gunung Siku Forest Reserve, Cameron Highland area was conducted on February-March 2015 and involved many agencies (Figure 7). The area comprised as secondary forest types were planted with 2500 saplings of five selected species which named were *Nageia wallichiana*, *Tabebuia pentaphylla*, *Shorea platyclados*, *Agathis borneensis* and *Gymnostoma sumatranum* (Start et al., 2015) with 3x3 m planting distance .

Figure 6: Illegal crop cultivation in Gunung Siku Forest Reserve, Cameron Highland at the end year 2013

Source by Centralised Enforcement Team report

Figure 7: The signboard of reforestation project in of Gunung Siku Forest Reserve, Cameron Highland

3.2 Data collection

Vernier calliper and diameter tape were used to measured diameter and height (ht). Full data sampling of three selected species had been measured the growth performance rates which were *Shorea platyclados*, *Agathis borneensis* and *Gymnostoma sumatranum* (Figure 8). Systematic line sampling was used in order to measure the growth of the sapling for each species (Figure 9). Then, parameter taken was diameter using vernier calliper and the height using meter tape and clinometer (Figure 10). The data collected twice with six month interval (Table 6) (Mohd Yunus, 2012). From data that collected twice, the saplings can be observed either survive or not in this area and the differences of performance can be measured within six months interval.

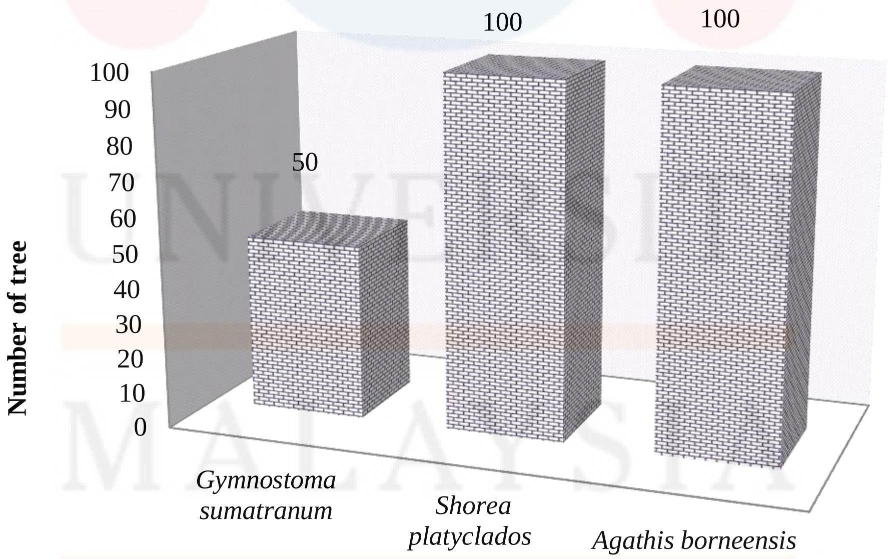

Figure 8: Number of tree

Figure 9: Reforestation site at Compartment 5 Gunung Siku Forest Reserve, Cameron Highland

Sourced by http://reach.org.my/2014/?p=760

Figure 10: Height measurement

Table 6: Tree parameter

			Number		Tree		Rate	
Family	Species	Common name	Plot	Tree	Diameter (cm)	Height (m)	Growth (%)	Mortality (%)

Data collection was done in February and August 2016 which can be seen that saplings increasing in growth performance within six month interval. Each selected saplings were marked for the second data collecting to ensure accuracy (Figure 11).

Figure 11: Second Data collected in August 2016

3.3 Calculation

Aryal et al. (2014) stated that to calculate aboveground biomass of each tree with diameter less than 6 cm, allometric equations that published by Hughes et al. (1999) can be used. It was because this area are planted saplings with having diameter less than 6 cm.

AGB is stand for aboveground biomass of the tree (Mg) and D is stand for the diameter at breast height, (cm). The equation of aboveground biomass as a following:

$$\text{AGB (kg)} = \frac{(exp(4.9375+1.0583\ \ln(D^2))1.14)}{10^6} \quad \text{(Eq. 1)}$$

Individuals in small diameter class with diameter less than 10 cm consist most of the tree population and also have rapid growth rate performance than large diameter class trees. The sapling planted in Gunung Siku Forest Reserve, Cameron Highland has small diameter in which has a probability in rapid growth although these species that is non- native to this area. Allometric equations for small diameter class biomass estimation are limited source though (Chaturvedi et al., 2013).

Another equation for aboveground where can used to get accurate data for small tree less than 10 cm which developed by Weaver et al. (1992) :

$$\text{AGB (kg)} = 0.3210(dbh)\exp(1.3925) \qquad \text{(Eq.2)}$$

AGB is stand for aboveground biomass of the tree (Kg) and dbh is stand for the diameter at breast height (cm).

Brown (1992) state that estimation of carbon pools in forest by knowing the biomass in that forest because 50% of the biomass is carbon. 50% of the biomass carbon and AGB will be used in equation. Results will be considered significant at 5% probability level. To estimation the carbon stock, the calculation will assume as the equation below:

$$\text{Carbon stock (kgC)} = \frac{50}{100} \times AGB \qquad \text{(Eq.3)}$$

CHAPTER 4

RESULT AND DISCUSSION

4.1 Variation among different species

The total values of monthly rate growth performance of *Shorea platyclados*, *Agathis borneensis* and *Gymnostoma sumatranum* was calculated as shown in Table 7. The monthly rate of growth performance was calculated to estimate the increasing of performance growth within a month for *Shorea platyclados, Agathis borneensis* and *Gymnostoma sumatranum*.

Table 7: Monthly rate of growth performance of each species on February and August 2016

Species	**Diameter average (cm)**		**Height average (m)**	
	February	**August**	**February**	**August**
Gymnostoma sumatranum	0.27	0.57	0.26	0.59
Shorea platyclados	0.15	0.27	0.17	0.25
Agathis borneensis	0.14	0.18	0.13	0.19
Growth performance (cm/month) (m/month)	0.56	1.03	0.55	1.03

The monthly rates of growth performance for diameter per month for three species were 0.56 cm/month on February 2016 and 1.03 cm/month on August 2016. Then, monthly rates of growth performance for height per month for three species were 0.55 m/month on February and 1.03 m/month on August 2016.

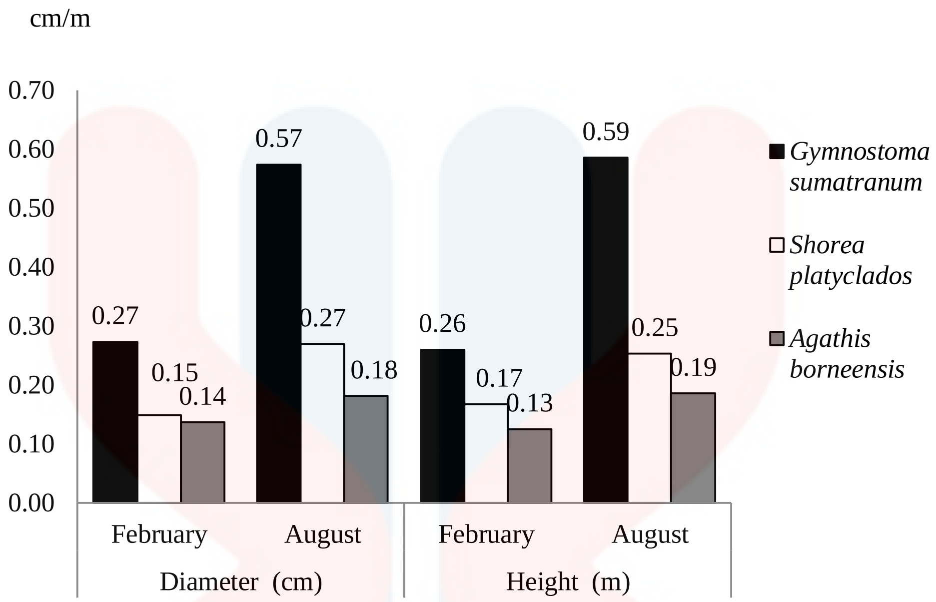

Figure 12: The growth performance of *Shorea platyclados*, *Agathis borneensis* and *Gymnostoma sumatranum* in February and August 2016

Based on Figure 12, diameter and height of *Gymnostoma sumatranum* was the fastest in growth performance which were 0.27 cm/month and 0.26 m/month on February 2016 and 0.57 cm/month and 0.59 m/month on August 2016 compared the other two species, within six months interval the data collection showed that an approximately two times amount faster. This was because *Gymnostoma sumatranum* was nitrogen fixation plant (Antony et al., 2013) that can live even though the forest lack of nitrogen cycle. The bigger saplings were held by *Gymnostoma sumatranum* in which the largest diameter of this species was 3.3 cm on February 2016 and 5.5 cm on August 2016.

Gymnostoma sumatranum had excellent in their growth performance with range from 0.2 cm to 4.3 cm of their diameter for each sapling. It was because this species are able to growth even the characteristic of soil was changing due to crop cultivation occurred in this area whereby leaded to infertile soil condition. Ultramafic soil was composed by mafic mineral that high in nickel, chromium, cobalt, magnesium and iron (Proctor et al., 2009) where most of ultramafic soil lower in nitrogen concentration.

Shorea platyclados and *Agathis borneensis* had shown a slower rate in growth performance in which differences of their growth was hard to find out (Figure 12). The monthly rate of growth performance for diameter and height of *Shorea platyclados* were 0.15 cm/month and 0.17 m/month on February 2016 and 0.27 cm/month and 0.25 m/month on August 2016. Then, *Agathis borneensis* had very slower in monthly rate of growth performance for diameter and height compared the other two species which were 0.14 cm/month and 0.13 m/month on February 2016 and 0.18 cm/month and 0.19 m/month on August 2016. This was because these two species did not survived with infertile soil condition and 100% of direct sunlight toward the land.

These two species showed an increment in range from 0.2 to 2.06 cm for diameter. The growth of diameter and height of Dipterocarpaceae family was depend on soil condition and direct sunlight toward the land (Hattori et al., 2013).These two species had smaller saplings than *Gymnostoma sumatranum* with the largest diameter on February 2016 which was only 1.7 cm for *Shorea platyclados* and 1.2 cm for *Agathis borneensis*. Then, the largest diameter of these two species on August 2016 which was only increased to 2.8 cm and 1.8 cm compared to *Gymnostoma sumatranum*.

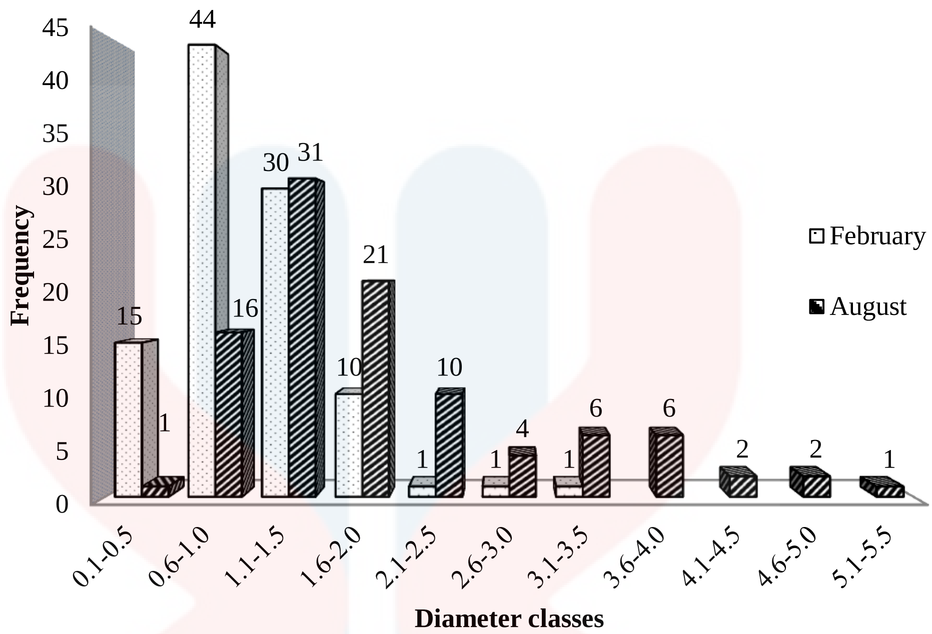

Figure 13: Frequency of *Shorea platyclados*, *Agathis borneensis* and *Gymnostoma sumatranum* with diameter classes in February and August 2016

The three selected species showed the different frequency of diameter of sapling. *Gymnostoma sumatranum* showed the most changes in growth performance which was 0.44% increase in diameter compared to *Shorea platyclados* and *Agathis borneensis* were 0.35% and 0.08% respectively. On February 2016 showed that the maximum diameter class of three species was in between 0.6 to 1.0 cm with 44 of saplings compared to the other diameter classes (Figure 13). However, the differences of growth performance can be seen in second data collection on August 2016 which within six months interval. The maximum diameter class of three species was in between 1.1 to 1.5 cm with 31 of saplings (Figure 13). Besides, the diameter classes become bigger from 0.1 to 3.3 cm on February 2016 to 0.1 to 5.5 cm on August 2016. This shown these species had increased growth performance in this area within six months interval.

4.2 Mortality rates

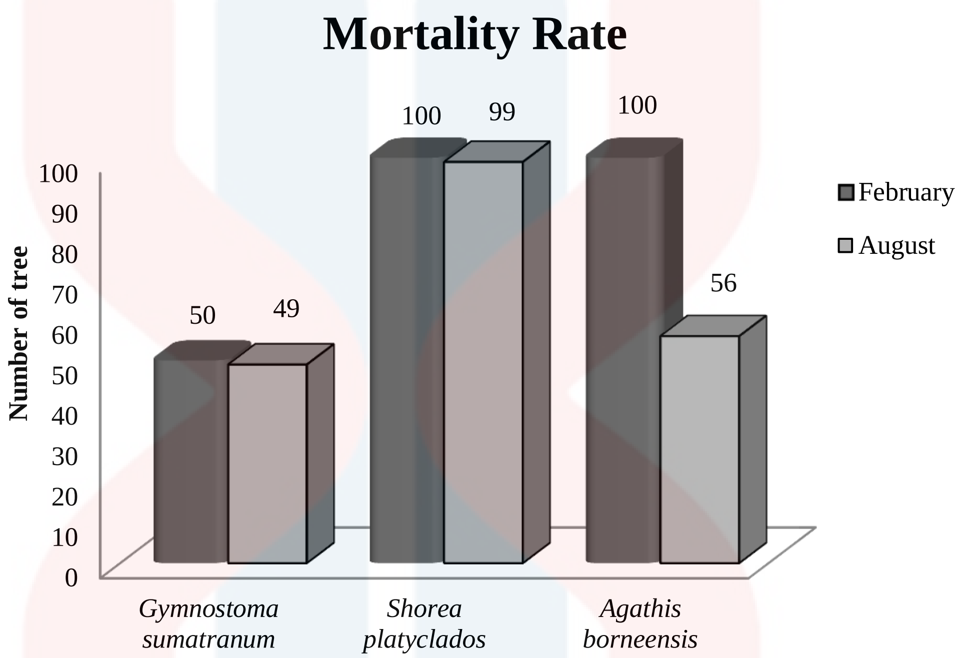

Figure 14: Mortality of *Shorea platyclados*, *Agathis borneensis* and *Gymnostoma sumatranum* on February and August 2016

Mortality rate show that 81% were survived well the given condition with *Shorea platyclados* 99%, *Agathis borneesis* 56% and *Gymnostoma sumatranum* 98% of survival. On August 2016, 44% saplings of *Agathis borneensis* did not survived compared two others species, *Shorea platyclados* and *Gymnostoma sumatranum* (Figure 14). This species did not survived because of abiotic factor where can see that competition among species and within species compete to get enough sunlight, water, nutrient and mineral in soil.

Other than that, an insufficient space was also one of the factors that occur to this species because this species need to compete with weeds to get space for their growth. Both of the other two species, *Shorea platyclados* and *Gymnostoma sumatranum* are held 99 and 49 of saplings that survived and growth well.

Only 2% of *Gymnostoma sumatranum* did survived on August 2016 within six months interval. Most of saplings of this species which were 49 from 50 saplings survived and growth well. *Gymnosoma sumatranum* also as the shrub *Scaevola micrantha* (Goodeniaceae) (Antony et al., 2013) in which this species was suitable in this area in terms able to help other species in their growth performance.

Shorea platyclados also showed changes within six months interval where 1% of this species did not survived (Figure 14) while others 99 from 100 saplings survived within six months interval. The planting of sapling dipterocarpaceae regeneration in degraded land had been encouraged (Adjers et al., 1995) due to the rehabilitation of degraded land by deforestation.

Only *Agathis borneensis* did not survived in this area compared the other two species, *Shorea platyclados* and *Gymnostoma sumatranum*. This was because the mortality rate of this species was related with factors that hindering their growth performance whereby infertile soil condition and direct sunlight toward land were the one of it factors. This species was also not suitable for soil condition that changing due to land and crop cultivation. Other two species of sapling are survived with acceptable mortality.

This area undergoes deforestation due to an increase of land and crop cultivation. Farm operators extensively expand their crop cultivation areas without knowing adverse impact to ecosystem. This attitude leads to the deforestation of forest in larger scale that leads to loss of biodiversity and the changing of natural cycle such as carbon and nitrogen cycle. Besides, the deforestation also made the soil condition become worst for tree.

4.3 Estimation of aboveground biomass and carbon stock

Two allometric equations were chosen to calculate AGB which were equation from Hughes, (1999) and Weaver, (1992). These two allometric equations were used to estimate AGB for three selected species in term to compare the varieties of the available allometric equations. These way were provide a variety that noticeable in biomass estimation (Morel et al., 2011).

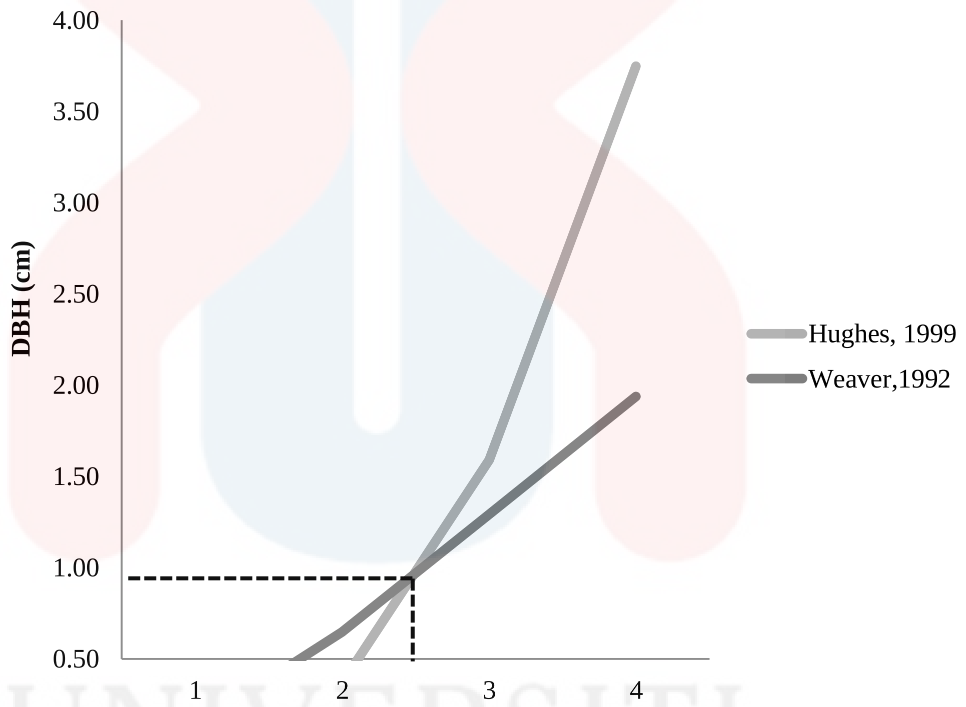

Figure 15: Hughes (1999) against Weaver (1992) for *Shorea platyclados*, *Agathis borneensis* and *Gymnostoma sumatranum* in February 2016 and August 2016

Equation of Weaver, (1992) appears to have the higher estimates for *Shorea platyclados*, *Agathis borneensis* and *Gymnostoma sumatranum* while equations of Hughes, (1999) are lower estimates which cannot be used in other certain diameter. Hughes, (1999) only can be used for diameter less than 1 cm in two data collection, February and August 2016 (Figure 15). Hughes, (1999) equation produced larger value of AGB that was not accurate for estimation biomass for saplings in this area because diameter of sapling was less than 6 cm.

The biomass estimation for each three species has shown that Weaver, (1992) equation was the significant estimated that can used for twice data collected within six months interval. Weaver, (1992) equation can be used for diameter less than 6 cm for both data collection within six months interval and it was more accurate to estimation biomass of sapling. This was because Weaver, (1992) produced small value that suitable for sapling in this area.

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4.4 Aboveground biomass and carbon stock

The total values of AGB and carbon stock of each three species were calculated as shown in Table 8. The total amount of both AGB and carbon stock were calculated for both data that taken to estimate the performance within six months.

Table 8: Aboveground biomass and carbon stock of *Gymnostoma sumatranum*, *Shorea platyclados* and *Agathis borneensis* for February and August 2016

Species	**Freq**	**Area (ha)**	**AGB (kg)**		**Increament (kg)**	**Carbon stock (kgC)**		**Increament (kgC)**
			Feb	**Aug**		**Feb**	**Aug**	
G. sumatranum	50	0.05	50.90	105.43	54.53	25.45	52.71	27.26
S. platyclados	100	0.09	58.01	102.36	44.35	29.01	51.18	22.17
A. borneensis	100	0.09	29.72	39.36	9.64	14.86	19.68	4.82
Total	250	0.23	138.63	247.15	108.52	69.32	123.57	54.25
Total AGB and Carbon stock at area planted per hectare (kg/ha)(kgC/ha)			602.74	1074.56	471.81	301.37	537.26	235.88

The total amount for AGB per hectare were 602.74 kg/ha on February 2016 and 1074.56 kg/ha on August 2016. Then, the total amount for carbon stock per hectare on February and August 2016 were 301.37 kgC/ ha and 537.26 kgC/ha respectively. The monthly increment for both AGB and carbon stock are 471.81 kg/ha and 235.88 kgC/ha within six month interval.

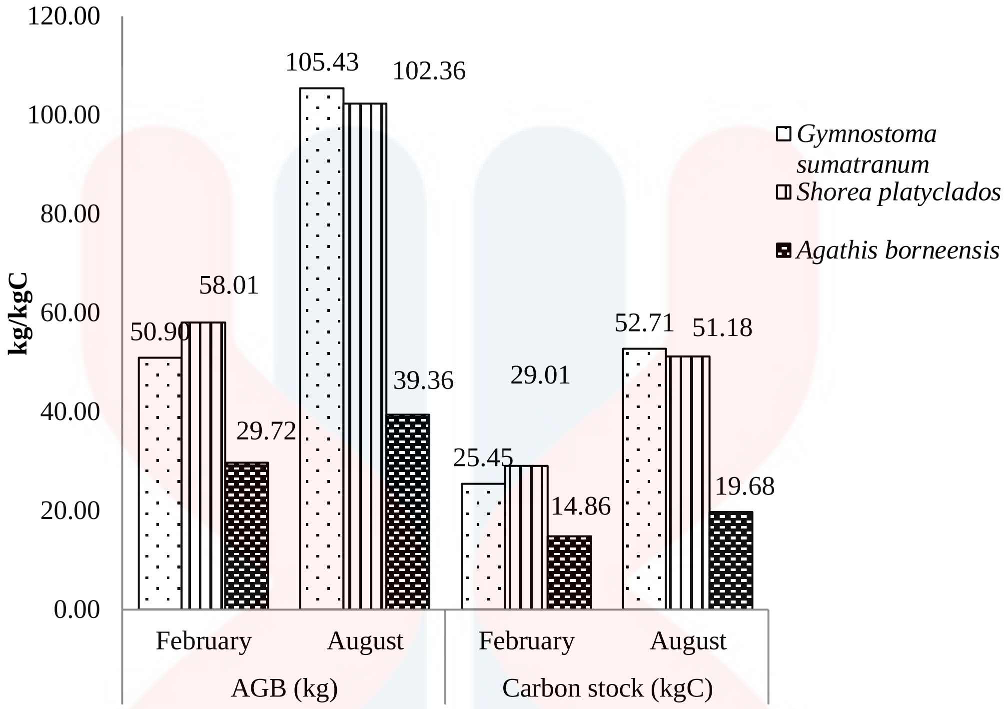

Figure 16: Aboveground biomass and carbon stock each species on February 2016 and August 2016

The area of this three species was 0.23 ha whereby the AGB and carbon stock calculation was based on this area. The AGB of *Shorea platyclados* was higher compared the other two species, *Gymnostoma sumatranum* and *Agathis borneensis* on February 2016 (Figure 16). The value AGB of *Shorea platyclados* was 58.01 kg/ha. This was because this species domination the area compared the other two species. This species held a big number of individual trees which was 100 of saplings compared the other two species, *Gymnostoma sumatranum* and *Agathis borneensis*. Therefore, the amount AGB of this species was contributing in this area for functioning in carbon cycle.

The AGB of *Gymnostoma sumatranum* was higher compared the other two species, *Shorea platyclados* and *Agathis borneensis* on August 2016 (Figure 16). The value AGB of *Gymnostoma sumatranum* was 105.43 kg/ha. The saplings showed a variety of larger diameter in which this species ranged from 0.9 to 3.3 cm on February and 2.1 to 5.5 cm on August 2016.

Biomass was connection with the age of tree and the ecological group, the biomass accumulation in a restoration project the can be different with a vary ratios either in a fast or slow of growth species and over time (Shimamoto et al., 2014). The larger of diameter of this species lead to the AGB value increase and contribute to this area.

Agathis borneensis species had a lowest AGB value, 29.72 kg/ha and 39.36 kg/ha for both February and August 2016 (Figure 16). On February 2016, only 56 of saplings are counted and the number of individual was same on August 2016. This was because most of *Agathis borneensis* species cannot be survive in this area for the early stage where had planted.

This factors lead to reducing number of individual tree occurred. Besides, the value diameter of this species is also smallest compared the other two species. The growth performance of this species was failing in which were between 0.1 to 0.4 cm.

The variation of carbon stock on February 2016 was 29.00 kgC/ha that held by *Shorea platyclados* (Figure 16). This species only increased 22.79 kgC/ha within six months interval compared to *Gymnostoma sumatranum*. The variation in carbon stock was higher in *Gymnostoma sumatranum* which was 52.71 kgC/ha on August 2016 (Figure 16). The carbon stock of this species increase within six months interval was 27.26 kgC/ha. The highest variation produced by these species in secondary forest indicating that this species may have help to obtain carbon stock in order to stabilization of carbon cycle.

Agathis borneensis had the lowest carbon stock on February and August 2016 with 14.86 kgC/ha and 19.68 kgC/ha whereby only increased 4.82 kgC/ha (Figure 16). This was because this species did not survived at this area. The biomass was calculated 50% of carbon from the biomass value of forest which provides estimated of the carbon pools in forest (Brown, 1992). Proven about 50% of AGB for each three species is the value of carbon stock of tree species in this area (Figure 16).

CHAPTER 5

CONCLUSION AND RECOMMENDATION

Through the measurement of *Shorea platyclados*, *Agathis borneensis* and *Gymnostoma sumatranum* in Gunung Siku Forest Reserve, Cameron Highland with six month interval showed that the growth performance of these three species. *Gymnostoma sumatranum* showed the most changes in growth performance which was 0.44% increase in diameter compared to *Shorea platyclados* and *Agathis borneensis* were 0.35% and 0.08% respectively. *Gymnostoma sumatranum* showed excellent in performance growth compare to the other two species. This species had largest diameter for both data collected which 3.3 cm on February and 5.5 cm on August 2016.

Although these three species was non-native to the area but mortality rate show that 81% are survived well the given condition with *Shorea platyclados* 99%, *Agathis borneesis* 56% and *Gymnostoma sumatranum* 98% of survival. The overall value of AGB and carbon stock per hectare of three species were 602.74 kg/ha and 301.37 kgC/ ha on February 2016 while 1074.56 kg/ha and 537.26 kgC/ha on August 2016 respectively.

The result showed that *Shorea platyclados* had highest AGB and carbon stock value on February 2016 which was 58.01 kg/ha and 29.01 kgC/ha while *Gymnostoma sumatranum* had highest AGB and carbon stock value on August 2016 which was 105.43/ha and 52.71 kgC/ha. Therefore, the

AGB and carbon stock in this study increasingly within six months interval for each species, obviously by *Gymnostoma sumatranum*.

Different type of method to develop a better method for measuring aboveground biomass and carbon stock needed in study to be conducted in deforested area. The plot should be including in order to measuring above ground biomass and carbon stocks in future study. Planting a native indigenous species can possibly increase the growth performance and also AGB and carbon stock subsequently. This research study can be a reference for future researches in term to produce a better method.

RESEARCH FLOW CHART

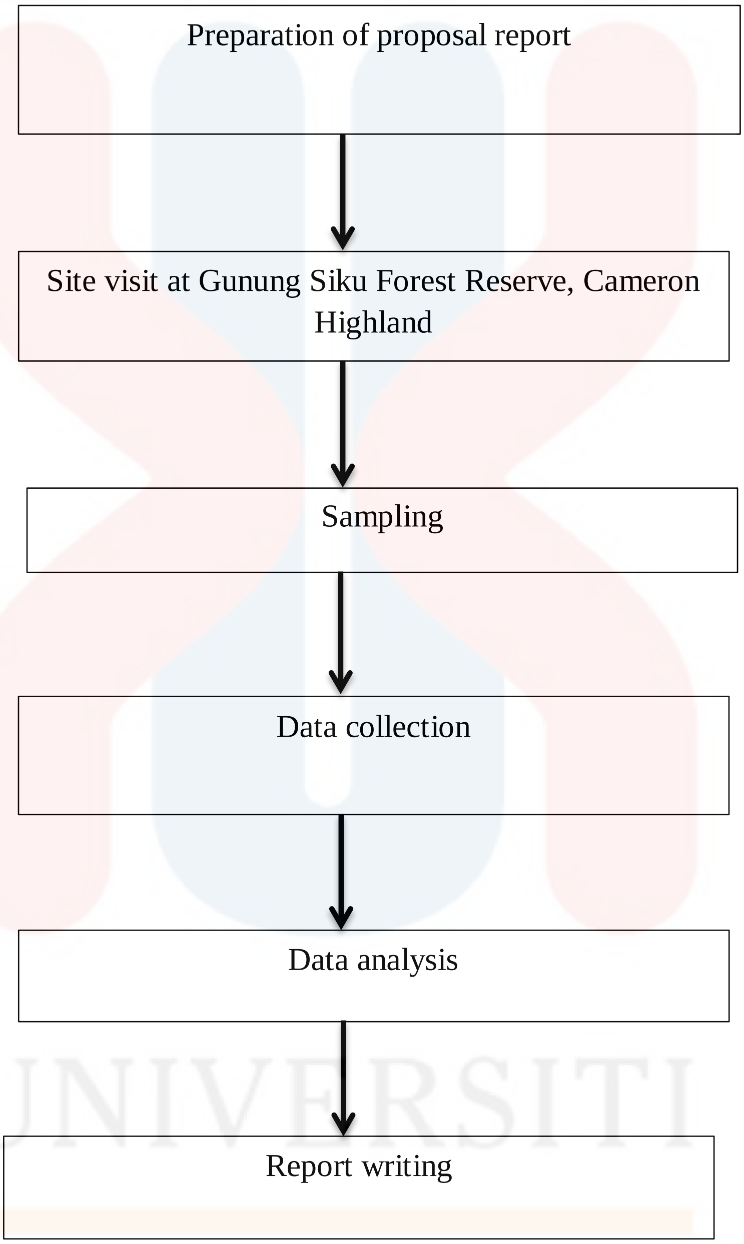

Figure 6: Flow chart for methodology in research

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APPENDICES

APPENDIX A

Table A: Data collection on February 2016 and August 2016 at Gunung Siku Forest Reserve, Cameron Highland

Species: *Gymnostoma sumatranum*

Local Name: Rhu Bukit

Family: Casuarinaceae

	Diameter (cm)			**Height (m)**			**AGB (kg)**		**Carbon stock (kgC)**	
No	**Feb**	**Aug**	**diff**	**Feb**	**Aug**	**diff**	**Feb**	**Aug**	**Feb**	**Aug**
1	1.1	2.1	1	1.36	2.3	0.94	1.42	2.71	0.71	1.35
2	1.5	3.1	1.6	1.3	3.9	2.6	1.94	4.00	0.97	2.00
3	2	3.1	1.1	2.16	3.8	1.64	2.58	4.00	1.29	2.00
4	3.3	3.5	0.2	2.02	2.8	0.78	4.26	4.52	2.13	2.26
5	1.1	3.5	2.4	1.3	4.3	3	1.42	4.52	0.71	2.26
6	1.1	3.7	2.6	0.9	3.8	2.9	1.42	4.77	0.71	2.39
7	0.9	2.5	1.6	1	2.95	1.95	1.16	3.23	0.58	1.61
8	1.2	5.5	4.3	1.54	4.2	2.66	1.55	7.10	0.78	3.55
9	1.7	2.5	0.8	1.86	2.15	0.29	2.20	3.23	1.10	1.61
10	1.5	4.9	3.4	1.67	4.3	2.63	1.94	6.32	0.97	3.16
11	1.7	4.7	3	1.73	4.9	3.17	2.20	6.06	1.10	3.03
12	2	2.9	0.9	1.58	2.7	1.12	2.58	3.74	1.29	1.87
13	1	2.9	1.9	1.41	3.5	2.09	1.29	3.74	0.65	1.87
14	2.7	3.2	0.5	1.8	3.7	1.9	3.49	4.13	1.74	2.06
15	2.2	3.4	1.2	2.2	3.5	1.3	2.84	4.39	1.42	2.19
16	2	3.9	1.9	2.22	3.9	1.68	2.58	5.03	1.29	2.52
17	1.2	3.7	2.5	1.07	3.6	2.53	1.55	4.77	0.78	2.39
18	1.7	null	null	1.17	null	null	2.20	null	1.10	null
19	1.2	3.8	2.6	1.39	3.1	1.71	1.55	4.90	0.78	2.45
20	1.4	4.5	3.1	1.46	5.16	3.7	1.81	5.81	0.90	2.90
21	1.3	2.8	1.5	1.22	1.8	0.58	1.68	3.61	0.84	1.81
22	2	4.1	2.1	1.38	3.4	2.02	2.58	5.29	1.29	2.65
23	1.8	3.7	1.9	1.93	3.9	1.97	2.33	4.77	1.16	2.39
24	1.8	3.7	1.9	1.83	4	2.17	2.33	4.77	1.16	2.39

APPENDIX B

Table B: Data collection on February 2016 and August 2016 at Gunung Siku Forest Reserve, Cameron Highland

Species: *Shorea platyclados*

Local Name: Meranti Bukit

Family: Dipterocarpaceae

	Diameter (cm)			Height (m)			AGB (kg)		Carbon stock (kgC)	
No	**Feb**	**Aug**	**diff**	**Feb**	**Aug**	**diff**	**Feb**	**Aug**	**Feb**	**Aug**
1	1.3	1.70	0.40	1.43	1.46	0.03	1.68	2.19	0.84	1.10
2	1	1.42	0.42	1.17	1.3	0.13	1.29	1.83	0.65	0.92
3	1	null	null	1.2	null	null	1.29	null	0.65	null
4	0.8	1.60	0.80	1.05	1.5	0.45	1.03	2.06	0.52	1.03
5	0.8	1.50	0.70	1.1	1.5	0.4	1.03	1.94	0.52	0.97
6	0.5	1.30	0.80	0.84	1.25	0.41	0.65	1.68	0.32	0.84
7	1.3	1.40	0.10	1.42	1.65	0.23	1.68	1.81	0.84	0.90
8	0.5	1.40	0.90	0.38	1.2	0.82	0.65	1.81	0.32	0.90
9	0.9	1.30	0.40	0.91	1.6	0.69	1.16	1.68	0.58	0.84
10	0.7	1.30	0.60	1.06	1.5	0.44	0.90	1.68	0.45	0.84
11	0.4	1.20	0.80	0.48	1.5	1.02	0.52	1.55	0.26	0.77
12	0.9	1.60	0.70	1.05	2.4	1.35	1.16	2.06	0.58	1.03
13	0.9	1.50	0.60	1.14	1.8	0.66	1.16	1.94	0.58	0.97
14	0.9	1.60	0.70	1.31	1.5	0.19	1.16	2.06	0.58	1.03
15	1	1.70	0.70	1.3	2.3	1	1.29	2.19	0.65	1.10
16	1.3	1.80	0.50	1.61	1.7	0.09	1.68	2.32	0.84	1.16
17	1.2	1.60	0.40	1.2	1.8	0.6	1.55	2.06	0.78	1.03
18	1	1.80	0.80	0.99	1.4	0.41	1.29	2.32	0.65	1.16
19	0.8	1.40	0.60	0.92	1.3	0.38	1.03	1.81	0.52	0.90
20	1.1	1.40	0.30	1.11	1.45	0.34	1.42	1.81	0.71	0.90
21	0.4	1.70	1.30	1.07	1.4	0.33	0.52	2.19	0.26	1.10
22	0.6	1.90	1.30	1.08	1.2	0.12	0.78	2.45	0.39	1.23
23	0.4	1.80	1.40	0.63	1.65	1.02	0.52	2.32	0.26	1.16
24	0.9	2.10	1.20	1.21	2.1	0.89	1.16	2.71	0.58	1.35
25	0.6	2.10	1.50	0.6	1.45	0.85	0.78	2.71	0.39	1.35
26	0.7	2.20	1.50	0.88	1.35	0.47	0.90	2.84	0.45	1.42
27	0.3	2.10	1.80	0.45	1.75	1.3	0.39	2.71	0.19	1.35
28	0.9	1.50	0.60	0.88	1.3	0.42	1.16	1.94	0.58	0.97
29	0.9	1.00	0.10	1.38	1.5	0.12	1.16	1.29	0.58	0.65
30	1.2	1.60	0.40	1.39	1.45	0.06	1.55	2.06	0.78	1.03
31	1	1.50	0.50	1.21	1.3	0.09	1.29	1.94	0.65	0.97

	Diameter (cm)			Height (m)			AGB (kg)		Carbon stock (kgC)	
No	Feb	Aug	diff	Feb	Aug	diff	Feb	Aug	Feb	Aug
32	1.3	1.80	0.50	1.25	1.3	0.05	1.68	2.32	0.84	1.16
33	1.2	1.30	0.10	1.4	1.5	0.1	1.55	1.68	0.78	0.84
34	1	1.10	0.10	1.19	1.29	0.1	1.29	1.42	0.65	0.71
35	0.9	1.30	0.40	1.21	1.3	0.09	1.16	1.68	0.58	0.84
36	0.7	0.90	0.20	0.71	1.91	1.2	0.90	1.16	0.45	0.58
37	0.9	2.30	1.40	1.03	1.1	0.07	1.16	2.97	0.58	1.48
38	1.7	1.80	0.10	1.19	1.5	0.31	2.20	2.32	1.10	1.16
39	1.1	1.50	0.40	0.99	1.4	0.41	1.42	1.94	0.71	0.97
40	1.2	1.30	0.10	0.67	1.05	0.38	1.55	1.68	0.78	0.84
41	0.3	2.20	1.90	0.42	1.41	0.99	0.39	2.84	0.19	1.42
42	0.8	1.80	1.00	0.44	2.5	2.06	1.03	2.32	0.52	1.16
43	0.5	1.00	0.50	0.37	1.2	0.83	0.65	1.29	0.32	0.65
44	0.6	2.20	1.60	0.62	1.35	0.73	0.78	2.84	0.39	1.42
45	1	1.90	0.90	0.93	1.85	0.92	1.29	2.45	0.65	1.23
46	1.4	2.80	1.40	1.07	1.46	0.39	1.81	3.61	0.90	1.81
47	1.1	1.30	0.20	1.1	1.34	0.24	1.42	1.68	0.71	0.84
48	0.7	1.50	0.80	1.24	1.35	0.11	0.90	1.94	0.45	0.97
49	1.5	2.00	0.50	1.33	1.45	0.12	1.94	2.58	0.97	1.29
50	0.8	1.30	0.50	0.69	1.7	1.01	1.03	1.68	0.52	0.84

APPENDIX C

Table C: Data collection on February 2016 and August 2016 at Gunung Siku Forest Reserve, Cameron Highland

Species: *Agathis borneensis*

Local Name: Damar Minyak

Family: Araucariaceae

	Diameter (cm)			Height (m)			AGB (kg)		Carbon Stock (kgC)	
No	**Feb**	**Aug**	**diff**	**Feb**	**Aug**	**diff**	**Feb**	**Aug**	**Feb**	**Aug**
1	0.9	1.10	0.20	0.69	1.2	0.51	1.16	1.42	0.58	0.71
2	0.9	1.10	0.20	0.84	1.2	0.36	1.16	1.42	0.58	0.71
3	0.8	1.00	0.20	0.51	1	0.49	1.03	1.29	0.52	0.65
4	0.7	0.80	0.10	0.67	0.9	0.23	0.90	1.03	0.45	0.52
5	1.4	1.60	0.20	1.04	1.8	0.76	1.81	2.06	0.90	1.03
6	0.8	1.80	1.00	0.73	1.9	1.17	1.03	2.32	0.52	1.16
7	1.3	1.70	0.40	1.06	1.8	0.74	1.68	2.19	0.84	1.10
8	0.8	0.90	0.10	0.66	0.8	0.14	1.03	1.16	0.52	0.58
9	1.2	1.50	0.30	0.9	1.7	0.8	1.55	1.94	0.78	0.97
10	0.7	1.00	0.30	0.59	0.9	0.31	0.90	1.29	0.45	0.65
11	1	1.30	0.30	0.67	0.9	0.23	1.29	1.68	0.65	0.84
12	1.1	1.80	0.70	0.7	1.9	1.2	1.42	2.32	0.71	1.16
13	0.9	1.00	0.10	0.63	0.9	0.27	1.16	1.29	0.58	0.65
14	1.1	1.15	0.05	0.81	0.9	0.09	1.42	1.48	0.71	0.74
15	1	1.20	0.20	0.75	0.8	0.05	1.29	1.55	0.65	0.77
16	0.4	0.50	0.10	0.28	0.9	0.62	0.52	0.65	0.26	0.32
17	1.1	1.30	0.20	0.79	0.8	0.01	1.42	1.68	0.71	0.84
18	0.9	1.05	0.15	0.82	0.9	0.08	1.16	1.35	0.58	0.68
19	1.2	1.50	0.30	1.8	1.95	0.15	1.55	1.94	0.78	0.97
20	0.3	0.90	0.60	0.5	0.8	0.3	0.39	1.16	0.19	0.58
21	0.7	0.80	0.10	0.97	1.15	0.18	0.90	1.03	0.45	0.52
22	0.5	0.60	0.10	0.55	0.9	0.35	0.65	0.77	0.32	0.39
23	0.5	0.80	0.30	0.75	0.96	0.21	0.65	1.03	0.32	0.52
24	0.3	0.60	0.30	0.39	0.8	0.41	0.39	0.77	0.19	0.39
25	0.4	0.70	0.30	0.56	0.7	0.14	0.52	0.90	0.26	0.45
26	0.4	0.90	0.50	0.67	0.9	0.23	0.52	1.16	0.26	0.58
27	0.7	0.80	0.10	0.89	0.9	0.01	0.90	1.03	0.45	0.52
28	1	1.10	0.10	0.87	1	0.13	1.29	1.42	0.65	0.71

APPENDIX D

Picture 1C: The picture with team group and staff of Pahang Forestry Department on February 2016

Picture 2C: The picture with team group and staff of Pahang Forestry Department on August 2016