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论文题目：

Estimation of Biomass and Carbon Stock in the Logged-Over Inland Tropical Forestsin Malaysia

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Nor Halizah Abd. Halim

ABSTRACT

This study was conducted in the logged-over-inland forests, Permanent Reserved Forest, Peninsular Malaysia to estimate tree biomass and carbon stock for above ground and below ground. The plots size was 100m x 100m each, all trees with diameter at breast height (DBH) of ≥10cm and above were enumerated. The plots were categorized into four (4) period years after logging, which are Period I (16-20 years after logging), Period II (21-25 years after logging), Period III (26-30 years after logging) and Period IV (>31 years after logging). Number of plots for Period (16-20 years after logging) was four (4) plots, Period II (21-25 years after logging) was four (4) plots, Period III (26-30 years after logging) was six (6) plots and Period IV (>31 years after logging) was six (6) plots, respectively. The total individual species was 7088 numbers of trees. In addition, non-dipterocarp group was showed dominant species than dipterocarp group. The non-dipterocarp species was contributed 6440 trees while dipterocarp indicated 648 trees only. Basal area for Period I (16-20 years after logging) was indicated 17.31 m^2/ha, Period II (21-25 years after logging) was 29.36 m^2/ha, Period III (26-30 years after logging) was 27.11 m^2/ha and Period IV (>31 years after logging) was 33.64 m^2/ha. Stand density for Period I (16-20 years after logging) was 201 No/ha, Period II (21-25 years after logging) was 433 No/ha, Period III (26-30 years after logging) was 354 No/ha and Period IV (>31 years after logging) was 405 No/ha. The estimated biomass (above ground and below ground) for Period I (16-20 years after logging) was 269.40 t/ha, Period II (21-25 years after logging) recorded 454.81 t/ha, Period III (26-30 years after logging) contributed 427.37 t/ha and Period IV (>31 years after logging) was 546.09 t/ha. The carbon stock was 134.71 t C/ha for Period I (16-20 years after logging), 227.41 t C/ha for Period II (21-25 years after logging), 213.68 t C/ha for Period III (26-30 years after logging) and 273.05 t C/ha for Period IV (>31 years after logging), respectively. Period IV (>31 years after logging) showed highest biomass and carbon stock while the lowest was in Period I (16-20 years after logging). This is indicate that long spatial period years after logging contains more biomass than shorter period years after logging. Carbon stock was contained higher with longer period years after logging than shorter period years after logging. This indicate that sustainable forest management practice was successful implement and permanent reserved forest can store carbon and also can help in mitigate climate change.

Keywords: biomass, carbon stock, dipterocarp, non-dipterocarp, inland forest, permanent reserved forest.

摘要

这项研究是在内陆采伐过的森林进行的，即永久保留森林，来估算马来西亚半岛地上和地下树木生物量与碳储量。共有二十个 100m x 100m 的样地，样地内树木胸径（DBH）≥10cm 起测。样地被分为采伐之后分为四个时期阶段，即 I 期（采伐后 16-20 年）、II 期（采伐后 21-25 年）、III 期（采伐后 26-30 年）、IV 期（采伐后＞31 年）。总个体数为 7088 株。此外，非龙脑香科树比龙脑香树更有优势。非龙脑香科植物为 6440 株，而龙脑香科植物为 648 株。胸高断面积（采伐后 16-20 年）为 17.31 平方米/公顷，II 期（采伐后 21-25 年）为 29.36 平方米/公顷，III 期（采伐后 26-30 年）为 27.11 平方米/公顷，IV 期（采伐后＞31 年）为 33.64 平方米/公顷。林分密度密度 I 期（采伐后 16-20）为 201（棵/公顷），II 期（采伐后 21-25 年）为 433（棵/公顷），III 期（采伐后 26-30 年）为 354（棵/公顷）和 IV 期为（采伐后> 31 年）405（棵/公顷）。生物量估算 I 期（采伐后 16-20 年）为 269.40 吨/公顷，II 期（采伐后 21-25 年）为 454.81 吨/公顷，III 期（采伐后 26-30 年）为 427.37 吨/公顷，IV 期（采伐后＞31 年）为 546.09 吨/公顷。碳储量 I 期为 134.71 吨碳/公顷（采伐后 16-20 年），II 期（采伐后 21-25 年）为 227.41 吨碳/公顷，III 期为（采伐后 26-30 年）213.68 吨碳/公顷，IV 期为（采伐后＞31 年）273.05 吨碳/公顷。IV 期（采伐后> 31 年）具有最高的生物量和碳储量，而最低的是 I 期（采伐后 16-20 年），这表明，I 期（采伐后 16-20 年）仍处于早期演替阶段，而 IV 期（采伐后＞31 年）已从之前的干扰中恢复。这表明，可持续森林管理试点的成功实践且永久保留森林可以有效地储存碳，也可以帮助减缓气候变化。

关键词：生物量，碳储量，龙脑香，非龙脑香，内陆森林，永久保留森林。

LIST OF ABBREVIATONS AND ACRONYMS

Variable	Description
a.m.s.l	Above mean sea level
AGB	Aboveground biomass
BGB	Below ground biomass
CO_2	Carbon dioxide
COP	Conference of the Parties
DBH	Diameter at breast height
FAO	Food and Agriculture Organization
FDPM	Forestry Department Peninsular Malaysia
FR	Forest Reserve
ha	Hectare
IPCC	Intergovernmental Panel on Climate Change
ITTO	International Tropical Timber Organization
m^2	Meter square
m^3	Cubic metre
PRF	Permanent Reserved Forest
REDD	Reducing Emissions from Deforestation and Forest Degradation
REDD+	Reducing Emissions From Deforestation And Forest Degradation and The Role of Conservation, Sustainable Management of Forests and Enhancement of Forest Carbon Stocks in Developing Countries
SMS	The Selective Management System
SFM	Sustainable Forest Management
Tonne (t)	Metric tonne
UNFCCC	United Nations Framework Convention on Climate Change

Table of Contents

List of Figures

List of Tables

CHAPTER I

INTRODUCTION

1.1 Description of Malaysia

Malaysia is a nation located in the Southeast Asia, bordered by Thailand, Indonesia, and Brunei, and shares water boundaries with Singapore, Vietnam, and the Philippines. Malaysia has coasts along the South China Sea.Malaysia is located within the latitude 1^{0} to 6^{0} 45’ North and longitudes 99^{0} 40’ to 119^{0} East.Malaysia is comprised of three (3) regions of Peninsular Malaysia, Sabah and Sarawak. Peninsular Malaysia with a total area of 13.16 million ha is located between latitudes 1^{o} 20’ and 6^{o} 45’ North and between longitudes 99^{o} 40’ and 104^{o} 20’ East. Its maximum width is 322km with a length from the northernmost to the southernmost tip of approximately 740km. Total land area of Sabah is 7.37 million ha with a latitudes 4 ^{o} and 7 ^{o} North and longitudes 115 ^{o} 20’ and 119 ^{o} 20’ East. With a total land area 12.30 million ha, Sarawak is situated on the northwest coast of the island of Borneo, between latitude 0 ^{o} 50’ and 5^{o} North and longitudes 109 ^{o} 35’ and 115 ^{o} 40’ East. It is maximum width approximately 257km with a length of about 740km. Thus, the total land area of Malaysia is estimated to be 32.83 million ha. The map of Malaysia is shown below (see Figure 1).

Figure 1 Map of Malaysia

Malaysia is a tropical country which has a hot and humid tropical climate marked by seasonal variations in rainfall. Thang, 2009 summaries of annual rainfall in Peninsular Malaysia is approximately 2540mm. Precipitation mostly happened during southwest monsoon on September to December. In the east of Malaysia, most rainfall received during northeast monsoon on October to February with Sabah receives 2630mm annual rainfall and Sarawak receives approximately 3850mm rainfall annually. Mean annual temperature is 27°C with a diurnal range of 9°C. Malaysia has high relative humidity approximately 85% to 95% especially in the coastal area.

1.2 Research questions

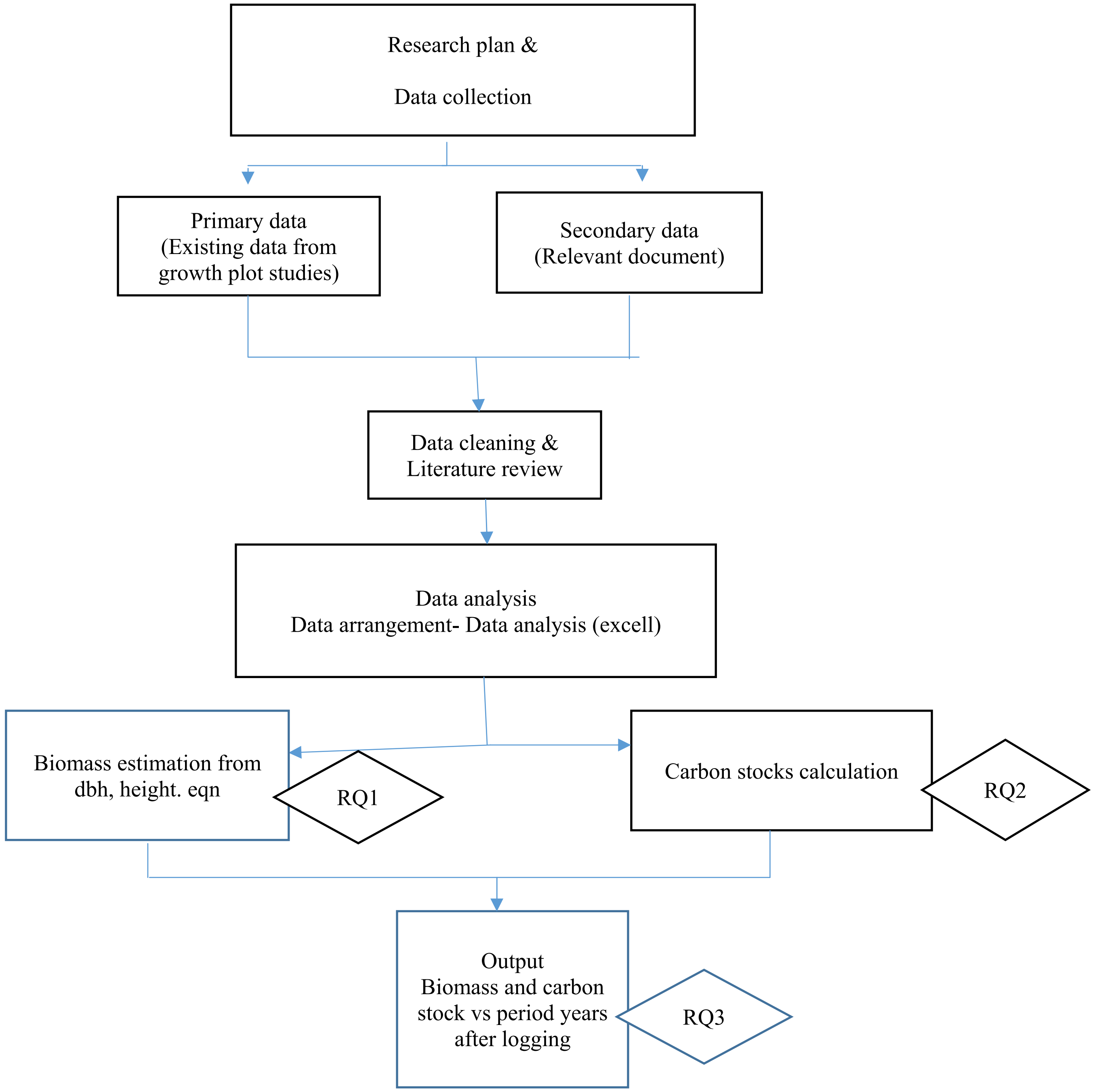
i. How much amount of biomass of different period years after logging in the Permanent Reserved Forest, Peninsular Malaysia?
ii. How much amount of carbon stock of different period years after logging in the Permanent Reserved Forest, Peninsular Malaysia?
iii. Different spatial period years after logging will vary to contribution of biomass content or not?

1.3 Research objectives

The main objectives of this study are as follows:

i. To compare and determine the biomass of tree by different period years after logging.
ii. To compare and estimate the carbon stock by different period years after logging.

1.4 Research approach



Notes: RQ stand for research questions.

Figure 2 Flow diagram of research approach

CHAPTER II

LITERATURE REVIEW

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2.1 Tropical forest ecosystems

Food and Agriculture Organization (FAO,2010) defines forest as the land that does not include agricultural and urban land usage management which covers more than 0.5 hectares with trees height of more than five meters with 10% canopy covering and are able to reach the threshold in situ. Areas planted with forest tree species such as Pines, *Acacia mangium*, *Gmelina arborea* and Rubber (*Hevea brasiliensis*) are known as forest plantations. They fall under the classification of forest since their end products feed the timber industry.

Malaysia is very fortunate to be endowed with large tract of tropical rainforests which consist of unique and complex ecosystems which are home to the the country's rich flora and fauna. Forests in Malaysia were recorded contain at least 15,000 species of flowering plants, of which 2,500 are tree species; 286 species of mammals; 600 species of birds; 140 species of snakes; 1000 species of vertebrates, more than 6000 species of butterflies and months, an estimated 20 to 80 thousand of invertebrates and an unaccounted number of species of insects and other life forms (Anon, 2001). Malaysia tropical rain forests nowadays not only provide direct benefits such as timber, it is also play a vital role in maintaining environmental stability and quality; protecting soil and water resources; conserving biological diversity; and preserving cultural, recreational and other intrinsic values which enhance people's quality of life.On the other hand, in 2014, the total land under forests in Malaysia was estimated 18.04 million hectares or 54.63% of total land area (FDPM, 2014). In Peninsular Malaysia, total forest area is 5.80 million per hectares. While in Sabah and Sarawak are 4.44 million per hectares and 7.80 million per hectares.

Forest that has attained great age and exhibit unique biodiversity system are known as natural forest (Guariguata and Pinard, 1998; Kukkonen *et al.*, 2008). Natural forest which are also known as virgin forest, possess large number of trees, shrubs and herbs, multi layered tree canopies, debris and forest litter on the floor (Hackl *et al.*, 2004). Many studies and literature brought up the argument about the importance of natural forest conservation. In Malaysia, natural forests were excessively logged back in the 1960s which were to serve the main purpose of harvesting the forest resources which has contributed to the income and subsequently to the economy of the country (Arifin *et al.*, 2008). However, the concerns on over-exploitation of natural forest resources has increased over the years due to the means of logging and harvesting approaches that does not take into account the negative impacts caused by those heavy machinery and clear felling on the soil quality.

Meanwhile, secondary forest is a forest area that undergoes natural regeneration after severe disturbances namely fire, pest infestation, shifting cultivation or timber logging at a long period of time (Brearley et al. 2004, Fearnside et al. 2007, Álvarez-Yépiz et al.2008). After being harvested heavily, the forest is left to re-grow by itself or naturally without any forest treatment (Neeff 2005, Fukushima et al. 2008, Kenzo et al. 2008, Holz et al.2009). Pioneer species such as *Macaranga* will colonize this left over area due to the opening of canopy that allows direct exposure towards sunlight (Perz and Skole 2003, Schedlbauer and Kavanagh, 2008). According to Chai (1997) secondary forests are forests which have developed by natural secondary succession on land abandoned after shifting agriculture and logging activities. Consequently, forest logging activities invariably cause some damages to the forest ecosystem and the surrounding environment. However, it has been observed that careful and proper planning of harvesting and the implementation of reduced impact logging practices will help reduced the severity of damage to the forest. Meanwhile, Chokkalingam and de Jong (2001) define secondary forests as "forest regenerating largely through natural processes after significant human and/or natural disturbance of the original forest vegetation at a single point in time or over an extended period, and displaying a major difference in forest vegetation at a single point in time or over an extended period, and displaying a major difference in forest structure and/ or canopy species composition with respect to nearby primary forests on similar sites". Secondary forests are generally classified based on the cause and intensity of degradation.

The natural regeneration of forests is an important part of the recovery of former shifting-cultivation areas. Shifting cultivation was reported to have contributed 25% to the carbon emissions in Asia over the past 150 years (Houghton and Hackler 1999). In 2005, the United Nations Food and Agricultural Organization (FAO) reported that about 60% of the world's remaining tropical forests are secondary or degraded forests (FAO 2005) compared to 31% as reported by Brown and Lugo (1990) in the 1980s.These figures indicate the increasing and significant role of secondary forests in tropical landscapes. Brown and Lugo (1990) discussed the detail of roles for secondary forest which stated that that secondary forests (i) are an important source of timber and non timber products, (ii) are a source of medicinal plants, (iii) provide wildlife habitats, (iv) act as reservoirs for biodiversity, and (v) provide ecological services and products to mankind. The recent Copenhagen Climate Change Summit 2009 reinforced commitments by signatory countries towards the *Kyoto Protocol* and Reducing Emissions from Deforestation and Forest Degradation (REDD) scheme as one of the initiatives to mitigate climate change. Such interest is amplified, as it was reported that 52% of the world's forests are found in the tropical region where deforestation. Therefore, degradation and loss of tropical forests have significant impacts on the global carbon cycle (Silver et al. 2000). Under the REDD initiative, countries are required to report their carbon storage and changes. Yet, Philip and Haron (2010) stated that the above and belowground biomass, litter, dead wood, and soil organic carbon must be monitored. Generally, the methods to determine forest biomass are use of information from forest inventories with regression models and remote sensing techniques (Brown 2002, Houghton 2005).

2.2 Forest types

The forest in Malaysia were classified into a few major types; lowland dipterocarp forest, hill dipterocarp forest, upper hill dipterocarp forest, oak-laurel forest, montane ericaceous forest, peat swamp forest and mangrove forest (Table 1). The Dipterocarp Forests is one of others forest types that are of vital economic and ecological importance. There are many genera, like Shorea, Dipterocarpus, Anisoptera, Dryobalanops, Parashorea, Vatica, Hopea, Cotylelobium, and Neobalanocarpus, with Malay names like Meranti, Balau, Kapur, Chengal, and Keruing(Wyatt-Smith 1963). These forests contain a high diversity of tree species (an estimated 6,000 species) and dominant species are uncommon. In term of major forest types, the distribution of these major forest types by regions is as shown in Table 2. Generally, most mature dipterocarps in Peninsular Malaysia are about 30-50 meters tall. Another characteristic of dipterocarp forests is the group habit of the emergents. In the richest forests, up to 80 percent of the emergent trees are Dipterocarpus, Dryobalanops, and Shorea. Hopea and Vatica usually are found in the main canopy. Berseraceae and Sapotaceae are other common main canopy families. Below the canopy a layer of shade-tolerant species thrives. This layer includes many species from the Euphorbiaceae, Rubiaceae, Annonaceae, Lauraceae, and Myristicaceae families. Ground vegetation usually is sparse, mainly small trees, and herbs are uncommon (Anon, 2000).

Table 1 The major forest types recognized in Malaysia

Forest Types	**Description**
Lowland dipterocarp forest	This occurs up to an elevation of 300m. Together with hill dipterocarp forest, it constitutes the main forest type in Malaysia. Primary lowland dipterocarp forest consists of dominant and co-dominant strata reaching 45m in height with emergent trees reaching 60m in height. An intermediate stratum of trees forms a canopy between 23m and 30m, below which grows suppressed vegetation. Where emergent trees are rare, the forest forms a three-layered stand. Ground vegetation is of moderate density. About half of the upper-story trees belong to the Dipterocarpaceae family.
Hill dipterocarp forest	This occurs between elevations of 300m and 1300m. Many of the lowland dipterocarp forest genera are represented but species composition varies. Ridges, for example, are often dominated by *Shorea curtisii* (Seraya forest), and non-dipterocarp species such as *Swintonia spicifera* occur frequently. Hill forests are found on ultisols, oxisols and podzols with low agricultural potential. They currently form the bulk of the productive permanent reserved forest.
Upper hill/montane forest	This occurs above 1300m on brown earth and podzol soils. In Peninsular Malaysia this forest type contains few dipterocarp species. Commonly found species belong to the Fagaceae (*Quercus*, *Lithocarpus* and *Castanopsis* spp.) and Lauraceae families. Other species include *Agathis alba*, *Engelhardtia* spp. and*Podocarpus* spp. *Ericaceous* ('mossy') forests with few oaks occur above 1600m in the cloud belt.*Pteris ovalifolia*, *Rhododendron* spp. and *Vaccinium* spp. are common on acid peaty gley soils. In Sabah, montane dipterocarp forests occur above the zone of hill dipterocarp forests in the Crocker Range and the central uplands. The main species here are *Shorea platyclados*, *Shorea venulosa* (on ultra basic rocks), *Shorea monticola, Shorea laevis*, *Hopea montana*, *Hopea dyeri*, *Dipterocarpus ochraceus*,*Vatica dulitentis*, and *Vatica umbonata*. At higher elevations these forests become oak-chestnut forests and, at elevations over 2000m, they are replaced by mossy forests rich in conifers and Ericaceae.
Heath forest	This is generally grouped with hill forests, and is also known as kerangas forest. Heath forest trees are small and poorly formed. Heath forest has a limited distribution and occurs on white sandy soils and beach terraces at all elevations. The main species and genera are Casuarina, *Agathis alba*, Dacrydium, Tristania and, infrequently, *Shorea albida*.
Beach forest	This is restricted to sandy coastal soils where it occupies strips seldom more than 100 metres wide. The main species is *Casuarina equisetifolia.*
Peat swamp forest	In Peninsular Malaysia, peat swamp forests once occupied extensive areas of the central and southern coastal plain. Many species not typically found in dipterocarp forests occur in peat swamp forests (with the notable exception of *Koompassia malaccensis* and some dipterocarp species). The main commercial species occur in two of the six sub-types of peat swamp forest: i) mixed swamp forest with ramin (*G. bancanus*), jongkong (*D. stenostachys*), swamp merantis (*Shorea uliginosa*, *S. teysmanniana*, *S. platycarpa* and *S. scabrida*), jelutong pacsa (*Dyera lowii*), sepetir (*Copaifera palustris*), and swamp kapur (*D. rappa*); and ii) alan (*S. albida*) forests.
Freshwater swamp forest	This occurs with peat swamp forest at low elevations that are only temporarily submerged by mineral-rich, less acidic fresh water during the rainy season. Floristic composition varies but the forest is often richer in dipterocarp species than true swamp (peat) forest. *Dipterocarpus coriaceus*, *Dipterocarpus costulatus*, *Dryobalanops oblongifolia*, *Hopea mengarawan* and Shorea and Vatica spp. represent the dipterocarps. Hopea spp. and Vatica spp. are also common, interspersed with non-dipterocarps such

	as *Intsia palembanica*, *K. malaccensis*, *Melanorrhoea*, *Palaquium*, *Pometia* and *Sindora* spp. Soils are partly drained levee soils or backswamp soils that are being widely reclaimed for agriculture.
Mangrove forest	This is found mainly on marine alluvial soils (tropaquents and saprists) along sheltered coasts and estuaries. Mangrove forest has a simple structure with *Rhizophora, Avicennia, Bruguiera, Sonneratia* and *Xylocarpus* spp. distributed in species-specific belts that follow soil and inundation patterns. Trees range in height from 7m to 25m. Mangroves are highly productive ecosystems and important spawning, nursery and feeding habitats for many marine fish and invertebrates. Mangrove wood is used for buildings, fish traps and for firewood and charcoal. Besides, there are two types of swamp palms are also included in the mangrove forest type, namely, nipah (*Nypa fruticans*) and nibong (*Oncosperma horridum*). Nipah is a multiple-use species that provides housing thatch, cigarette paper, sugar, alcohol, vinegar, salt and other products. This species frequently grows in pure stands. Nibong occurs in the drier zone of the mangrove forest.

Table 2 Distribution and extent of major forest types in Malaysia, 2010 (million ha)

Region	Land area	Natural forest			Total forested land	Percentage total of forested land
		Dry inland forest	Swamp forest	Mangrove forest		
Peninsular Malaysia	13.18	4.58	0.24	0.10	5.86	44.40
Sabah	7.37	3.17	0.12	0.32	3.61	49.00
Sarawak	12.30	7.98	1.12	0.14	9.24	75.10
Malaysia	**32.85**	**15.73**	**1.48**	**0.56**	**17.77**	**54.10**

Source: Forestry Department, Peninsular Malaysia, Sabah, Sarawak (2011).

2.3 Sustainable Forest Management

Malaysia is one of the countries with high percentage of forested land among other developing countries. The estimated forested land in Malaysia in 2010 was 17.77 million hectares or 54.1% of the total land area, whereas forested land in Peninsular Malaysia was 5.86 million hectares with almost 44.4 percent. Therefore, of the total forested land, 14.49 million hectares Malaysia land area legally constituted as permanent reserved forest (PRF) approximately 10.37 million hectares are designated as production forests and the remaining 4.12 million hectares are managed are managed as protection forests such as water catchments, high elevation and difficult topographical features. Peninsular Malaysia permanent reserved forests was estimated 4.80 million hectares under National Forestry Act, 1984. Table 3 shows permanent reserved forests in Malaysia in 2010. The permanent reserved forestsis being managed based on sustainable forest management (SFM) principles and practices. According to Brown (1992) the definition of sustainable forest management adopted by the International Tropical Timber Council-sustainable forest management is the process of managing permanent forest land to achieve one or more clearly specified objectives of management with regard to continuous flow of desired forest products and services without undue reduction in its inherent values and future productivity and without undesirable effects in the physical and social environment.Currently, Malaysia implements strongly sustainability measures in its forest management based on International Tropical Timber Organization (ITTO) guidelines. As well as, Malaysia was strongly committed to managing its natural production in a sustainable manner: to ensure continuous timber production, maintain forest multiple functions, conserve biodiversity and control environmental impact. (Mohd Yunus 1993, Anon 1994 and Anon 1996).

Table 3 Permanent reserved forest in Malaysia, 2010 (million ha)

Region	Protection forest	Production forest	Total PRFs
Peninsular Malaysia	1.98	2.82	4.80
Sabah	1.04	2.55	3.59
Sarawak	1.10	5.00	6.10
Malaysia	**4.12**	**10.37**	**14.49**

Source: Forestry Department, Peninsular Malaysia, Sabah, Sarawak (2011).

2.4 Forest management system in Malaysia

In Peninsular Malaysia, the production forests of the permanent reserved forest are managed under two management systems, the Malayan Uniform System or MUS (based on a 55-year cutting cycle), and the Selective Management System or SMS (based on a 30-year cutting cycle). Under the MUS, all mature commercial trees above 45cm diameter at breast height (DBH) are harvested in one operation in the area being logged (Wyatt-Smith 1963, Thang 2000). However, under the SMS, management (felling) regimes are determined using pre-felling inventory data.Following logging under the MUS, all remaining large trees of non-commercial species are removed by poison girdling. The next tree crop develops from seedlings and consequently is of uniform age. According to Wyatt-Smith (1988), the MUS is not environmentally degrading, although it is not oriented towards gene conservation.As the MUS relies primarily on seedlings and saplings to establish succeeding crops, silvicultural treatments are designed to favour these groups, often at the expense of larger trees. This bias tends to encourage more poison girdling than is necessary and, in some cases, excessive opening of the canopy. Over time, however, the emphasis of management has moved from seedlings and saplings to the remaining large trees. This has reduced the incidence of poison girdling and has promoted a more conservation-oriented approach to silvicultural treatments (Hashim 1997).

After modification, the MUS has been applied successfully in lowland dipterocarp forests. It is unsuitable for hill dipterocarp forests, however, owing to the more difficult terrain, uneven stocking, a lack of natural regeneration, erosion risks on steep slopes and the secondary growth promoted by canopy opening. Finally, in 1978, the SMS was introduced for hill forests. This system is based on the selective removal of the mature crop in a single operation, an approach that allows flexibility in harvesting regimes because it emphasizes the recruitment of trees with a diameter between 15cm and 45 cm for the next crop. It also discourages poison girdling of non-commercial species and so better conserves forest genetic resources. The cutting limit for selective felling is not less than 50cm DBH for dipterocarp species and 45cm DBH for non-dipterocarp species. The cutting limit for the dipterocarp *Neobalanocarpus heimii*, however, is set above 60cm. Thang (1988) stated that the difference in the cutting limits between dipterocarps and non-dipterocarps is kept at no less than 5cm in order to preserve a higher proportion of dipterocarp species for the next crop. According to Thang (1987), the SMS is designed to optimize the management objective of economic and efficient forest harvesting, forest sustainability and minimum forest development costs. Table 4 shows the operations sequence of the SMS systems (Mohd Yunus 1993).

Table 4 Sequence of operations forselective management system

Year	Operation
n-2 to n-1	Pre-felling forest inventory of 10% sampling intensity using systematic line-plots to determine appropriate cutting limits (regimes).
n-1 to n	Tree marking incorporating directional felling. Marking tree to be felled, marking of mother trees, marking of protection and protected trees and demarcating boundaries of buffer zone for watercourses.
n	Felling all marked trees.
n+1/4 to n+1/2	Forest survey to determine fines on trees unfelled and damage to residual; and royalty on short logs and tops.
n+2 to n+5	Post-felling forest inventory of 10% sampling intensity using systematic line plots to determine residual stocking and appropriate silvicultural treatments.
n+10	Forest inventory of regenerated forest to determine status of the forest

Note: n – Year of felling

2.5 Origin status of forest

The definitions of origin forest in terms of good, moderate and poor were used based on the Second National Forest Inventory 1981-1982 (FDPM 1987). Good forest means forest in rolling to hilly terrain up to approximately 1,000 meter altitude above sea level, dominated by the following major species groups such as *Shorea* spp. (dark red), *Shorea* spp. (light red), *Koompassia malaccense*, *Lauraceae* and *Eugenia* spp. with an average volume of trees diameter 30cm DBH and above is 239 m^3/ha. Moderate forest means forest in rolling to hilly terrain up to approximately 1,000 meter altitude above sea level, dominated by the following major species groups such as *Shorea* spp. (dark red), *Shorea* spp. (light red), *Koompassia malaccense*, Lauraceae and *Eugenia* spp. with an average volume of trees diameter 30cm DBH and above is 211 m^3/ha. Poor forest means forest frequently on poor drained or rocky soils up to 1,000 meter altitude above sea level, dominated by the following major species group such as *Shorea* spp. (dark red), Lauraceae, Burseraceae, Sapotaceae and *Eugenia* spp. with an average volume of trees diameter of 30 cm DBH and above is 153m^3/ha.

2.6 Biomass and Carbon stocks

There are important to estimate of the accumulated biomass in the forest ecosystem in order to assess the productivity and sustainability of the forest. So that, when forests are being cleared or burned, we can know the potential amount of carbon that can be emitted in the form of carbon dioxide. Besides, biomass estimation also enables us to estimate the amount of carbon dioxide that can be sequestered from the atmosphere by the forest. Thus, the accurate assessment of biomass estimates of a forest is important for many applications like timber extraction, tracking changes in the carbon stocks of forest and global carbon cycle. Forest biomass can be estimated through field measurement and remote sensing and geographic information system (GIS) methods (Noridah et al. 2014). In addition, forest biomass is also useful for sustainable management of the forest, assessing forest structure and condition, and estimating forest productivity and carbon fluxes based on sequential changes in biomass (Brandeis et al. 2006, Cole and Ewel 2006). In the developing countries, about 38 % of the primary energy consumption is accounted by the forest biomass (Sims 2003). Therefore the evaluation of biomass stocks is an important management strategy for the recovery of the such forests.

Forest biomass, expressed in terms of dry weight of living organisms, is an important measurement for analyzing ecosystem productivity and also for assessing energy potential and the role of forests in the carbon cycle (FAO 2010). According to Golley (1983) tree biomass for the rain forest ecosystem was the highest value in the world is about 415 t/ha, that is almost 90% represent for stem, 2% represent leave and 9% represent root. Brown (1997) stated that biomass is defined as the total amount of living organic matter in trees and expressed in tonnes per hectare. This term is more useful as unit of yield than volume as it allows comparisons to be made among different trees species and tree components. The term has been widely used as a unit of yield since the 1970s as it is a more useful measure than volume as it allows comparisons to be made between different trees as well as among different tree components. Above ground biomass (AGB) maybe defined as a combination of all tree components above ground level and is important in estimating the productivity of a forest (Kato etal. 1978). In addition, FAO (2005) has defined biomass as "the organic material both above and below the ground, and both living and dead, e.g, trees, crops, grasses, tree litter, roots, etc". Above ground biomass, below ground biomass, dead wood, litter and soil organic matter are the main carbon pools in any forest ecosystem (FAO, 2005; IPCC, 2003; IPCC, 2006). Above ground biomass includes all living biomass above the soil, while below ground biomass (BGB) includes all biomass of live roots excluding fine roots (<2mm diameter). Majority of biomass assessments are done for AGB of trees because these generally account for the greatest fraction of total living trees diameter at breast height (DBH) and taller than 1.3 m. The above ground biomass, thus defined, often make the field work more practical and reduces the risks of measurement errors (e.g double counting or omitting of trees in sample plots), especially in dense forests. Excluding the foliage biomass is justifiable as such biomass store carbon only temporarily.

Tropical forests are known to play an important role in carbon sequestration because of their high carbon storage (Lal and Augustin 2012). Adopted from Singh, 2005 forestry is only the major option for carbon sequestration in the terrestrial ecosystem among agricultural systems. Plants store carbon for as long as they live, in terms of live biomass. Once they die, the biomass becomes a part of the food chain and eventually enters the soil as soil carbon. Carbon accumulation potential in forests is large enough that forests offer the possibility of sequestering significant amounts of additional carbon in relatively short periods-decades (Luxmoore 2001). The carbon sequestration process involved in individual tree is an important concern in environmental system (Sedjo & Marland 2003). As well as forests store large amounts of carbon in the wood and roots of their trees. So, the forest expansions and sustainable forests, as mitigation measure, have a significant contribution to the environmental benefit but any shrinkage of forests, as CO_2 emission, has a long term influence and impact. Therefore, the sustainable forest, as a carbon sinks, is the key factor to balance the greenhouse gas (GHGs) emission (Levy et al. 2004). The process of carbon sequestration is the most rapid during the early stage of the life of tree while, as tree reaches maturity the above two processes become increasingly similar. Additionally, the rate of carbon sequestration is less particularly in over mature stage of the tree. Hence, the tree or forest expands the capacity of carbon sequestration also increases and vice-versa (Sedjo & Marland, 2003). Forest has a prime role in sequestering carbon from the atmosphere. In reality, the forest is a reservoir, a component or components of the climate system where GHGs is stored, as well sink (Pearce et al. 2003). Thus the forest is the complement of carbon sequestration. Conclusively, sustainable forests are reliable sinks of GHGs (Levy et al. 2004). Among these, the community forest management which is a successful example of sustainable forest management is the preferable option of carbon sequestration, primarily in developing countries (Klooster & Masera 2000).

In the tropic, the rain forests prominently role as bedrock in ameliorating and maintaining global climate change by reducing the accumulation of greenhouse gases (Shukla et al. 1990). However, they are fragile habitats and being destroyed at unprecedented rates through deforestation. Deforestation has been blamed as one of the main agents for the increasing of global warming, deteriorating site quality, alteration of carbon stocks, and losses of biodiversity. This drastic removal of biomass may have implications on the regional climate, biodiversity, the global carbon cycle and the large scale of atmospheric circulation. Deforestation and forest degradation contribute about 15% to 20% of global carbon emissions, and most of that contribution comes from tropical regions (FDPM and UPM 2013).

In the other hand, in areas undergoing deforestation above ground biomass is also a source of carbon emission to the atmosphere (Houghton et al. 2000). Carbon stored in forest biomass has been increasingly attracting attention in recent decades, as deforestation and tropical land-use change lead to significant emissions of greenhouse gases (Fearnside2000). Deforestation, especially in tropical countries, contributes substantially to increasing greenhouse gas concentrations in the atmosphere (ICPP 2007). In this context, the United Nations collaborative initiative on reducing emissions from deforestation and forest degradation (REDD+) in developing countries is an effort to mitigate global warming. The REDD+ goes beyond deforestation and forest degradation and includes the role of conservation, sustainable management of intact forests and enhancement of forest carbon stocks to create a monetary value for carbon stored in forests. But uncertainties still remain in the absolute magnitude of above ground biomass and carbon sequestration in different tropical forest ecosystem.

Recently, biomass and carbon sequestration function of forests is of great concern due to the global warming phenomenon, and hence managing forests with a proper system would play a vital role in mitigating global warming in the future. Estimation of biomass in stands provides the basic data for forest ecosystem management. The carbon numbers, along with information about the uncertainty of the measurements, are important for countries planning to participate in the Reducing Emissions from Deforestation and Degradation (REDD+) program. REDD+ is an international effort to create a financial value for the carbon stored in forests. It offers incentives for countries to preserve their forestland in the interest of reducing carbon emissions and investing in low-carbon paths of development.

The change in the forest areas and the changes in forest biomass due to management and regrowth greatly influence the transfer of carbon between the terrestrial forest ecosystem and the atmosphere. Hence, estimating the forest carbon stocks is mainly important to assess the magnitude of carbon exchange between the forest ecosystem and the atmosphere. Assessment of the amount of carbon sequestered by a forest will give us an estimate of the amount of carbon emitted into the atmosphere when this particular forest area is deforested or degraded. Furthermore, it will help us to quantify the carbon stocks which in turn will enable us to understand the current status of carbon stocks and also derive the near-future changes in the carbon stocks.

Moreover, for the successful implementation of mitigating policies to take advantage of the REDD programme of United Nations Frame-work Convention in Climate Change (UNFCCC), these countries should have well-authenticated estimates of forest carbon stocks (Miah et al.2011, Chaturvedi et al. 2011). Disturbances such as forest cutting and wood extraction affect the balance of carbon fixation in to rest ecosystems because forests become sources of CO_2 to the atmosphere (Brown 2002). The removal species with high wood density, large trunk diameter and high basal area may deplete carbon stock in forests up to 70% (Bunker et al. 2005).In natural conditions, carbon release is caused by respiration and decomposition biomass evaluation across world regions may help monitor carbon stocks and identify the impact of these changes in natural ecosystems.Furthermore, regenerating secondary forests were reported to have the potential to assimilate and store large quantities of carbon. This is primarily due to the higher recruitment and growth rate of tree species in these forests compared to primary forest tree species (Whitmore 1986, Swaine and Agyeman 2008). In addition, carbon cycle of terrestrial ecosystems plays a key role in regulating CO_2 concentration in the atmosphere (Moore and Braswell 1994, Dixon et al. 1994, Houghton et al. 2000). Thus, enhancing carbon storage in terrestrial ecosystems, and especially in forests, will be a key factor in the maintenance of the atmosphere's carbon balance.

In summaries, the scope of the problem of Climate Change global response is contained in the United Nations Framework Convention on Climate Change adopted at the World Summit on Sustainable Development called "Earth Summit" held in Rio de Janeiro, Brazil in 1997 and the *Kyoto Protocol* adopted at the third session of the conference of the Parties in December 1997 in Kyoto, Japan. Decisions which aimed at stabilizing concentrations of greenhouse gases in the atmosphere at a level which prevents dangerous interference with the global climate system were taken. Since the 13th Conference of the Parties (COP13) to the United Nations Framework Convention on Climate Change (UNFCCC) in Bali in 2007, the UNFCCC has progressively recognized the package of measures now known as REDD+, which stands for Reducing Emissions from Deforestation and forest Degradation, as well as the conservation and sustainable management of forests, and the enhancement of forest carbon stocks in developing country forests. At the COP16 in Cancun in 2010, REDD+ was officially incorporated into the UNFCCC's agreement on climate change. At COP17 in Durban in 2011, negotiators agreed on monitoring guidelines as safeguards for REDD+ implementation and on the means for developing estimates of emissions that would have occurred in the absence of REDD+ (Barnes et al. 1998).

2.7 Biomass and carbon stocks study

Many studies have been carried out to determine the allometric equation for biomass such Kato et al. (1978) and Kenzo et al. (2009). The preliminary study about biomass was conducted by Kato et.al (1978), for an area of 0.2 ha in Pasoh Forest Reserve, Negeri Sembilan showed that the biomass of a tree with a canopy 35-40m above ground biomass contributed of 475 t/ ha. While, the study by Niiyama and Noor (2010) studied for both above ground and below ground biomass (roots) of various species of trees in the Pasoh Forest Reserve, Negeri Sembilan founded that coarse root biomass before and after correction of root was estimated at 63.8 and 82.7 Mg/ha, indicated that a large number of roots (23%) were lost during sampling. Total below ground biomass and the above ground biomass was estimated to be 95.9 and 536 Mg/ha, respectively. While the distribution ratio of biomass (BGB / AGB) is about 0.18. This study has also developed allometric equations based on DBH coarse roots of which may be useful for assessing carbon stocks in soil under stands of other forest in Southeast Asia.

Previous study also conducted in Pasoh Forest Reserve, Negeri Sembilan, Peninsular Malaysia of a 15-year-old logged-over forest that has been done by Faridah et al. (2002). The study area was selectively logged in 1984. A one (1) ha (100m x 100m) plot was established and further divided into 100 contiguous subplots of10m x 10m. All trees with diameter at breast height (DBH) of 1cm or above were enumerated in a one hectare plots. The study accounted that above ground biomass of a 15-year-old logged-over forest at Pasoh was 160.8 t/ha, a reasonable value for a 15-year-old forests suggesting the capability of this forest to recover from previous forest harvesting.

Study conducted by Kueh and Lim (1999) in the Ayer Hitam, Puchong, Selangor founded the density of biomass for trees >10cm DBH and above in all six (6) compartments is from 83.69 to 232.39 t/ha or an average biomass value was 175.01 t/ha. Therefore, the content of biomass and carbon stocks in Ayer hitam Forest Reserves was estimated to be on average each of 37,261.3 tons and 18,630 tonnes. Variations in biomass density among the compartments indicate the different stages of recovery of different stages of succession. However, the same study area studied by Ismariah and Ahmad Fadli (2007) founded that the above ground biomass and below ground was in the ranged from 209 to 222 t/ha while the carbon stock was ranged from 104-111 t/ha.

The study conducted by Ramli (2014) in 2 ha plots Compartment 2W/3W, Piah Forest Reserve, Kuala Kangsar, Perak fo all the trees with diameter >10cm DBH and above were measured. The sizes of plot were 100m x 100m. This plot was production forest which have been logged for the first time in years 1970 and for second rotation in years 2011 (41 years). The study discovered the aboveground biomass and belowground biomass was 222.67 and 56.53, respectively. Family Dipterocarpaceae was dominated the biomass value was 75.57 t/ha. The total carbon stock for the study area was 139.60 t C/ha and estimated to be 10.36 million tonnes carbon in Piah Reserve Forest. The study founded that carbon value was dominated by family Dipterocarpaceae (37.79 t C/ha), followed by family Euphorbiaceae (21.36 t C/ha) and family Sapotaceae was 9.77 t/ Cha. Meanwhile, University Putra Malaysia (2012) conducted study for Quantification and Economic Evaluation of Carbon Stock in 4 hectares Compartment 54, Piah Forest Reserve, Kuala Kangsar. In this plot, trees with DBH ≥10cm were measured and identified. Results showed that the estimated aboveground biomass (including litter and coarse downed woody materials) and carbon stock for the Compartment 54, Piah Forest Reserved, Kuala Kangsar, Perak was 319.5 t/ha and 157.57 t C/ha.

Previous study by Neto et al. (2012) were studied about contribution of forest biomass organic matter to above ground and below ground carbon contents at Ayer Hitam Forest Reserve, for three (3) 0.1 ha forest plots in Peninsular Malaysia for above ground carbon from biomass and below ground carbon in the soil. Total carbon content in the soil decreased with depth from 1.86 (0–29 cm) to 0.81% (90–120 cm), whereas bulk density in the same layers increased from 1.15 to 1.51 g cm^{-3}. The 60–120 cm layers contained 42% of the total carbon. The amounts of carbon found up to 120 cm depth, excluding large roots, superficial litter and coarse debris were 154, 174 and 208 t ha^{-1} in the three (3) plots studied. Plots were very heterogeneous with regard to herbaceous vegetation, these contributing less than 0.01 t ha-^{1} carbon-main roots making up 30% and aerial parts being 3% richer. The three (3) plots had 87, 195 and 205 t ha^{-1} of carbon from biomass of trees above the ground. Annual increments of litter, debris and root carbon were also estimated.

According to Syafinie and Ainuddin (2015) to estimate above ground biomass and carbon stock in logged-over lowland tropical forest which are Bubu Forest Reserve. Summarized inventory data were used with a modified equation to estimate total above ground biomass and carbon stock. All selected tree were harvested and samples for analyzed from different component (main stem, branches, twigs, leaves). Therefore, two allometric equation were formulated for two different groups based on the wood density from the sampled tree which is high wood density class (AGB=0.055633 x $DBH^{2.75756}$) and medium wood density class (AGB=0.00023 x $DBH^{3.75745}$). Whereas carbon density of most trees sampled in this area was between 45% and 47%. The total aboveground biomass and carbon stock for Bubu Forest Reserved are 501.74 t/ha and 225.55 t C/ha. In that study, allometric equation with wood gravity specific as a predictor variable can yielded more accurate predictions, even when based on lower sample size than the equation that didn't include wood specific gravity. Brown and Lugo (1982) summaries the condition suggested that almost 18% decrease in forest area of Peninsular Malaysia region in accordance of decreasing about 28% total biomass show that forest area decrease reason of the changes the forest area to agriculture land suggest rubber plantation in oil palm plantation.

CHAPTER III

METHODOLOGY

3.1 Description of the Study Area

The study area was located in permanent reserved forest (PRF) area, and randomly distributed among eight (8) states of Peninsular Malaysia namely, Pahang, Perak, Perlis, Johor, Kelantan, Selangor, Kedah and Terengganu. The total study plot were twenty (20) plots.The background information of the twenty (20) plots was show in Table 5. The forest type of these plots were inland forests including both lowland dipterocarp forest (< 300 meter a.s.l) and hill dipterocarp forest (>300 meter a.s.l). Timber harvesting or logging activity in these PRFs areas regulated through the selective management system (SMS). The original forest in terms of good, moderate and poor were based on the Second National Forest Inventory 1981-1982 (FDPM 1987).

A total of twenty (20) plots study were chosen randomly based on period years after logging as shown in Table 3.2. The location of growth plot study was shown in Figure 3. The years 2013/2014 was used as the reference year in relation to the year that compartment was logged. The growth plots data will divided into four (4) period categories years after logging which;

i. Period I = 16 to 20 years after logging
ii. Period II = 21 to 25 years after logging
iii. Period III = 26 to 30 years after logging
iv. Period IV = ≥31 and above years after logging

Table 5 Back ground information of twenty (20) growth plots study in the PRF.

No.	State	District	Location of Reserved forest	Years of logging	Status of the original forest	Years after logging	Logging stratum (Year after logging)	Plot number	Period categories
1	Pahang	Kuala Lipis	Ulu Jelai FR, Compt. 575	1996	moderate	17	16-20	GP 33	I
2	Pahang	Temerloh	Krau FR, Compt. 9	1994	poor	19	16-20	GP 42	I
3	Perak	Kuala Kangsar	Gunong Korbu FR, Compt. 38	1994	good	20	16-20	GP 50	I
4	Perlis	Perlis	Wang Mu FR, Compt. 10	1996	poor	17	16-20	GP 66	I
5	Johor	Johor Selatan	Ulu Sedili FR, Compt. 120	1991	good	23	21-25	GP 5	II
6	Johor	Johor Timur	Mersing FR, Compt. 25	1989	poor	24	21-25	GP 9	II
7	Perak	Hulu Perak	Papulut FR, Compt. 43	1991	moderate	22	21-25	GP 61	II
8	Perlis	Perlis	Mata Ayer FR, Compt. 12	1991	poor	23	21-25	GP 64	II
9	Johor	Johor Utara	Labis FR, Compt. 37	1986	good	28	26-30	GP 2	III
10	Kelantan	Kelantan Selatan	Batu Papan FR, Compt. 51	1983	good	30	26-30	GP 28	III
11	Kelantan	Kelantan Barat	Stong FR, Compt. 113	1987	moderate	27	26-30	GP 23	III
12	Pahang	Jerantut	Tekam FR, Blk. JT. 08/84	1984	moderate	30	26-30	GP 35	III
13	Perak	Larut Matang	Bintang Hijau FR, Compt. 235	1987	poor	26	26-30	GP 54	III
14	Selangor	Hulu Selangor	Gading FR, Compt. 6	1988	poor	26	26-30	GP 77	III
15	Johor	Johor Utara	Maokil FR, Compt. 148	1978	poor	35	>31	GP 3	IV
16	Pahang	Rompin	Ibam FR, Compt. 165	1980	poor	33	>31	GP 48	IV
17	Johor	Johor Tengah	Lenggor FR, Compt. 101	1983	good	31	>31	GP 11	IV
18	Kedah	Kedah Utara	Bukit Perangin FR, Compt. 44A	1980	good	34	>31	GP 14	IV
19	Kelantan	Kelantan Timur	Cabang Tongkat FR, Compt. 27	1982	moderate	32	>31	GP 26	IV
20	Terengganu	Terengganu Barat	Jeranggau FR, Compt. 22	1980	moderate	33	>31	GP 88	IV

Table 6 Location and forest type of growth plots study

State	Location of forest reserve	Forest type	X	Y
Pahang	Compt. 575, Ulu Jelai FR	Lowland dipterocarp	WL 565704	WMR 265712
	Compt. 165 Ibam FR	Lowland dipterocarp	WL 538740	WMR 242871
	Compt. 116, Tekam FR	Lowland dipterocarp	WA 514776	WMR 448949
	Compt. 9, Krau FR	Hill dipterocarp	VE 472674	WMR 419354
Perak	Compt. 38, Gunung Korbu FR	Hill dipterocarp	WM 641724	WMR 212905
	Compt. 43, Papulut FR	Hill dipterocarp	QZ 425604	WMR 574247
	Compt. 235, Bintang Hijau FR	Lowland dipterocarp	WF 556524	WMR 643704
Perlis	Compt. 10, Wang Mu FR	Lowland dipterocarp	WM 639853	WMR 252114
	Compt. 12, Mata Ayer FR	Lowland dipterocarp	QZ 475324	WMR 643704
Johor	Compt. 120, Ulu Sedili FR	Lowland dipterocarp	WM 624536	WMR 250490
	Compt. 25 Mersing FR	Lowland dipterocarp	QN 284870	WMR 704855
	Compt. 37, Labis FR	Lowland dipterocarp	QZ 428649	WMR 529113
	Compt. 148, Maokil FR	Lowland dipterocarp	QY 317035	WMR 581761
	Compt. 101, Lenggor FR	Lowland dipterocarp	QN 246314	WMR 737708
Kelantan	Compt. 51, Batu Papan FR	Lowland dipterocarp	VE 415965	WMR 469406
	Compt. 27, Cabang Tongkat FR	Lowland dipterocarp	VD 398350	WMR 4115585
	Compt. 113, Stong FR	Hill dipterocarp	WA 514776	WMR 448949
Selangor	Compt. 6, Gading FR	Lowland dipterocarp	QY 358562	WMR 536756
Kedah	Compt. 44A, Bukit Perangin FR	Lowland dipterocarp	QT 246084	WMR 728204
Terengganu	Compt. 22, Jerangau FR	Lowland dipterocarp	RV 565888	WMR 552643

3.2 Climate and Rainfall

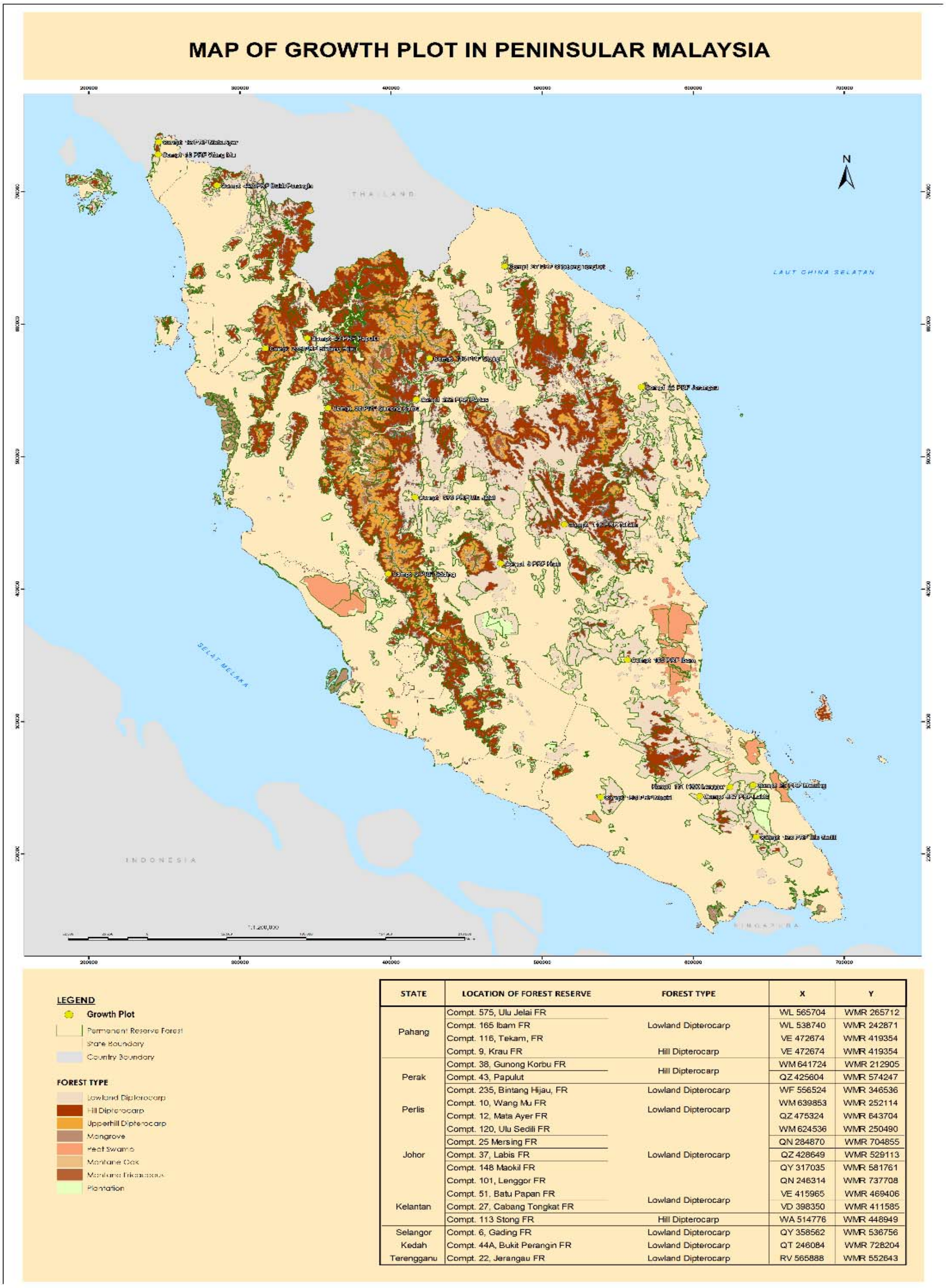
The weather of Peninsular Malaysia is warm and humid all year round with temperatures ranging from 21◦ C to 32◦ C, as is characteristic for a humid tropical climate. The precipitation climate characterized by two rainy seasons associated with the Southwest Monsoon from May to September and the Northeast Monsoon from November to March (Wong et al.2009).

3.3 Topograpic and soil types

Peninsular Malaysia is generally hilly or mountainous and over 40% of the land is above 150m a.s.l. with 23% over 300m (Wyatt-Smith, 1963). The mountains run in a series of ranges in a north-south direction. The largest of these, the Main (Titiwangsa) Range,is a continuous granitic range extending from beyond the Perak-Thailand border to the Negeri Sembilan-Melaka boundary near Tampin. Soil in Peninsular Malaysia are generally acidic, predominatly weathered from igneous rocks (granite) into oxisols and ultisols. The alluvial soil that accumulate in river valley systems are also mainly soils washed down from hills (Saw 2015).

3.4 Data Collection

This study was used data from the growth plot study. The plots were established by Forestry Department Peninsular Malaysia. These plots were established based on the following characteristic, namely; (i) located in the Permanent Reserve Forest, (ii) number of years after logging to sufficiently represent the different stages of forest development after logging and (iii) available information on Pre-Felling Inventory and Post Felling Inventory for the purpose of stocking and species comparison. Growth information including species name, health status and diameter at breast height (DBH) were recorded during the measurement.



STATE	LOCATION OF FOREST RESERVE	FOREST TYPE	X	Y
Pahang	Compt. 575, Ulu Jelai FR	Lowland Dipterocarp	WL 565704	WMR 265712
	Compt. 165 Ibam FR		WL 538740	WMR 242871
	Compt. 116, Tekam, FR		VE 472674	WMR 419354
	Compt. 9, Krau FR	Hill Dipterocarp	VE 472674	WMR 419354
Perak	Compt. 38, Gunong Korbu FR	Hill Dipterocarp	WM 641724	WMR 212905
	Compt. 43, Papulut		QZ 425604	WMR 574247
Perlis	Compt. 235, Bintang Hijau, FR	Lowland Dipterocarp	WF 556524	WMR 346536
	Compt. 10, Wang Mu FR	Lowland Dipterocarp	WM 639853	WMR 252114
	Compt. 12, Mata Ayer FR		QZ 475324	WMR 643704
Johor	Compt. 120, Ulu Sedili FR	Lowland Dipterocarp	WM 624536	WMR 250490
	Compt. 25 Mersing FR		QN 284870	WMR 704855
	Compt. 37, Labis FR		QZ 428649	WMR 529113
	Compt. 148 Maokil FR		QY 317035	WMR 581761
	Compt. 101, Lenggor FR		QN 246314	WMR 737708
Kelantan	Compt. 51, Batu Papan FR	Lowland Dipterocarp	VE 415965	WMR 469406
	Compt. 27, Cabang Tongkat FR		VD 398350	WMR 411585
	Compt. 113 Stong FR	Hill Dipterocarp	WA 514776	WMR 448949
Selangor	Compt. 6, Gading FR	Lowland Dipterocarp	QY 358562	WMR 536756
Kedah	Compt. 44A, Bukit Perangin FR	Lowland Dipterocarp	QT 246084	WMR 728204
Terengganu	Compt. 22, Jerangau FR	Lowland Dipterocarp	RV 565888	WMR 552643

Figure 3 The location of growth plots study

3.5 Plot Design

The size of each plot is one (1) hectare [(100 meter x 100 meter)] with 25 sub plots of 20 meter x 20 meter and 9 sub plots of 10 meter x 10 meter (Figure 4). In 20 meter x 20 meter sub plots, all trees 10cm diameter at breast height (DBH) and larger were measured while in the 10 meter x 10 meter sub plots all trees 5cm to 10cm DBH were measured (FDPM 1992).

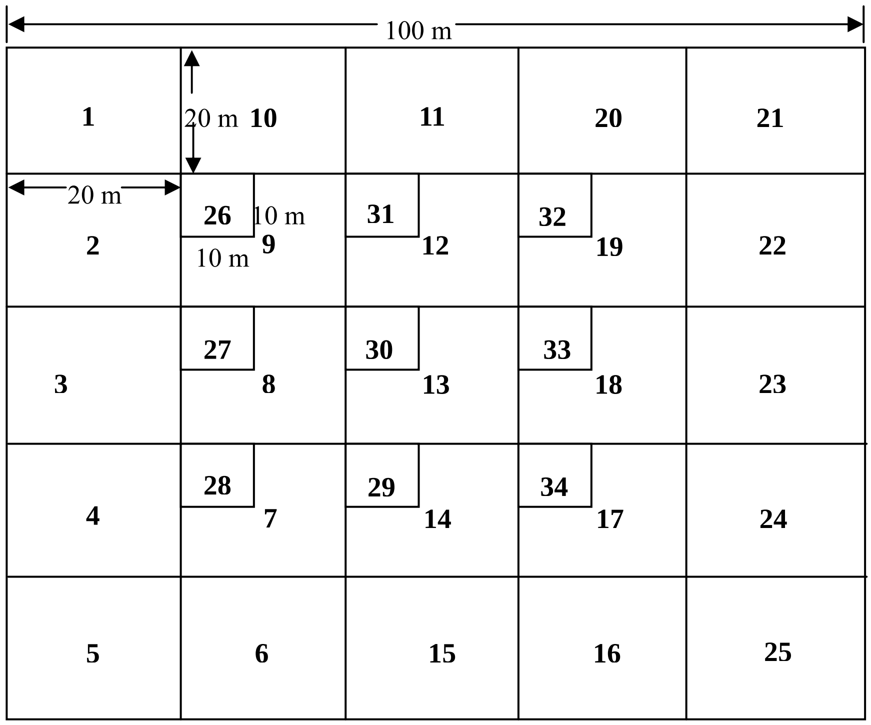


Figure 4 Layout design of growth plot in Peninsular Malaysia

3.6 Data analysis

Data collected from the study plot were entered into a computer using Microsoft EXCEL software. Subsequently, this study were used the data of the last enumeration in 2013/2014. In the analysis of maximum density limits, only trees with DBH greater than 10cm DBH and above were considered to be used. Value of ≥10cm DBH is used accordance with the practice of the Forestry Department Peninsular Malaysia (FDPM 1997). Data were analysis in terms of diameter, basal area, above ground biomass, below ground biomass and carbon stock.

Basal area

Basal area was calculated for all trees ≥10cm DBH in the plots. The following formula was used:

Tree basal area (BA) $= \pi\ (DBH/2)^2$

Where,

BA = basal area (m^2)

DBH = diameter at breast height (cm)

π = 22/7

3.7 Determination of Biomass and Carbon Stock

Determination of the biomass of trees is important to see the changes of biomass of the forest area that have been logged. In this study, the aboveground biomass is estimated by using Kato et al. (1978) allometric. This allometric is often used to estimate the aboveground biomass in many areas of lowland dipterocarp forests such as Piah Forest Reserve, Perak (Ramli 2014), Ayer Hitam Forest Reserve, Selangor (Kueh & Lim 1999) and Pasoh Forest Reserve, Negeri Sembilan (Kato et al. 1978). While, as for the determination of below ground biomass was using allometric that recommended by Niyama et al. (2010). The total aboveground biomass was estimated using regression formula from Kato et.al (1978) which is summation from weight of stems, branches and leaves. The height (H) of a given tree can be estimated from its DBH (D) by the following formula:

$$\frac{1}{H} = \frac{1}{2.0D} + \frac{1}{61}$$

Where:

H = tree height (m)

From the values of D and H, the dry mass of stem, branches, and leaves of the tree are estimated. The biomass values (kg) for stem (Ms), branches (Mb) and leaves (M_l) are calculate as follows:

$$Ms = 0.0313\ x\ (D^2H)^{0.9733}$$

Where:

M_S = Stem biomass (kg)

$$Mb = 0.136\ x\ Ms^{1.070}$$

Where:

M_b = Branch biomass (kg)

And:

$$\frac{1}{Ml} = \frac{1}{0.124Ms^{0.794}} + \frac{1}{125}$$

Where:
M_l =Leaf biomass (kg)

The total Above ground biomass (TAGB) was computed by summing the above ground biomass of individual trees ($Ms + Mb + M_l$) estimated from the above equations.

TAGB $= M_S + M_B + M_l$

Where:
TAGB= Total biomass (kg)

While for estimated below ground biomass was using Niiyama et al. (2010) which;

$$Mr = 0.023\ x\ D^{2.59}$$

Where:
Mr = below ground biomass (kg)

Therefore, the overall total amount of biomass (TB) was computed by summing the total value of above ground biomass and value of below ground biomass estimated from the above equations.

TB $= M_T + Mr$

Carbon

This study will use the assumption of carbon stocks is 50% or 0.5 of the biomass (above ground and below ground biomass) as previous studies in Ayer Hitam Forest Reserve, Selangor (Kueh & Lim 1999; Neto et.al. 2012). Determination of a community forest carbon stocks is particularly important in order to see the effects of natural disturbances and interruptions in connection with humans.

Carbon Stock Value (t/ha) = Value of above ground biomass and below ground biomass (t/ha) x 0.5

CHAPTER IV

RESULT

4.1 Composition of trees

Twenty (20) plots of 100m x100m (1 ha) each were measured for this study. Based on the result, a total of 7088 individuals trees represented from two major group of dipterocarp and non-dipterocarp. Generally, non-dipterocarp group was showed dominant than dipterocarp group. Non-dipterocarp group was contributed 6440 trees while dipterocarp indicated 648 trees only (see Figure 5).

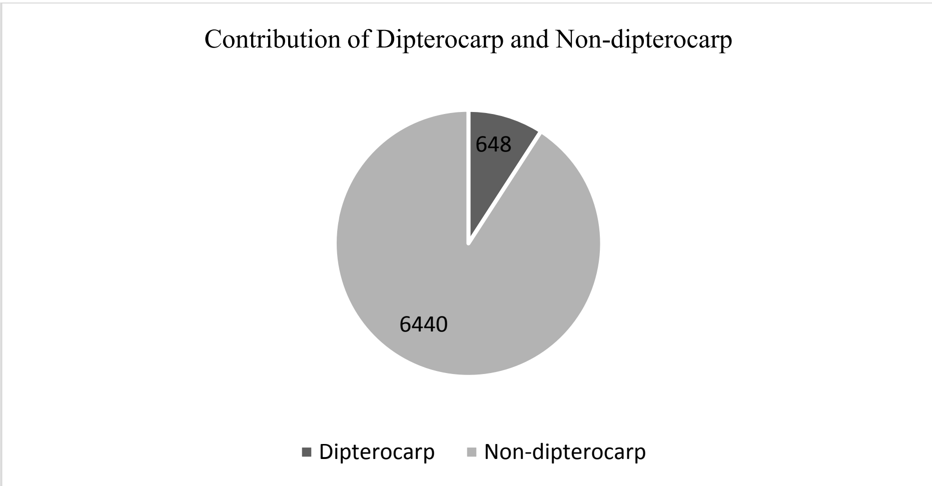


Figure 5 Contribution numbers of trees ≥10cm DBH and above in twenty (20) ha study plots, PRF.

Tree density and average DBH

In this study, tree density for Period I (16-20 years after logging) was founded 201 No/ha, Period II (21-25 years after logging) was 433 No/ha, Period III (26-30 years after logging) was 354 No/ha and Period IV (>31 years after logging)was 405 No/ha, respectively.The Period IV (>31 years after logging) contained the highest tree density, while smallest tree density was founded in Period I (16-20 years after logging). The highest average DBH was represented in Period I (16-20 years after logging) was indicated 30.0cm, followed by Period IV (>31 years after logging) 27.7cm, Period III (26-30 years after logging) 26.9cm and the lowest was in Period II (21-25 years after logging) 25.6cm. However, basal area was recorded highest in Period IV (>31 years after logging) was indicated 33.64m^2/ha, followed by Period II (21-25 years after logging) was recorded 29.36 m^2/ha, Period III (26-30 years after logging) was 27.11 m^2/ha and Period I (16-20 years after logging) was calculated 17.31 m^2/ha) (Table 7).

Table 7 Comparison of tree density (No/ha), average DBH (cm) and basal area ($m^{2/}$ha) by four (4) period years after logging.

Period (years after logging)	Tree density (No/ha)	Average DBH (cm)	Basal area (m^2/ha)
Period I (16-20 years after logging)	201	30.0	17.31
Period II (21-25 years after logging)	433	25.6	29.36
Period III (26-30 years after logging	354	26.9	27.11
Period IV (> 31 years after logging)	405	27.7	33.64

The distribution of the tree with DBH size is based on the 10cm class starting at 10cm up to >80cm. From the overall DBH distribution it is stated that DBH class with 10.0-19.9cm has the highest number of trees. Period II (21-25 years after logging) recorded 203 No/ha followed by Period IV (>31 years after logging) which is 179 No/ha, Period III (26-30 years after logging) was 157 No/ha, and Period I (16-20 years after logging) contributed smallest 54 No/ha. However, DBH size classes >80.0cm contained lowest trees. Period IV (>31 years after logging) showed 2 No/ha, followed by Period III (26-30 years after logging) was 5 No/ha, Period II (21-25 years after logging) recorded 203 No/ha and Period IV (>31 years after logging) which is 8 No/ha. All the data for the class distribution is show the in Figure 6.This is clearly reflected by the species composition of trees, density of trees in different diameter classes which gave a nearly reverse-J curve and the value of the biomass. In line DBH and tree density showed relationship in each size class. The frequency of individual tree in DBH classes showed the normal inverse J curve distribution.

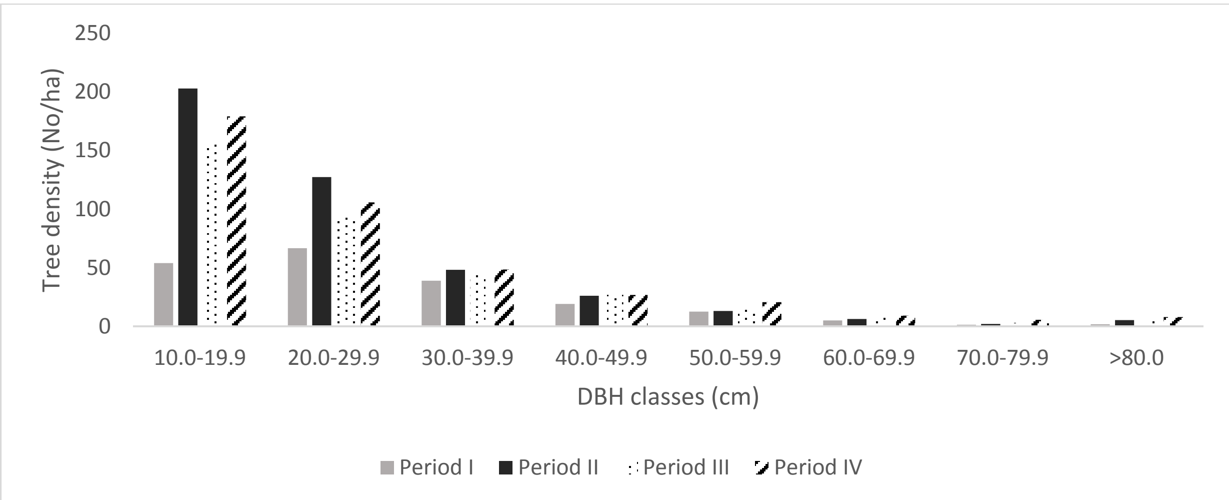


Figure 6 Distributionof tree density (No/ha) by diameter classes

4.2 Tree biomass and carbon stock

4.2.1 Estimated above ground and below ground biomass by period years after logging

The principal element for the estimation of forest's carbon stocks is the estimation of forest biomass. The study for biomass (above ground and below ground) was estimated by four (4) period years after logging to indicate the proportion of biomass. The estimated biomass for all species in the study plots was presented separately for above ground biomass and below ground biomass.

Biomass in Period I (16-20 years after logging) by study plots

Above ground biomass and below ground biomass showed variation among the study areas. Table 8 show the biomass of the forest for Period I (16-20 years after logging). Above ground biomass for Period I (16-20 years after logging) was calculated 222.54 t/ha. While below ground biomass was 46.86 t/ha. The stand-level biomass in plots ranged from 180.80 t/ha to 385.42 t/ha, with an average of 269.40 t/ha.

Table 8 Biomass (t/ha) in Period I (16-20 years after logging)

Growth plot number	AGB (t/ha)	BGB (t/ha)	Total biomass (t/ha)
GP 33	195.14	41.37	236.51
GP 42	227.16	47.71	274.87
GP 50	317.65	67.77	385.42
GP 66	150.20	30.59	180.80
Average	**222.54**	**46.86**	**269.40**

Biomass in Period II (21-25 years after logging)by study plots

Plot GP 64 in Period II (21-25 years after logging) was represented the maximum biomass 656.82 t/ha, while the minimum biomass was 322.30 t/ha represented in plot GP 5, with an average biomass was 454.81 t/ha. Above ground biomass was calculated373.38 t/ha. While below ground biomass was 81.43 t/ha (Table 9).

Table 9 Biomass (t/ha) in Period II (21-25 years after logging)

Growth plot number	AGB (t/ha)	BGB (t/ha)	Total biomass (t/ha)
GP 5	267.97	54.33	322.30
GP 9	316.22	66.96	383.18
GP 61	377.36	79.60	456.95
GP 64	531.97	124.85	656.82
Average	**373.38**	**81.43**	**454.81**

Biomass in Period III (26-30 years after logging)by study plots

Table 10 shows the biomass of Period III (26-30 years after logging). The stand-level biomass in plots ranged from 278.79 to 596.90 t/ha, with an average biomass was indicated 427.37 t/ha. Above ground biomass for Period III (26-30 years after logging) was calculated 351.18 t/ha. While below ground biomass was 76.18 t/ha.

Table 10 Biomass (t/ha) in Period III (26-30 years after logging)

Growth plot number	AGB (t/ha)	BGB (t/ha)	Total biomass (t/ha)
GP 2	482.88	114.02	596.90
GP 28	414.57	89.37	503.94
GP 23	343.76	76.26	420.02
GP 35	309.28	64.81	374.08
GP 54	231.82	46.97	278.79
GP 77	324.81	65.68	390.49
average	**351.18**	**76.18**	**427.37**

Biomass in Period IV (>31 years after logging) by study plots

Table 11 shows the biomass of Period IV (>31 years after logging). The stand-level biomass in plots ranged from 386.61 t/ha to 702.65 t/ha, with an average of 546.09 t/ha. Above ground biomass was indicated 446.89 t/ha. While below ground biomass was 99.21 t/ha.

Table 11 Biomass (t/ha) in Period IV (>31 years after logging)

Growth plot number	AGB (t/ha)	BGB (t/ha)	Total biomass (t/ha)
GP 3	537.59	124.32	661.91
GP 48	395.30	86.38	481.68
GP 11	320.22	66.39	386.61
GP 14	360.61	78.56	439.18
GP 26	572.37	130.27	702.65
GP 88	495.23	109.32	604.55
Average	**446.89**	**99.21**	**546.09**

Comparison of biomass in four (4) period years after logging

There were variations in values of biomass density among different period years after logging. Thus, among four (4) period years after logging in PRF Peninsular Malaysia, Period IV (>31 years after logging) contained the highest biomass, followed by Period II (21-25 years after logging), Period III (26-30 years after logging) and Period I (16-20 years after logging). The highest biomass was founded 546.09 t/ha in Period IV (>31 years after logging), meanwhile the lowest biomass was in Period I (16-20 years after logging) was 269.40 t/ha. Table 12 shows the comparison of biomass value for four (4) period years after logging.

Table 12 Comparison of biomass (t/ha) in four (4) period years after logging

Period (years after logging)	AGB (t/ha)	BGB (t/ha)	Total biomass (t/ha)
Period I (16-20 years after logging)	222.54	46.86	269.40
Period II (21-25 years after logging)	373.38	81.43	454.81
Period III (26-30 years after logging)	351.18	76.18	427.37
Period IV (>31 years after logging)	446.89	99.21	546.09

4.2.2 Estimated above ground biomass and below ground biomass by major group

There are a wide variations of biomass between dipterocarp and non-dipterocarp by four (4) period years after logging. The biomass density in each Period was contributed by the non-dipterocarp species which ranged from 73.62% to 94.62%. In this case, dipterocarp species showed ranged from 5.38% to 26.38% of the total of biomass (Table 13). Therefore, the contribution biomass of dipterocarp 5.38%, non-dipterocarp was 94.62% in Period I (16-20 years after logging). The biomass of dipterocarp was 9.85%, while non-dipterocarp was 90.15% in the Period II (21-25 years after logging). Dipterocarps estimated 17.90%, non-dipterocarp was 82.10% in the Period III (26-30 years after logging) and Period IV (>31 years after logging) was 26.38% for dipterocarp, while 73.62% for non-dipterocarp. The largest biomass volume of non-dipterocarp species were given in Period II (21-25 years after logging) indicated 412.20 t/ha, while the smallest biomass was in Period I (16-20 years after logging) was calculated 254.48 t/ha. The dipterocarp group was obtaining highest biomass in Period IV (>31 years after logging) was 142.12 t/ha. While the lowest biomass of dipterocarp value was belong to Period I (16-20 years after logging) was 14.92 t/ha.

Above ground biomass showed higher value in the Period II (21-25 years after logging) was 338.94 t/ha for non-dipterocarp while BGB was showing 73.26 t/ha. Furthermore, AGB was lowest value showed for non-dipterocarp was 210.28 t/ha, while BGB was 44.20 t/ha in the Period I (16-20 years after logging).

Whereas, this study area for dipterocarp group show highest AGB founded 114.86 t/ha, while BGB 27.26 t/ha in the Period IV (>31 years after logging). As a result of dipterocarp contained lowest AGB was 12.26 t/ha, which smallest BGB 2.66 t/ha in the Period I (16-20 years after logging).

Table 13 Comparison of biomass for dipterocarp and non-dipterocarp by four (4) Period years after logging

Period (Years after logging)	**DIPTEROCARP**						**NON-DIPTEROCARP**					
	Tree density (No/ha)	**%**	**AGB (t/ha)**	**BGB (t/ha)**	**Total biomass (t/ha)**	**%**	**Tree density (No/ha)**	**%**	**AGB (t/ha)**	**BGB (t/ha)**	**Total biomass (t/ha)**	**%**
Period I	8	3.54	12.26	2.66	14.92	5.38	193	96.46	210.28	44.20	254.48	94.62
Period II	33	7.84	34.44	8.17	42.61	9.85	400	92.16	338.94	73.26	412.20	90.15
Period III	32	8.48	74.47	17.88	92.35	17.90	323	91.52	276.72	58.30	335.02	82.10
Period IV	49	11.86	114.86	27.26	142.12	26.38	356	88.14	332.02	71.95	403.97	73.62

4.2.3 Estimated above ground and below ground biomass by diameter classsizes

Biomass by different diameter class sizes for Period I (16-20 years after logging)

It was found that DBH of trees were distributed varied with different size classes. Table 14 shows the distribution of diameter class for biomass values of Period I (16-20 years after logging). The DBH classes (30.0-39.9cm) was contributed highest biomass 52.58 t/ha among the DBH class, while the smallest proportion of biomass was founded in DBH class (10.0-19.9cm) contributed 10.72 t/ha.

Table 14 Total biomass (t/ha) in different diameter class sizes and tree density (No/ha) for Period I (16-20 years after logging)

DBH (cm)	Tree density (No/ha)	AGB (t/ha)	BGB (t/ha)	Total biomass (t/ha)
10.0 - 19.9	54	9.06	1.66	10.72
20.0 - 29.9	67	31.70	5.93	37.63
30.0 - 39.9	39	43.97	8.61	52.58
40.0 - 49.9	19	40.74	8.41	49.16
50.0 - 59.9	13	42.31	9.18	51.49
60.0 - 69.9	5	25.26	5.75	31.01
70.0 - 79.9	2	10.19	2.43	12.63
>80.0	2	13	4.14	20.56
Total	**201**	**222.54**	**46.86**	**269.40**

Biomass by different diameter class sizes for Period II (21-25 years after logging)

The biomass values by DBH class of Period II (21-25 years after logging) was founded highest in DBH class (>80.0 cm) about 85.89 t/ha while lower proportion of biomass among the DBH class was founded 17.76 t/ha in DBH class (70.0-79.9cm) Table 15.

Table 15 Total biomass (t/ha) in different diameter class sizes and tree density (No/ha) for Period II (21-25 years after logging)

DBH (cm)	Tree density (No/ha)	AGB (t/ha)	BGB (t/ha)	Total biomass (t/ha)
10.0 - 19.9	203	32.41	5.95	38.36
20.0 - 29.9	127	61.65	11.54	73.19
30.0 - 39.9	48	56.20	11.03	67.23
40.0 - 49.9	26	55.34	11.42	66.76
50.0 - 59.9	13	43.96	9.53	53.49
60.0 - 69.9	7	30.19	6.83	37.02
70.0 - 79.9	2	14.36	3.40	17.76
>80.0	6	67.72	18.17	85.89
Total	**433**	**373.38**	**81.43**	**454.81**

Biomass (t/ha) by different diameter class sizes for Period III (26-30 years after logging)

Table 16 shows biomass values by DBH class of Period III (26-30 years after logging). The DBH classes (>80.0cm) was contributed 75.27 t/ha which the highest biomass while DBH (70.0-79.9cm) contributed the smallest biomass 27.80 t/ha.

Table 16 Total biomass (t/ha) in different diameter class sizes and tree density (No/ha) for Period III (26-30 years after logging)

DBH (cm)	**Tree density No/ha)**	**AGB (t/ha)**	**BGB (t/ha)**	**Total biomass (t/ha)**
10.0 - 19.9	157	24.59	4.51	29.10
20.0 - 29.9	93	46.48	8.71	55.19
30.0 - 39.9	45	51.55	10.10	61.65
40.0 - 49.9	29	59.17	12.19	71.36
50.0 - 59.9	15	49.11	10.68	59.79
60.0 - 69.9	8	38.45	8.77	47.21
70.0 - 79.9	3	22.44	5.35	27.80
>80.0	5	59.40	15.87	75.27
Total	**354**	**351.18**	**76.18**	**427.37**

Biomass in different diameter class sizes for Period IV (>31 years after logging)

Table 17 shows biomass values by DBH class of Period IV (>31 years after logging). The DBH classes (>80cm) was contributed 126.51 t/ha of biomass which the highest biomass among the DBH classes, while the smallest proportion of biomass among the DBH classes was founded in DBH classes (10.0-19.9cm) contributed 32.88 t/ha.

Table 17 Total biomass (t/ha) in different diameter class sizes and tree density (No/ha) for Period IV (>31 years after logging)

DBH (cm)	**Tree density (No/ha)**	**AGB (t/ha)**	**BGB (t/ha)**	**Total biomass (t/ha)**
10.0 - 19.9	**179**	27.78	5.10	32.88
20.0 - 29.9	106	51.57	9.66	61.22
30.0 - 39.9	49	54.36	10.64	65.00
40.0 - 49.9	27	56.90	11.74	68.64
50.0 - 59.9	21	70.13	15.24	85.37
60.0 - 69.9	10	46.52	10.60	57.13
70.0 - 79.9	6	39.83	9.52	49.35
>80.0	8	99.80	26.71	126.51
Total	**405**	**446.89**	**99.21**	**546.09**

Comparison of biomass in different diameter class sizes for four (4) period years after logging

All the characteristics of diameter size classes on different period years after logging were given in Table 18. Based on results, distribution of biomass among the diameter size classes showed variability. Consequently, based on diameter class size 10.0-19.9cm showed higher biomass in Period II (21-25 years after logging) contributed 38.36 t/ha, followed by Period IV (>31 years after logging) indicated 32.88 t/ha, Period III (26-30 years after logging) was 29.10 t/ha and Period I (16-20 years after logging) was 10.72t/ha. Furthermore, diameter class sizes 50.0-59.9cm recorded highest biomass in Period IV (>31 years after logging) was 85.37 t/ha, followed by Period III (26-30 years after logging) was 59.79 t/ha, Period II (21-25 years after logging) was 53.49 t/ha and Period I (16-20 years after logging) was 51.49 t/ha. While diameter size class >80cm contributed highest biomass in Period IV (>31 years after logging) was 126.51 t/ha followed by Period II (21-25 years after logging) was 85.89 t/ha, Period III (26-30 years after logging) was 75.27 t/ha and Period I (16-20 years after logging) was 20.56 t/ha.

Table 18 Comparison of biomass (t/ha) in different diameter class sizes and tree density (No/ha) for four (4) period years after logging

	PERIOD I				**PERIOD II**				**PERIOD III**				**PERIOD IV**			
DBH (cm)	**Tree density (No/ha)**	**AGB (t/ha)**	**BGB (t/ha)**	**Biomass (t/ha)**	**Tree density (No/ha)**	**AGB (t/ha**	**BGB (t/ha)**	**Biomass (t/ha)**	**Tree density (No/ha)**	**AGB (t/ha**	**BGB (t/ha)**	**Biomass (t/ha)**	**Tree density (No/ha)**	**AGB (t/ha**	**BGB (t/ha)**	**Biomass (t/ha)**
10.0-19.9	54	9.06	1.66	10.72	203	32.41	5.95	38.36	157	24.59	4.51	29.10	179	27.78	5.10	32.88
20.0-29.9	67	31.70	5.93	37.63	127	61.65	11.54	73.19	93	46.48	8.71	55.19	106	51.57	9.66	61.22
30.0-39.9	39	43.97	8.61	52.58	48	56.20	11.03	67.23	45	51.55	10.10	61.65	49	54.36	10.64	65.00
40.0-49.9	19	40.74	8.41	49.16	26	55.34	11.42	66.76	29	59.17	12.19	71.36	27	56.90	11.74	68.64
50.0-59.9	13	42.31	9.18	51.49	13	43.96	9.53	53.49	15	49.11	10.68	59.79	21	70.13	15.24	85.37
60.0-69.9	5	25.26	5.75	31.01	7	30.19	6.83	37.02	8	38.45	8.77	47.21	10	46.52	10.60	57.13
70.0-79.9	2	10.19	2.43	12.63	2	14.36	3.40	17.76	3	22.44	5.35	27.80	6	39.83	9.52	49.35
>80	2	13	4.14	20.56	6	67.72	18.17	85.89	5	59.40	15.87	75.27	8	99.80	26.71	126.51
Total	**201**	**222.54**	**46.86**	**269.40**	**433**	**373.38**	**81.43**	**454.81**	**354**	**351.18**	**76.18**	**427.37**	**405**	**446.89**	**99.21**	**546.09**

4.3 Carbon stock

4.3.1 Estimated above ground and below ground carbon stock by period years after logging

The total biomass and carbon stock above ground and below ground showed in Table 19. Assuming that 50% of the tree biomass is carbon. It is also shows that in terms of carbon value there are variation in each period years after logging. Based on results, in the Period I (16-20 years after logging) total biomass was 269.40 t/ha,so that the value of carbon was 134.70 t C/ha. Furthermore, in Period II (21-25 years after logging) biomass indicated that 454.81 t/ha, so that carbon recorded 227.41 t C/ha. Result in Period III (26-30 years after logging) recorded the total biomass was 427.37 t/ha, indicated that carbon values was 213.68 t C/ha and Period IV (>31years after logging) showed biomass was 546.09 t/ha, which calculated 273.05 t C/ha. Consequently, the study founded that Period IV (>31 years after logging) showed higher of carbon stock, while in Period I (16-20 years after logging) showed the lower carbon stock.

Table 19 Comparison of biomass (t/ha) and carbon (t C/ha) by four (4) period years after logging

Period (Years after logging)	Biomass (t/ha)			Carbon stock (t C/ha)		
	Above ground	Below ground	Total	Above ground	Below ground	Total
Period I	222.54	46.86	269.40	111.27	23.43	134.70
Period II	373.38	81.43	454.81	186.69	40.72	227.41
Period III	351.18	76.18	427.37	175.59	38.09	213.68
Period IV	446.89	99.21	546.09	223.44	49.60	273.05

4.3.2 Estimated above ground and below ground carbon stock by major group

From the study, result of carbon value by major group has given in Table 20. The non-dipterocarp showed dominant values in carbon stock. The highest carbon in non-dipterocarp was founded in Period II (21-25 years after logging) contained 206.1 t C/ha, followed by Period IV (>31years after logging) indicated 201.99 t C/ha, Period III (26-30 years after logging) showed 167.51 t C/ha and Period I (16-20 years after logging) recorded 127.24 t C/ha, respectively. In addition, largest carbon values for dipterocarp recorded in Period IV (>31 years after logging) was 71.06 t C/ha, followed by Period III (26-30 years after logging) indicated 46.17 t C/ha, Period II (21-25 years after logging) showed 21.31 t C/ha and Period I (16-20 years after logging) calculated 7.46 t C/ha, each.

Table 20 Comparison of carbon stock for dipterocarp and non-dipterocarp by four (4) period years after logging

Period (Years after logging)	Dipterocarp		Non-dipterocarp	
	Biomass (t/ha)	Carbon (t C/ha)	Biomass (t/ha)	Carbon (t C/ha)
Period 1	14.92	7.46	254.48	127.24
Period II	42.61	21.31	412.20	206.10
Period III	92.35	46.17	335.02	167.51
Period IV	142.12	71.06	403.97	201.99

4.3.3 Estimated above ground and below ground carbon stock by diameter size classes

Based on results, distribution of carbon stock among the diameter size classes showed variability. Table 21 shows of carbon stock in four (4) period years after logging by DBH classes. Carbon stock potential in different period years after logging years was correlated to DBH size classes. Consequently, based on diameter size class 10.0-19.9cm showed higher carbon stock in Period II (21-25 years after logging) 19.18 t C/ha, followed by Period IV (>31 years after logging) 16.44 t C/ha, Period III (26-30 years after logging) 14.55 t C/ha and Period I (16-20 years after logging) 5.36t C/ha. Therefore, diameter size class 50.0-59.9cm recorded highest carbon stock in Period IV (>31 years after logging) 42.68 t C/ha, followed by Period III (26-30 years after logging) 29.89 t C/ha, Period II (21-25 years after logging) 26.75 t C/ha and Period I (16-20 years after logging) 25.74 t C/ha. While diameter size class >80 cm contributed highest carbon in Period IV (63.25 t C/ha) followed by Period II (42.95 t C/ha), Period III (37.64 t C/ha) and Period I (16-20 years after logging) 10.28 t C/ha.

Table 21 Comparison of carbon (t C/ha) in diameter size classes for four (4) period years after logging

DBH (cm)	Period I		Period II		Period III		Period IV	
	Biomass (t/ha)	Carbon (t C/ha)	Biomass (t/ha)	Carbon (t C/ha)	Biomass (t/ha)	Carbon (t C/ha)	Biomass (t/ha)	Carbon (t C/ha)
10.0-19.9	10.72	5.36	38.36	19.18	29.10	14.55	32.88	16.44
20.0-29.9	37.63	18.81	73.19	36.59	55.19	27.59	61.22	30.61
30.0-39.9	52.58	26.29	67.23	33.62	61.65	30.82	65.00	32.50
40.0-49.9	49.16	24.58	66.76	33.38	71.36	35.68	68.64	34.32
50.0-59.9	51.49	25.74	53.49	26.75	59.79	29.89	85.37	42.68
60.0-69.9	31.01	15.51	37.02	18.51	47.21	23.61	57.13	28.56
70.0-79.9	12.63	6.31	17.76	8.88	27.80	13.90	49.35	24.67
>80.0	20.56	10.28	85.89	42.95	75.27	37.64	126.51	63.25

CHAPTER V

DISCUSSION AND CONCLUSION

In this presentation study showed above ground biomass ranged from 222.54 t/ha to 446.89 t/ha. As the results of this study, biomass value was showed in agreement with mean values from the previous study estimated biomass in Pasoh Forest Reserve, Negeri Sembilan by Kato et al. (1978) in lowland dipterocarp forest which indicated the biomass contained for tree with canopy 35-40 m contribute AGB about 475 t/ha. In addition, study by Niiyama et al. (2010) founded AGB value and BGB value was 536 and 95.9 t/ha, respectively. These studies showed lowest biomass compared to biomass study in Pasoh Forest Reserve. This is because of the forest stand is still not fully recovering from early disturbance of logging activity. In the other hand, present study showed in line with study done by Ramli (2014) in Piah Forest Reserve, Perak which calculated AGB approximately to be 222.67 t/ha which have been logged in first time in 1970 and second rotation in 2011 (41 years after logging). The other disturbances forest that showed the lowest AGB was study by Faridah Hanum et al. (2002) recorded AGB was 160.8 t/ha of a 15-year-old logged over forest at Pasoh, Peninsular Malaysia which are a reasonable value for a 15-years old forest. In addition, that previous study showed of high densities of pioneer species, such as *Macaranga* spp., *Vitex pinnata* and young trees of primary species, such as *Dipterocarpus* spp. and *Shorea* spp., indicate that this forest is still in early stage of succession. This forest is recovering after disturbances in the past, mainly due to logging activities. Furthermore, the other disturbances forest was Ayer Hitam Forest Reserve showed lowest biomass values ranged 83.7 – 232.4 t/ha (Kueh & Lim 1999). According to Brown et al.(1991) the logged forest area condition inclined to have small tree size and causes of the lower in biomass content and carbon stock.

However, biomass value also depends on the altitude of the forest area. Syafinie and Ainuddin (2015) founded AGB in secondary forest was little highest about 491.00 t/ha in Bubu Forest Reserve, Perak which categorized as lowland forest. This is in consistent with present study for AGB in Period IV (>31 years after logging).The AGB value will decrease with high altitude causes of the total trees number were lower compared to lowland area which contained highest number of tree. It is show that this area was mainly recovered from the disturbance. Previous study by Hoshinzaki et al. (2013) for temporal and spatial variation of forest biomass in relation to stand dynamics in a mature, lowland tropical rainforest, Malaysia calculated changes in above ground biomass in the Pasoh Forest Reserve, Peninsular Malaysia estimated the total above ground biomass of a mature stand using tree census data obtained in a 6-ha plot every 2 years from 1994 to 1998. The total above ground biomass decreased consistently from 1994 (431 Mg ha^{-1}) to 1998(403 Mg ha^{-1}) (1 Mg = 103kg). These are much lower than that in 1973 for a 0.2 ha portion of the same area, suggesting that the the total above ground biomass reduction might have been consistent in recent decades. This trend contrasted with a major trend for neotropical forests. During 1994–1998, the forest gained 23.0 and 0.88 Mg ha^{-1} of the total above ground biomass by tree growth and recruitment, respectively, and lost 51.9 Mg ha^{-1} by mortality. Overall, the biomass decreased by 28.4 Mg ha^{-1} (i.e. 7.10 Mg $ha^{-1}\cdot year^{-1}$), which is almost equivalent to losing a 76cm-diameter living tree per hectare per year. Analysis of positive and negative components of biomass change revealed that deaths of large trees dominated the total above ground biomass decrease. The forest biomass also varied spatially, with the total above ground biomass density ranging 212–655 Mg ha^{-1}on a 0.2-ha basis (*n*= 30 subplots, 1998) and 365–440 Mg ha^{-1} on a 1 ha basis. A large decrease of the total above ground biomass density (>50 Mg per ha per 2 years) in several 0.2-ha subplots contributed to the overall decrease in the 6-ha total above ground biomass. The biomass obtained from this study is compared with other Malaysian forest areas is shows in Table 22.

In this study, comparison of the DBH class size distribution and biomass showed some evidences of biomass reduction in larger size classes, 60.0-69.9cm. Additionally (Nizami et al. 2009) reported that the tree biomass increases with the increasing diameter size class resulting from selective logging in this area. Diameter size class 60.0-69.9cm and 70.0-79.9cm Period I-Period IV showed reduction reflected of logging in excess of regrowth was also a significant cause of loss, and usually destroyed the small size of tree during the tree felling and log dragging process.

On the other hand according to Shamsudin et al.(2010) total tree density will not effect to biomass and carbon stock value because the main factor that effect biomass estimation was from DBH size and height of the tree. Since tree diameter sizes at (>80.0cm) were highest propotion of biomass when compared to other diameter size classes so carbon stock are the highest in this diameter size class. It indicated that carbon stocks potential was rely on tree diameter size class. It does not mean that other small diameter class size are not important, because the mainly groups of small tree sizes at 10.0-19.9cm will grow to bigger size in the near future. They will have greater potential for future carbon stocks if the forests are under appropriate management without human disturbances. Carbon stock was depended not only on rates of productivity but also on the size of the tree (Huston and Marland 2003).

Table 22 Aboveground biomass estimations (t/ha) in Malaysia from 1969- 2016

Region	Area / Type	Total (t/ha)	Source
Peninsular Malaysia*	All Type (average)	271	Aman and Parlan, 2009
	Undisturbed mix dipterocarp forest	360	Abu Bakar, 2000
#Peninsular Malaysia	Inland Forest (logged forest)	222.54-446.89#	Present study, 2016
	Disturbed forest	230	Abu Bakar, 2000
Perlis*	Mata Ayer Forest Reserve	402.6	Hikmat, 2005
Kedah*	Langkawi (mangrove forest)	115.56	Norhayati and Latiff, 2001
	Mount Mat Chinchang	527.94	Raffae, 2002
Negeri Sembilan*	Pasoh Forest Reserve	475	Kato et. al, 1978
	Tanjung Tuan	234.20	Mat Salleh et al. 2003
Selangor*	Ayer Hitam Forest Reserve	209-222	Ismariah and Fadli, 2007
		355	Lepun, 2002
		278	Lim and Tagat, 1983
		83.7 – 232.4	Kueh and Lim, 1999
	Bangi Forest Reserve	200.6	Norashidah, 1993
	(logged over forest)	362.32	Lajuni, 1996
Pahang*	Cameron Highlands	288	Kira, 1969
	Tasik Chini Forest Reserve	425.43	Norwahidah, 2005
	Taman Negara (Merapoh)	453.14	Norziana, 2003
	Bukit Rengit (Krau)	574	Fakhrul Hatta, 2003
	Perlok	419	Fakhrul Hatta
	Lesong Virgin Jungle Reserve	955.61	Suhaili, 2004
	Tersang Forest Reserve	383.05	Mohd Ridza, 2004
	Lepar Forest Reserve	399.01	Mohd Ridza, 2004
	Fraser Hill	306.40	Shamsul, 2002
Pahang	Mount Brinchang	242.60	Faridah Hanum et al. 2012
Terengganu*	Bukit Bauk Forest Reserve	551.2	Hikmat, 2005
Johor*	Mount West Janing	305.07	Soepadmoe, 1987
Perak	Piah Forest Reserve	222.67	Ramli, 2014
	Bubu Forest Reserve	501.74	Syafinie and Ainuddin,2015
	Ulu Endau	210.10	
	Endau-Rompin	167.49	
	Mount Pulai	320.60	Hikmat, 2005
Sarawak*	Lambir Forest Reserve	502	Yamakura et al. 1986
	Mount Mulu	280-330	Proctor et al. 1983
Sabah*	Ulu Segama	261	Pinard and Putz, 1996
	Deramakot Forest Reserve:		
	Primary Forest	482 -522	Seino et al. 2005
	Old logged Forest	483-596	
	Malua Forest Reserve	323	Saner et al. 2012
	East Coast Sabah	493	Kira, 1969

*Source from Syafinie and Ainuddin, 2015.

#Aboveground and belowground biomass were 269.40 – 546.09 t/ha.

Malaysia forest have carbon density range from 89 to 276 t C/ha in vegetation (FAO, 2005). This wide range of values shows high variation of carbon density within Malaysian forest. Cairns et al. (1997) stated that mature lowland forest have approximately 216 t C/ha while Ismariah and Ahmad Fadli (2007) estimated carbon density for logged over forest ranging from 104 t C/ha to 111 t C/ha in secondary forest. Table values of carbon density done on Malaysia available in literature.

Brown and Lugo (1982) summarized the total carbon sequestration estimates of tropical forest in Malaysia was 112.5 to 223 t C/ha, which consistent with present study. As a result of this study for Period II (21-25 years after logging) of carbon stock value was consistent with reported by Syafinie and Ainuddin (2015) were 225.55 t C/ha in Bubu Forest Reserve, Perak. Furthermore, study by Ramli (2014) in Piah Forest Reserve, Perak in production forest reported carbon value was 139.60 t C/ha. This result showed consistent with present study in Period I (16-20 years after logging). This result might be due to recover from disturbances. Based on results, carbon stock for Period I (16-20 years after logging) showed lower than study by University Putra Malaysia (2012) founded that carbon was 157.57 t C/ha in Compartment 54 Piah Forest Reserve, Kuala Kangsar, Perak. While Ayer Hitam forest Reserve, Selangor recorded the lower carbon stock ranged from 90-111 t C/ha. This forest have been logged in year 1930 that is forest ecosystem still in process from recovering from disturbance (Kueh & Lim 1999; Ismariah & Fadli 2007). It is important to preserve secondary forest as a carbon stock reservoir that could substitute primary forest in the future. In (Table 23) it showed the comparison of carbon stocks in varies forest types in Malaysia.

Table 23 Carbon stock estimations (t C/ha) in Malaysia from 1969- 2016

Region	Area/ Types	Carbon (t C/ha)	Sources
*Peninsular Malaysia	Superior	260	Abu Bakar, 2000
	Good	220	
	Moderate	190	
	Partly exploited	160	
	Disturbed	130	
	Poor edaphic and upper hill	130	
	Swamp	100	
	Mangrove	130	
*Peninsular Malaysia	Average	135.51	Aman and Parlan, 2009
Peninsular Malaysia	Inland Forest (logged forest)	134.7-273.05	Present study, 2016
*Mata Ayer, Perlis	Primary	201.3	Hikmat, 2005
*Bukit Bauk, Terengganu	Primary	275.6	
*Mt. Pulai, Johor	Primary	160.3	
*Mt. Pulai, Johor	Logged over	89.57	Kueh and Lim, 1999
*Ayer Hitam, Selangor	Logged over	104-111	Ismariah and Ahmad Fadli, 2007
*Langkawi	Mangrove	115.56	Norhayati and Latiff, 2001
**Pasoh, Negeri Sembilan	Lowland dipterocarp (logged over)	188.22	Abd Rahman and Philip, 2009
Perak	Piah Forest Reserve Lowland dipterocarp (logged over)	111.12	Ramli, 2014
	Bubu Forest Reserve	225.55	Syafinie and Ainuddin, 2015

**Source* from Syafinie and Ainuddin, 2015; ** Ramli, 2014

Based on result from this study showed the objectives of the study to estimated biomass and carbon stocks was obtained. From four (4) period years after logging showed the long spatial period years after logging contained more carbon. In addition, present study founded carbon stock vary in diameter size class. Bigger diameter class size contained more carbon. While, bigger diameter class size slow in growth rate but small and medium diameter class size were growth fast. So that it is have a great potential for carbon. Furthermore, carbon stock will increase in the future if conserve of manage the small tree at 10.0–19.9 and 30–39.9cm. Managing forest with sustainable management practice and proctect from illegal logging will avoid potential carbon loss to atmosphere. The different stage of forest growth cycle, habitat variation and tree density make biomass and carbon stock various. In overall, present result will be useful to Forestry Department Peninsular Malaysia in managing the forest. In addition, this shows that Forestry Department Peninsular Malaysia successfully managed the forest with sustainable forest management practice. Permanent reserved forest play other ecosystem services they may provide to humanity such as a particular role in social, economic, and environmental synergies because of their multi-beneficial functions for ecosystem services, including the service of carbon stock that helps mitigate global climate change. It is possible permanent reserved forest could act as carbon stock. Lastly, The *Kyoto protocol* clearly affirms the importance of increasing our understanding of forest carbon budgets and the role of forests in offsetting global carbon emission. This study has contributed in that direction. Forest managers interested in forest carbon management for stewardship purposes or to attain certification in sustainable forest management may benefit from these findings. It can also serve as basis for entry into Clean Development Mechanism (CDM) markets. It is also important for Foresty Department in planning to participate in the Reducing Emissions from Deforestation and Forest Degradation and the Role of Conservation, Sustainable Management of Forests and Enhancement of Forest Carbon Stocks in Developing Country (REDD+) program.

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APPENDIX A

Table 1 Numbers of trees ≥10cm DBH and above in twenty (20) ha plots, Permanent Reserved Forest.

Major group	Genera/Species	No. of tree
Dipterocarp	*Shorea*	357
Dipterocarp	*Dipterocarpus*	82
Dipterocarp	*Dryobalanops aromatica*	57
Dipterocarp	*Hopea*	51
Dipterocarp	*Parashorea*	46
Dipterocarp	*Vatica*	36
Dipterocarp	*Anisoptera*	14
Dipterocarp	*Neobalanocarpus sp.*	5
	subtotal	**648**
Non- Dipterocarp	*Eugenia spp.*	1541
Non- Dipterocarp	Lauraceae	724
Non- Dipterocarp	*Macaranga gigantea*	417
Non- Dipterocarp	Burseraceae	382
Non- Dipterocarp	Annonaceae	293
Non- Dipterocarp	Myristicaceae	280
Non- Dipterocarp	Sapotaceae	156
Non- Dipterocarp	*Elateriospermum*	151
Non- Dipterocarp	*Artocarpus*	121
Non- Dipterocarp	*Endospermum malaccense*	105
Non- Dipterocarp	*Ochanostachys amentacea*	95
Non- Dipterocarp	*Diospyros spp.*	93
Non- Dipterocarp	*Pometia spp.*	89
Non- Dipterocarp	Fagaceae	70
Non- Dipterocarp	*Milletia spp.*	64
Non- Dipterocarp	*Streblus sp.*	63
Non- Dipterocarp	*Dillenia reticulata*	62
Non- Dipterocarp	*Sapium baccata*	61
Non- Dipterocarp	*Barringtonia spp.*	60
Non- Dipterocarp	*Xanthophyllum spp.*	59
Non- Dipterocarp	*Xylopia spp.*	58
Non- Dipterocarp	*Pellacalyx sp.*	57
Non- Dipterocarp	*Memecylon sp.*	56
Non- Dipterocarp	*Scaphium macrocarpum*	55
Non- Dipterocarp	*Calophyllum spp.*	54
Non- Dipterocarp	*Garcinia atroviridis*	52
Non- Dipterocarp	Anacardiaceae	49
Non- Dipterocarp	*Vitex spp.*	42
Non- Dipterocarp	*Gironniera sp.*	41
Non- Dipterocarp	*Dialium spp.*	40
Non- Dipterocarp	*Porterandia sp.*	36
Non- Dipterocarp	*Pentaspadon spp.*	35

Non- Dipterocarp	*Baccaurea sp.*	34
Non- Dipterocarp	*Pentace spp.*	34
Non- Dipterocarp	*Cratoxylum spp.*	33
Non- Dipterocarp	*Neolamarckia cadamba*	32
Non- Dipterocarp	*Kokoona spp.*	31
Non- Dipterocarp	*Pithecellobium bubalinum*	31
Non- Dipterocarp	*Castanopsis spp.*	30
Non- Dipterocarp	*Koompassia excelsa*	30
Non- Dipterocarp	*Sindora spp.*	28
Non- Dipterocarp	*Breynia sp.*	27
Non- Dipterocarp	*Scorodocarpus sp.*	27
Non- Dipterocarp	*Heritiera spp.*	26
Non- Dipterocarp	*Pertusadina sp.*	25
Non- Dipterocarp	*Terminalia spp.*	25
Non- Dipterocarp	*Lagerstroemia sp.*	24
Non- Dipterocarp	*Ficus sp.*	23
Non- Dipterocarp	*Strombosia javanica*	23
Non- Dipterocarp	*Parkia spp.*	22
Non- Dipterocarp	*Xerospermum spp.*	20
Non- Dipterocarp	*Intsia palembanica*	18
Non- Dipterocarp	*Ixonanthes sp.*	18
Non- Dipterocarp	*Mallotus sp.*	18
Non- Dipterocarp	*Cyathocalyx sp.*	17
Non- Dipterocarp	*Pternandra sp.*	16
Non- Dipterocarp	*Mesua ferrea*	15
Non- Dipterocarp	*Pimeliodendron sp.*	14
Non- Dipterocarp	*Elaeocarpus sp.*	13
Non- Dipterocarp	*Nephelium spp.*	13
Non- Dipterocarp	*Pterospermum spp.*	13
Non- Dipterocarp	*Aquilaria malaccensis*	12
Non- Dipterocarp	*Durio spp.*	12
Non- Dipterocarp	*Lophopetalum spp.*	12
Non- Dipterocarp	*Pterocymbium spp.*	12
Non- Dipterocarp	*Swintonia spp.*	12
Non- Dipterocarp	*Cynometra malaccensis*	11
Non- Dipterocarp	*Mangifera spp.*	10
Non- Dipterocarp	*Saraca sp.*	10
Non- Dipterocarp	*Sonneratia sp.*	10
Non- Dipterocarp	*Aglaia spp.*	9
Non- Dipterocarp	*Coelostegia spp.*	9
Non- Dipterocarp	*Gonystylus confusus*	9
Non- Dipterocarp	Rosaceae	9
Non- Dipterocarp	*Styrax sp.*	9
Non- Dipterocarp	*Trema sp.*	9
Non- Dipterocarp	*Lansium sp.*	7
Non- Dipterocarp	*Palma palmaceae*	7
Non- Dipterocarp	*Dyera sp.*	6

Non- Dipterocarp	*Gluta spp.*	6
Non- Dipterocarp	*Alstonia spp.*	5
Non- Dipterocarp	*Bouea sp.*	5
Non- Dipterocarp	*Bridelia*	5
Non- Dipterocarp	*Lithocarpus sp.*	5
Non- Dipterocarp	Unidentifiable	5
Non- Dipterocarp	*Bombax sp.*	4
Non- Dipterocarp	*Carallia spp.*	4
Non- Dipterocarp	*Ctenolophon parvifolius*	4
Non- Dipterocarp	*Hopea sp.*	4
Non- Dipterocarp	*Neesia spp.*	4
Non- Dipterocarp	*Phyllanthus sp.*	4
Non- Dipterocarp	*Pterygota sp.*	4
Non- Dipterocarp	*Adenathera sp.*	3
Non- Dipterocarp	*Buchanania sp.*	3
Non- Dipterocarp	*Campnosperma sp.*	3
Non- Dipterocarp	*Drypetes sp.*	3
Non- Dipterocarp	*Erythrina sp.*	3
Non- Dipterocarp	*Hibiscus sp.*	3
Non- Dipterocarp	*Hydnocarpus spp.*	3
Non- Dipterocarp	*Palaquium sp.*	3
Non- Dipterocarp	*Sandoricum sp.*	3
Non- Dipterocarp	*Santiria sp.*	3
Non- Dipterocarp	*Avorrhoea sp.*	2
Non- Dipterocarp	*Cananga odoratum*	2
Non- Dipterocarp	*Citrus sp.*	2
Non- Dipterocarp	*Diplospora sp.*	2
Non- Dipterocarp	Fagraea	2
Non- Dipterocarp	*Flacourtia sp.*	2
Non- Dipterocarp	*Maesa ramentacea*	2
Non- Dipterocarp	*Parartocarpus spp.*	2
Non- Dipterocarp	*Payena sp.*	2
Non- Dipterocarp	*Sarcotheca sp.*	2
Non- Dipterocarp	*Sterculia spp.*	2
Non- Dipterocarp	*Tetrameles spp.*	2
Non- Dipterocarp	*Antidesma sp.*	1
Non- Dipterocarp	*Cedrela, Toona sp.*	1
Non- Dipterocarp	*Duabanga sp.*	1
Non- Dipterocarp	*Eurycoma sp.*	1
Non- Dipterocarp	*Ganua sp.*	1
Non- Dipterocarp	*Glochidion sp.*	1
Non- Dipterocarp	*Melanochyla sp.*	1
Non- Dipterocarp	*Ormosia sp.*	1
Non- Dipterocarp	*Prunus sp.*	1
Non- Dipterocarp	*Rhodamnia sp.*	1
Non- Dipterocarp	*Tristania spp.*	1
	subtotal	**6440**
	Total	**7088**

Appendix B

Table 2: Tree density (No/ha), average DBH (cm) and basal area (m^2) in Period I (16-20 years after logging)

Growth Plot Number	Tree Density (No/ha)	Average DBH (cm)	Basal area (m^2)
GP 33	177	29.6	15.17
GP 42	160	34.3	17.30
GP 50	269	29.9	24.28
GP 66	196	26.0	12.49
average	**201**	**30.0**	**17.31**

Table 3 Biomass (t/ha), tree density (no/ha), average DBH (cm) and basal area (m^2) in Period II (21-25 years after logging)

Growth plot number	tree density (no/ha)	Average DBH (cm)	Basal area (m^2)
GP 5	362	25.3	22.30
GP 9	548	22.3	27.03
GP 61	407	26.8	29.76
GP 64	413	27.9	38.36
average	**433**	**25.6**	**29.36**

Table 4 Biomass (t/ha), tree density (no/ha), average DBH (cm) and basal area (m^2) in Period III (26-30 years after logging)

Growth plot number	tree density (no/ha)	Average DBH (cm)	Basal area (m^2)
GP 2	404	26.5	34.88
GP 28	401	27.2	31.77
GP 23	325	26.6	25.86
GP 35	303	28.4	24.26
GP 54	305	25.6	19.23
GP 77	388	27.0	26.68
average	**354**	**26.9**	**27.11**

Table 5 Biomass (t/ha), tree density (no/ha), average DBH (cm) and basal area (m^2) in Period IV (> 31 years after logging)

Growth plot number	tree density (no/ha)	Average DBH (cm)	Basal area (m^2)
GP 3	429	27.7	39.02
GP 48	319	30.1	29.78
GP 11	456	23.6	26.25
GP 14	325	28.0	27.33
GP 26	402	30.6	41.58
GP 88	499	26.3	37.86
average	**405**	**27.7**	**33.64**

APPENDIX C

Table 6 Summary of tree density, average DBH, basal area, AGB, BGB and carbon stock in Period I (16-20 years after logging)

Species names (code)	Genera/ Species name	No. of Tree	Tree density (No/ha)	Average DBH (cm)	BA (m^2/ha)	AGB (t/ha)	BGB (t/ha)	Total biomass (t/ha)	Carbon (t C/ha)
1010200	Shorea	2	1	34.5	0.05	0.72	0.15	0.87	0.43
1010206	Shorea leprosula	4	1	29.1	0.08	0.95	0.19	1.14	0.57
1010208	Shorea macroptera	1	0	69.4	0.09	1.45	0.34	1.79	0.89
1010211	Shorea parvifolia	8	2	27.9	0.14	1.74	0.35	2.09	1.04
1010303	Shorea bracteolata	5	1	33.9	0.14	1.81	0.38	2.20	1.10
1010307	Shorea hypochra	1	0	43.8	0.04	0.50	0.10	0.60	0.30
2010600	Anisoptera	1	0	33.1	0.02	0.26	0.05	0.31	0.15
2010700	Dipterocarpus	1	0	58.5	0.07	0.98	0.22	1.20	0.60
2011000	Hopea	1	0	84.5	0.14	2.25	0.56	2.82	1.41
2011103	Hopea ferrea	4	1	38.1	0.12	1.49	0.30	1.79	0.89
2011400	Vatica	2	1	16.7	0.01	0.11	0.02	0.13	0.06
3050800	Mangifera spp.	1	0	14.2	0.00	0.03	0.01	0.04	0.02
3051100	Pentaspadon spp.	29	7	36.8	0.96	13.33	2.93	16.26	8.13
3060000	Annonaceae	20	5	23.6	0.25	2.80	0.54	3.34	1.67
3110500	Neesia spp.	2	1	35.7	0.06	0.81	0.17	0.98	0.49
3130000	Burseraceae	31	8	31.3	0.76	10.05	2.16	12.21	6.10
3370100	Calophyllum spp.	3	1	27.5	0.05	0.59	0.11	0.70	0.35
3400100	Cratoxylum spp.	1	0	42.6	0.04	0.47	0.10	0.56	0.28
3452100	Pithecellobium sp.	2	1	27.0	0.03	0.37	0.07	0.44	0.22
3452600	Sindora spp.	1	0	22.9	0.01	0.10	0.02	0.12	0.06
3770000	Sapotaceae	5	1	36.1	0.20	2.94	0.71	3.66	1.83
3770800	Palaquium sp.	2	1	40.5	0.07	0.85	0.17	1.02	0.51
3831000	Scaphium spp.	3	1	43.7	0.12	1.63	0.35	1.98	0.99
3831002	Scaphium macrocarpum	1	0	21.0	0.01	0.08	0.02	0.10	0.05
3880200	Gonystylus spp.	1	0	18.3	0.01	0.06	0.01	0.07	0.03
3880204	Gonystylus confusus	1	0	37.7	0.03	0.35	0.07	0.42	0.21
4270100	Dillenia spp.	6	2	24.3	0.07	0.78	0.15	0.92	0.46
4270107	Dillenia reticulata	23	6	39.0	0.81	11.11	2.40	13.51	6.75
4451300	Koompassia sp.	1	0	48.3	0.05	0.63	0.13	0.76	0.38
4530200	Artocarpus spp.	2	1	23.5	0.03	0.30	0.06	0.36	0.18
4530210	Artocarpus kemando	1	0	24.4	0.01	0.12	0.02	0.14	0.07
4690800	Pellacalyx sp.	16	4	27.4	0.27	3.25	0.65	3.90	1.95
5450600	Cynometra spp.	2	1	39.5	0.07	1.00	0.22	1.22	0.61
5450800	Dialium spp.	7	2	29.2	0.16	2.16	0.46	2.62	1.31
5451200	Intsia palembanica	1	0	68.4	0.09	1.40	0.33	1.73	0.86
6050000	Anacardiaceae	1	0	22.2	0.01	0.10	0.02	0.11	0.06
6280100	Diospyros spp.	7	2	22.2	0.10	1.29	0.28	1.57	0.79
6340000	Fagaceae	7	2	37.7	0.26	3.76	0.84	4.60	2.30

6340100	Castanopsis spp.	10	3	31.7	0.24	3.22	0.69	3.91	1.95
6340200	Lithocarpus sp.	1	0	20.0	0.01	0.07	0.01	0.09	0.04
6430000	Lauraceae	90	23	28.1	1.69	21.13	4.38	25.51	12.75
6550000	Myristicaceae	20	5	23.8	0.26	2.90	0.57	3.48	1.74
6550400	Myristica spp.	5	1	21.8	0.05	0.54	0.10	0.64	0.32
6550404	Myristica maingayi	2	1	19.5	0.02	0.14	0.03	0.17	0.08
6610300	Ochanostachys amentacea	11	3	24.7	0.17	2.05	0.43	2.48	1.24
6610400	Scorodocarpus sp.	4	1	27.2	0.07	0.81	0.16	0.97	0.48
6610500	Strombosia sp.	7	2	40.1	0.27	3.74	0.84	4.58	2.29
6680100	Xanthophyllum spp.	3	1	30.8	0.07	0.84	0.17	1.02	0.51
6751500	Pometia spp.	2	1	41.4	0.07	0.96	0.20	1.16	0.58
6890600	Pentace spp.	4	1	40.9	0.17	2.44	0.55	2.99	1.49
7000000	Unidentifiable	4	1	22.2	0.04	0.41	0.08	0.48	0.24
7050300	Buchanania sp.	3	1	28.1	0.05	0.53	0.10	0.63	0.31
7070400	Diplospora sp.	2	1	19.0	0.01	0.13	0.02	0.16	0.08
7110100	Bombax sp.	3	1	29.3	0.05	0.58	0.11	0.70	0.35
7160500	Kokoona spp.	13	3	25.3	0.18	1.99	0.38	2.38	1.19
7180200	Terminalia spp.	3	1	29.0	0.05	0.59	0.11	0.70	0.35
7180204	Terminalia subspathulata	2	1	33.3	0.04	0.52	0.10	0.62	0.31
7260100	Tetrameles spp.	2	1	36.1	0.06	0.81	0.17	0.97	0.49
7330800	Baccaurea sp.	2	1	16.0	0.01	0.08	0.02	0.10	0.05
7332200	Drypetes sp.	3	1	29.9	0.06	0.70	0.14	0.83	0.42
7332300	Elateriospermum	26	7	30.6	0.55	6.94	1.42	8.35	4.18
7334300	Pimeliodendron sp.	2	1	37.2	0.06	0.88	0.19	1.06	0.53
7370200	Garcinia atroviridis	1	0	17.5	0.01	0.05	0.01	0.06	0.03
7370400	Mesua ferrea	1	0	19.1	0.01	0.07	0.01	0.08	0.04
7440100	Barringtonia spp.	6	2	20.6	0.06	0.66	0.13	0.78	0.39
7450900	Erythrina sp.	3	1	36.9	0.08	1.04	0.21	1.24	0.62
7451600	Milletia spp.	2	1	22.3	0.02	0.26	0.05	0.31	0.15
7451800	Parkia spp.	2	1	27.5	0.03	0.34	0.07	0.41	0.20
7452400	Saraca sp.	1	0	24.2	0.01	0.12	0.02	0.14	0.07
7460200	Ixonanthes sp.	3	1	45.4	0.15	2.11	0.47	2.59	1.29
7480100	Lagerstroemia sp.	23	6	22.8	0.27	2.93	0.56	3.50	1.75
7490100	Hibiscus sp.	2	1	37.2	0.06	0.72	0.14	0.86	0.43
7510100	Aglaia spp.	1	0	24.5	0.01	0.12	0.02	0.14	0.07
7510800	Lansium sp.	3	1	22.0	0.03	0.34	0.06	0.40	0.20
7511100	Cedrela, Toona sp.	1	0	14.7	0.00	0.03	0.01	0.04	0.02
7530700	Streblus sp.	4	1	13.2	0.01	0.11	0.02	0.13	0.06
7570300	Eugenia spp.	176	44	28.1	3.36	42.12	8.71	50.83	25.41
7713400	Pertusadina sp.	1	0	103.2	0.21	3.50	0.94	4.45	2.22
7751300	Nephelium spp.	1	0	25.6	0.01	0.14	0.03	0.16	0.08
7751700	Xerospermum spp.	3	1	36.8	0.08	1.07	0.22	1.29	0.64
7810200	Sonneratia sp.	1	0	43.7	0.04	0.50	0.10	0.60	0.30
7830700	Pterocymbium spp.	2	1	24.6	0.02	0.25	0.05	0.30	0.15
7830800	Pterospermum spp.	1	0	27.9	0.02	0.17	0.03	0.20	0.10

7830900	Pterygota sp.	2	1	31.9	0.04	0.47	0.09	0.56	0.28
7880100	Aquilaria malaccensis	3	1	30.1	0.07	0.89	0.19	1.07	0.54
8331100	Breynia sp.	1	0	12.6	0.00	0.02	0.00	0.03	0.01
8332400	Endospermum sp.	19	5	40.8	0.73	10.12	2.19	12.32	6.16
8333500	Macaranga spp.	46	12	27.5	0.76	8.84	1.74	10.58	5.29
8333600	Mallotus sp.	3	1	18.3	0.02	0.18	0.03	0.22	0.11
8334600	Sapium sp.	13	3	32.1	0.28	3.42	0.68	4.09	2.05
8334601	Sapium baccata	1	0	41.6	0.03	0.44	0.09	0.53	0.27
8500200	Memecylon sp.	7	2	20.8	0.06	0.64	0.12	0.75	0.38
8500300	Pternandra sp.	1	0	29.8	0.02	0.20	0.04	0.24	0.12
8530300	Ficus sp.	2	1	37.2	0.07	0.96	0.21	1.17	0.59
8713000	Neolamarckia sp.	16	4	40.9	0.56	7.56	1.58	9.14	4.57
8713001	Neolamarckia cadamba	2	1	19.8	0.02	0.15	0.03	0.17	0.09
8713600	Porterandia sp.	2	1	17.2	0.01	0.11	0.02	0.13	0.06
8810100	Duabanga sp.	1	0	31.2	0.02	0.22	0.04	0.26	0.13
8910200	Gironniera sp.	2	1	17.6	0.01	0.11	0.02	0.13	0.06
8910300	Trema sp.	8	2	39.2	0.25	3.24	0.66	3.90	1.95
8930900	Vitex spp.	3	1	47.6	0.17	2.65	0.64	3.29	1.64
	Unknown	1	0	20.3	0.01	0.08	0.01	0.09	0.05
	Total	**802**	**201**	**31.5**	**17.31**	**222.54**	**46.86**	**269.40**	**134.70**

Table 7. Summary of tree density, average DBH, basal area, AGB, BGB and carbon stock in Period II (21-25years after logging)

Species names (code)	Genera/ Species name	No. of Tree	Tree density (No/ha)	Average DBH (cm)	BA (m^2/ha)	AGB (t/ha)	BGB (t/ha)	Total biomass (t/ha)	Carbon (t C/ha)
1010100	Shorea	1	0	38.9	0.03	0.38	0.08	0.45	0.23
1010102	Shorea ovata	3	1	26.5	0.04	0.50	0.10	0.60	0.30
1010200	Shorea	36	9	25.5	0.57	6.85	1.39	8.24	4.12
1010204	Shorea johorensis	1	0	17.0	0.01	0.05	0.01	0.06	0.03
1010206	Shorea leprosula	3	1	28.0	0.05	0.52	0.10	0.62	0.31
1010208	Shorea macroptera	2	1	16.9	0.01	0.09	0.02	0.11	0.06
1010209	Shorea ovalis	2	1	21.2	0.02	0.18	0.03	0.21	0.10
1010211	Shorea parvifolia	6	2	18.2	0.04	0.38	0.07	0.45	0.23
1010300	Shorea	1	0	12.9	0.00	0.02	0.00	0.03	0.01
1010303	Shorea bracteolata	1	0	23.8	0.01	0.11	0.02	0.13	0.07
1010306	Shorea henryana	6	2	40.0	0.23	3.14	0.68	3.82	1.91
2010500	Shorea	1	0	39.8	0.03	0.40	0.08	0.48	0.24
2010600	Anisoptera	2	1	45.9	0.09	1.24	0.27	1.50	0.75
2010700	Dipterocarpus	3	1	38.1	0.09	1.11	0.22	1.34	0.67
2010810	Dipterocarpus grandiflorus	6	2	23.1	0.07	0.72	0.14	0.86	0.43
2010900	Dryobalanops spp.	1	0	43.1	0.04	0.48	0.10	0.58	0.29
2011000	Hopea	4	1	59.3	0.55	9.62	3.03	12.65	6.33

2011103	Hopea ferrea	1	0	53.2	0.06	0.79	0.17	0.96	0.48
2011200	Neobalanocarpus sp.	1	0	54.3	0.06	0.83	0.18	1.01	0.50
2011300	Parashorea	39	10	21.4	0.49	6.03	1.29	7.33	3.66
2011400	Vatica	11	3	18.9	0.09	1.00	0.19	1.19	0.60
3051100	Pentaspadon spp.	3	1	26.6	0.04	0.47	0.09	0.56	0.28
3060000	Annonaceae	53	13	25.4	1.07	14.77	3.77	18.54	9.27
3062500	Xylopia spp.	14	4	22.6	0.15	1.53	0.29	1.82	0.91
3110200	Coelostegia spp.	8	2	25.9	0.12	1.33	0.26	1.58	0.79
3110300	Durio spp.	8	2	22.9	0.10	1.06	0.21	1.27	0.63
3110500	Neesia spp.	1	0	50.8	0.05	0.71	0.15	0.86	0.43
3130000	Burseraceae	108	27	28.6	2.25	29.25	6.26	35.52	17.76
3370100	Calophyllum spp.	29	7	26.8	0.47	5.57	1.11	6.68	3.34
3400100	Cratoxylum spp.	8	2	28.2	0.14	1.72	0.34	2.06	1.03
3452100	Pithecellobium sp.	4	1	29.6	0.08	0.99	0.20	1.18	0.59
3770000	Sapotaceae	30	8	26.3	0.53	6.73	1.43	8.16	4.08
3831000	Scaphium spp.	24	6	28.4	0.45	5.48	1.11	6.59	3.30
3880200	Gonystylus spp.	2	1	31.9	0.04	0.48	0.09	0.57	0.29
4270100	Dillenia spp.	16	4	27.7	0.37	5.09	1.15	6.24	3.12
4451300	Koompassia sp.	1	0	12.2	0.00	0.02	0.00	0.02	0.01
4451302	Koompassia malaccense	3	1	49.2	0.16	2.40	0.54	2.94	1.47
4530200	Artocarpus spp.	4	1	28.4	0.08	0.97	0.20	1.16	0.58
4530211	Artocarpus lanceifolius	1	0	62.9	0.08	1.16	0.26	1.42	0.71
4530213	Artocarpus nitidus	1	0	39.1	0.03	0.38	0.08	0.46	0.23
4530214	Artocarpus rigidus	1	0	52.0	0.05	0.75	0.16	0.91	0.45
4690800	Pellacalyx sp.	8	2	20.9	0.08	0.78	0.15	0.93	0.47
4830300	Heritiera spp.	13	3	22.3	0.15	1.62	0.32	1.94	0.97
5450600	Cynometra spp.	7	2	39.3	0.25	3.48	0.76	4.23	2.12
5450800	Dialium spp.	13	3	36.4	0.41	5.64	1.22	6.86	3.43
5451200	Intsia palembanica	8	2	79.3	1.21	20.20	5.51	25.71	12.85
6011000	Hopea sp.	4	1	17.1	0.02	0.21	0.04	0.25	0.12
6050000	Anacardiaceae	4	1	33.2	0.11	1.52	0.33	1.85	0.92
6050700	Gluta spp.	2	1	18.2	0.01	0.12	0.02	0.14	0.07
6051600	Swintonia spp.	2	1	37.9	0.06	0.71	0.14	0.85	0.43
6280100	Diospyros spp.	18	5	19.8	0.19	2.27	0.47	2.74	1.37
6340000	Fagaceae	25	6	24.7	0.34	3.88	0.75	4.63	2.32
6340100	Castanopsis spp.	1	0	39.5	0.03	0.39	0.08	0.47	0.24
6430000	Lauraceae	162	41	27.7	3.35	44.19	9.73	53.92	26.96
6470100	Fagraea	2	1	22.7	0.02	0.20	0.04	0.24	0.12
6530200	Artocarpus	13	3	32.9	0.32	4.06	0.83	4.89	2.45
6550000	Myristicaceae	87	22	20.4	0.88	9.89	2.03	11.91	5.96
6550400	Myristica spp.	2	1	28.0	0.04	0.52	0.11	0.62	0.31
6610300	Ochanostachys amentacea	21	5	39.0	0.76	10.52	2.29	12.81	6.41
6610400	Scorodocarpus sp.	8	2	34.4	0.21	2.71	0.55	3.27	1.63
6610500	Strombosia sp.	2	1	14.2	0.01	0.06	0.01	0.07	0.04
6680100	Xanthophyllum spp.	17	4	22.2	0.20	2.23	0.44	2.66	1.33
6700000	Rosaceae	6	2	23.9	0.07	0.70	0.13	0.83	0.42
6751500	Pometia spp.	13	3	23.9	0.16	1.81	0.35	2.16	1.08
6890600	Pentace spp.	11	3	21.7	0.11	1.17	0.22	1.40	0.70
7050000	Anarcadiaceae	17	4	24.7	0.23	2.57	0.50	3.07	1.54
7050200	Bouea sp.	1	0	19.6	0.01	0.07	0.01	0.08	0.04
7050300	Buchanania sp.	1	0	36.9	0.03	0.33	0.07	0.40	0.20
7060400	Cyathocalyx sp.	9	2	17.2	0.05	0.46	0.08	0.54	0.27
7160500	Kokoona spp.	5	1	25.9	0.09	1.17	0.24	1.40	0.70

7160600	Lophopetalum spp.	3	1	26.9	0.06	0.86	0.18	1.04	0.52
7180200	Terminalia spp.	1	0	58.9	0.07	1.00	0.22	1.22	0.61
7330800	Baccaurea sp.	9	2	18.6	0.07	0.80	0.16	0.95	0.48
7332300	Elateriospermum	12	3	35.1	0.34	4.48	0.94	5.41	2.71
7334300	Pimeliodendron sp.	7	2	20.6	0.07	0.85	0.17	1.02	0.51
7350300	Flacourtia sp.	1	0	10.9	0.00	0.02	0.00	0.02	0.01
7370200	Garcinia atroviridis	22	6	18.3	0.17	1.72	0.33	2.05	1.03
7370400	Mesua ferrea	7	2	37.0	0.25	3.57	0.80	4.37	2.18
7440100	Barringtonia spp.	20	5	16.8	0.11	1.00	0.18	1.19	0.59
7451600	Milletia spp.	33	8	28.1	0.67	8.59	1.83	10.42	5.21
7451800	Parkia spp.	5	1	21.9	0.05	0.51	0.09	0.60	0.30
7452400	Saraca sp.	1	0	11.6	0.00	0.02	0.00	0.02	0.01
7460100	Ctenolophon parvifolius	3	1	36.1	0.08	1.06	0.22	1.28	0.64
7460200	Ixonanthes sp.	6	2	17.1	0.04	0.31	0.06	0.37	0.19
7480100	Lagerstroemia sp.	1	0	49.2	0.05	0.66	0.14	0.80	0.40
7510100	Aglaia spp.	3	1	16.7	0.02	0.14	0.03	0.17	0.09
7530700	Streblus sp.	4	1	21.2	0.05	0.66	0.14	0.80	0.40
7570300	Eugenia spp.	382	96	23.2	5.41	66.47	14.15	80.62	40.31
7610500	Strombosia javanica	1	0	12.6	0.00	0.02	0.00	0.03	0.01
7640100	Avorrhoea sp.	1	0	44.5	0.04	0.52	0.11	0.63	0.31
7713400	Pertusadina sp.	1	0	85.8	0.14	2.33	0.59	2.92	1.46
7751300	Nephelium spp.	2	1	17.8	0.01	0.12	0.02	0.14	0.07
7751700	Xerospermum spp.	8	2	20.4	0.07	0.64	0.12	0.76	0.38
7830700	Pterocymbium spp.	6	2	36.8	0.20	2.70	0.58	3.28	1.64
7830800	Pterospermum spp.	7	2	25.8	0.12	1.44	0.30	1.74	0.87
7830900	Pterygota sp.	1	0	28.7	0.02	0.18	0.03	0.21	0.11
7831100	Sterculia spp.	2	1	19.7	0.02	0.16	0.03	0.19	0.10
7840100	Styrax sp.	4	1	18.5	0.03	0.25	0.05	0.29	0.15
7880100	Aquilaria malaccensis	5	1	39.5	0.16	2.05	0.42	2.47	1.24
8050400	Campnosperma sp.	1	0	22.8	0.01	0.10	0.02	0.12	0.06
8070100	Alstonia spp.	1	0	17.2	0.01	0.05	0.01	0.06	0.03
8290100	Elaeocarpus sp.	2	1	17.7	0.01	0.12	0.02	0.14	0.07
8331100	Breynia sp.	12	3	22.7	0.13	1.44	0.27	1.71	0.86
8332400	Endospermum sp.	43	11	21.6	0.45	4.78	0.92	5.71	2.85
8333500	Macaranga spp.	115	29	21.4	1.16	12.20	2.35	14.54	7.27
8333600	Mallotus sp.	2	1	18.3	0.01	0.12	0.02	0.14	0.07
8334600	Sapium sp.	15	4	31.2	0.31	3.70	0.73	4.42	2.21
8500200	Memecylon sp.	9	2	19.7	0.08	0.85	0.16	1.01	0.51
8500300	Pternandra sp.	2	1	38.9	0.07	0.95	0.20	1.15	0.57
8530300	Ficus sp.	5	1	38.5	0.23	3.44	0.83	4.27	2.13
8713000	Neolamarckia sp.	11	3	22.9	0.14	1.60	0.32	1.92	0.96
8910200	Gironniera sp.	18	5	20.7	0.17	1.80	0.34	2.15	1.07
8910300	Trema sp.	1	0	12.9	0.00	0.02	0.00	0.03	0.01
8930900	Vitex spp.	3	1	21.5	0.03	0.33	0.06	0.39	0.19
	Total	**1730**	**433**	**29.0**	**29.36**	**373.38**	**81.43**	**454.81**	**227.41**

Table 8. Summary of tree density, average DBH, basal area, AGB, BGB and carbon stock in Period III (26-30 years after logging)

Species names (code)	Species name	No. of Tree	Tree density (No/ha)	Average DBH (cm)	BA (m^2/ha)	AGB (t/ha)	BGB (t/ha)	Total biomass (t/ha)	Carbon (t C/ha)
1010100	Shorea	7	1	33.5	0.12	1.51	0.31	1.82	0.91
1010101	Shorea curtisii	2	0	75.6	0.17	2.77	0.73	3.50	1.75
1010104	Shorea pauciflora	1	0	30.2	0.01	0.14	0.03	0.16	0.08
1010200	Shorea	40	7	40.4	1.27	19.17	4.81	23.98	11.99
1010205	Shorea lepidota	1	0	18.8	0.00	0.04	0.01	0.05	0.02
1010206	Shorea leprosula	20	3	33.7	0.39	5.46	1.24	6.70	3.35
1010208	Shorea macroptera	1	0	47.4	0.03	0.40	0.08	0.49	0.24
1010209	Shorea ovalis	4	1	36.5	0.09	1.31	0.29	1.60	0.80
1010211	Shorea parvifolia	17	3	42.1	0.55	8.28	1.99	10.27	5.13
1010300	Shorea	4	1	40.4	0.13	2.01	0.50	2.50	1.25
1010303	Shorea bracteolata	5	1	37.5	0.11	1.41	0.30	1.71	0.86
1010400	Shorea	3	1	43.3	0.07	0.99	0.20	1.20	0.60
2010500	Shorea	5	1	56.4	0.25	3.77	0.92	4.69	2.34
2010508	Shorea guiso	1	0	20.2	0.01	0.05	0.01	0.06	0.03
2010600	Anisoptera	5	1	48.6	0.20	3.12	0.75	3.87	1.93
2010700	Dipterocarpus	39	7	40.8	1.24	18.72	4.66	23.38	11.69
2010703	Dipterocarpus cornutus	4	1	30.4	0.05	0.62	0.12	0.74	0.37
2010800	Dipterocarpus	1	0	22.1	0.01	0.06	0.01	0.07	0.04
2010900	Dryobalanops spp.	1	0	13.3	0.00	0.02	0.00	0.02	0.01
2010902	Dryobalanops oblongifolia	1	0	43.0	0.02	0.32	0.07	0.38	0.19
2011000	Hopea	22	4	29.8	0.30	3.72	0.75	4.47	2.24
2011200	Neobalanocarpus sp.	1	0	40.3	0.02	0.27	0.06	0.33	0.16
2011400	Vatica	6	1	19.8	0.03	0.31	0.06	0.36	0.18
3050400	Campnosperma spp.	1	0	46.0	0.03	0.37	0.08	0.45	0.23
3051100	Pentaspadon spp.	3	1	27.3	0.03	0.36	0.07	0.43	0.22
3060000	Annonaceae	48	8	22.8	0.39	4.51	0.90	5.41	2.70
3062500	Xylopia spp.	26	4	23.9	0.23	2.61	0.51	3.12	1.56
3070300	Dyera sp.	2	0	13.3	0.00	0.03	0.01	0.04	0.02
3110200	Coelostegia spp.	1	0	13.3	0.00	0.02	0.00	0.02	0.01
3110300	Durio spp.	1	0	23.9	0.01	0.08	0.01	0.09	0.05
3130000	Burseraceae	129	22	26.5	1.56	19.82	4.19	24.02	12.01
3130400	Santiria sp.	1	0	34.2	0.02	0.18	0.04	0.22	0.11
3370100	Calophyllum spp.	10	2	32.7	0.19	2.68	0.59	3.27	1.63
3400100	Cratoxylum spp.	22	4	24.7	0.23	2.85	0.59	3.45	1.72
3452100	Pithecellobium sp.	10	2	27.4	0.12	1.43	0.29	1.71	0.86
3452600	Sindora spp.	8	1	46.0	0.26	3.81	0.86	4.68	2.34
3770000	Sapotaceae	59	10	21.7	0.45	5.09	1.00	6.09	3.05
3770300	Ganua sp.	1	0	14.5	0.00	0.02	0.00	0.03	0.01
3770800	Palaquium sp.	1	0	28.8	0.01	0.12	0.02	0.14	0.07
3831000	Scaphium spp.	16	3	34.8	0.30	4.06	0.86	4.92	2.46
3880200	Gonystylus spp.	2	0	14.2	0.01	0.04	0.01	0.05	0.02
4270100	Dillenia spp.	6	1	40.9	0.16	2.17	0.47	2.64	1.32
4451300	Koompassia sp.	13	2	49.6	0.60	9.40	2.42	11.81	5.91

4451301	Koompassia excelsa	1	0	44.5	0.03	0.35	0.07	0.42	0.21
4451302	Koompassia malaccense	1	0	65.9	0.06	0.86	0.20	1.06	0.53
4530200	Artocarpus spp.	16	3	25.7	0.18	2.33	0.49	2.81	1.41
4530209	Artocarpus int.f.silvestris	6	1	18.0	0.03	0.23	0.04	0.28	0.14
4530211	Artocarpus lanceifolius	1	0	51.3	0.03	0.48	0.10	0.59	0.29
4690300	Carallia spp.	1	0	15.7	0.00	0.03	0.00	0.03	0.02
4690800	Pellacalyx sp.	18	3	24.2	0.19	2.32	0.50	2.82	1.41
4830300	Heritiera spp.	3	1	32.5	0.06	0.77	0.17	0.94	0.47
5450602	Cynometra malaccensis	1	0	58.4	0.04	0.65	0.14	0.80	0.40
5450800	Dialium spp.	10	2	39.9	0.24	3.32	0.72	4.04	2.02
5451200	Intsia palembanica	6	1	43.8	0.17	2.37	0.51	2.88	1.44
6050000	Anacardiaceae	7	1	36.7	0.14	1.95	0.41	2.36	1.18
6050700	Gluta spp.	2	0	45.4	0.08	1.16	0.28	1.43	0.72
6051600	Swintonia spp.	3	1	34.6	0.06	0.90	0.20	1.10	0.55
6280100	Diospyros spp.	18	3	19.0	0.10	1.11	0.22	1.33	0.66
6340000	Fagaceae	20	3	26.8	0.24	3.03	0.64	3.67	1.83
6340100	Castanopsis spp.	6	1	36.0	0.11	1.33	0.27	1.60	0.80
6340200	Lithocarpus sp.	1	0	27.3	0.01	0.11	0.02	0.13	0.06
6430000	Lauraceae	299	50	26.1	3.51	44.48	9.47	53.95	26.98
6530200	Artocarpus	14	2	24.0	0.14	1.65	0.33	1.99	0.99
6530204	Artocarpus elasticus	3	1	30.0	0.05	0.59	0.12	0.71	0.36
6550000	Myristicaceae	54	9	22.8	0.43	4.90	0.96	5.86	2.93
6550400	Myristica spp.	2	0	14.5	0.01	0.04	0.01	0.05	0.03
6610300	Ochanostachys amentacea	15	3	19.6	0.08	0.83	0.16	0.98	0.49
6610400	Scorodocarpus sp.	13	2	22.8	0.12	1.50	0.32	1.83	0.91
6610500	Strombosia sp.	2	0	32.2	0.04	0.52	0.11	0.63	0.31
6680100	Xanthophyllum spp.	13	2	28.0	0.18	2.42	0.52	2.93	1.47
6700000	Rosaceae	2	0	69.4	0.13	1.94	0.45	2.40	1.20
6751500	Pometia spp.	13	2	29.5	0.20	2.73	0.61	3.34	1.67
6890600	Pentace spp.	8	1	40.5	0.21	3.02	0.67	3.70	1.85
7000000	Unidentifiable	1	0	16.9	0.00	0.03	0.01	0.04	0.02
7050000	Anarcadiaceae	1	0	14.3	0.00	0.02	0.00	0.02	0.01
7060400	Cyathocalyx sp.	4	1	26.1	0.04	0.39	0.07	0.46	0.23
7160500	Kokoona spp.	4	1	34.2	0.07	0.85	0.17	1.02	0.51
7160600	Lophopetalum spp.	7	1	22.8	0.05	0.53	0.10	0.63	0.32
7180200	Terminalia spp.	13	2	20.6	0.10	1.17	0.25	1.42	0.71
7330800	Baccaurea sp.	13	2	21.5	0.09	0.93	0.18	1.11	0.55
7332300	Elateriospermum	53	9	27.0	0.65	8.13	1.69	9.81	4.91
7370200	Garcinia atroviridis	13	2	17.6	0.06	0.55	0.10	0.65	0.33
7370400	Mesua ferrea	3	1	43.5	0.09	1.25	0.27	1.52	0.76
7440100	Barringtonia spp.	14	2	24.9	0.15	1.93	0.40	2.33	1.16
7450100	Adenathera sp.	1	0	24.0	0.01	0.08	0.01	0.09	0.05
7451600	Milletia spp.	4	1	17.4	0.02	0.15	0.03	0.17	0.09
7451800	Parkia spp.	5	1	33.8	0.09	1.13	0.23	1.37	0.68
7452400	Saraca sp.	4	1	33.5	0.07	0.88	0.18	1.05	0.53
7460100	Ctenolophon parvifolius	1	0	47.5	0.03	0.40	0.08	0.49	0.24

7460200	Ixonanthes sp.	2	0	38.5	0.04	0.51	0.10	0.61	0.30
7490100	Hibiscus sp.	1	0	18.1	0.00	0.04	0.01	0.04	0.02
7510100	Aglaia spp.	2	0	22.2	0.01	0.14	0.03	0.17	0.09
7511000	Sandoricum sp.	2	0	20.1	0.01	0.10	0.02	0.12	0.06
7530500	Parartocarpus spp.	1	0	24.0	0.01	0.08	0.01	0.09	0.05
7530700	Streblus sp.	48	8	27.6	0.61	7.65	1.59	9.23	4.62
7570300	Eugenia spp.	496	83	23.5	4.72	57.48	11.96	69.43	34.72
7570700	Rhodamnia sp.	1	0	22.3	0.01	0.06	0.01	0.08	0.04
7640100	Avorrhoea sp.	1	0	39.6	0.02	0.26	0.05	0.32	0.16
7640200	Sarcotheca sp.	1	0	18.3	0.00	0.04	0.01	0.05	0.02
7720400	Citrus sp.	1	0	11.3	0.00	0.01	0.00	0.01	0.01
7751300	Nephelium spp.	5	1	27.3	0.07	0.98	0.22	1.20	0.60
7751700	Xerospermum spp.	8	1	22.6	0.06	0.63	0.12	0.76	0.38
7830700	Pterocymbium spp.	3	1	17.1	0.01	0.11	0.02	0.13	0.06
7840100	Styrax sp.	5	1	27.1	0.05	0.58	0.11	0.69	0.34
7880100	Aquilaria malaccensis	2	0	29.0	0.02	0.26	0.05	0.31	0.16
8070100	Alstonia spp.	3	1	21.9	0.02	0.27	0.05	0.33	0.16
8290100	Elaeocarpus sp.	6	1	33.0	0.09	1.12	0.22	1.34	0.67
8330400	Antidesma sp.	1	0	47.1	0.03	0.40	0.08	0.48	0.24
8331100	Breynia sp.	1	0	15.5	0.00	0.03	0.00	0.03	0.01
8331200	Bridelia	2	0	57.6	0.11	1.66	0.41	2.06	1.03
8332400	Endospermum sp.	7	1	24.3	0.07	0.83	0.16	0.99	0.50
8332401	Endospermum malaccense	3	1	36.1	0.06	0.85	0.18	1.04	0.52
8333500	Macaranga spp.	166	28	28.3	2.14	26.87	5.55	32.42	16.21
8333501	Macaranga gigantea	5	1	25.2	0.05	0.58	0.12	0.70	0.35
8333600	Mallotus sp.	11	2	20.6	0.07	0.82	0.16	0.99	0.49
8334600	Sapium sp.	9	2	26.6	0.09	1.09	0.21	1.31	0.65
8334601	Sapium baccata	3	1	26.9	0.03	0.38	0.07	0.45	0.23
8500200	Memecylon sp.	18	3	22.9	0.14	1.55	0.30	1.85	0.92
8530300	Ficus sp.	7	1	18.9	0.04	0.39	0.08	0.47	0.23
8713000	Neolamarckia sp.	4	1	26.0	0.05	0.63	0.13	0.76	0.38
8713600	Porterandia sp.	10	2	24.8	0.09	1.06	0.21	1.27	0.64
8910200	Gironniera sp.	6	1	16.8	0.02	0.20	0.04	0.24	0.12
8930900	Vitex spp.	32	5	24.6	0.27	3.00	0.57	3.57	1.79
	Unknown	2	0	17.9	0.01	0.08	0.01	0.09	0.05
	Total	**2126**	**354**	**30.2**	**27.11**	**351.18**	**76.18**	**427.37**	**213.68**

Table 9. Summary of tree density, average DBH, basal area, AGB, BGB and carbon stock in Period IV (>31years after logging)

Species names (code)	Species name	No. of Tree	Tree density (No/ha)	Average DBH (cm)	BA (m^2/ha)	AGB (t/ha)	BGB (t/ha)	Total biomass (t/ha)	Carbon (t C/ha)
1010100	Shorea	22	4	56.60455	1.23	19.57	5.07	24.64	12.32
1010102	Shorea ovata	1	0	18.5	0.00	0.04	0.01	0.05	0.02
1010104	Shorea pauciflora	2	0	20	0.01	0.13	0.03	0.16	0.08
1010200	Shorea	38	6	39	0.98	14.10	3.20	17.30	8.65
1010201	Shorea acuminata	4	1	45.625	0.21	3.45	0.97	4.43	2.21
1010203	Shorea hemsleyyana	1	0	42.4	0.02	0.31	0.06	0.37	0.19
1010204	Shorea johorensis	4	1	19.925	0.02	0.23	0.04	0.27	0.14
1010206	Shorea leprosula	9	2	35.12222	0.18	2.51	0.56	3.06	1.53
1010207	Shorea macrantha	1	0	34.2	0.02	0.18	0.04	0.22	0.11
1010208	Shorea macroptera	4	1	21.65	0.03	0.25	0.05	0.30	0.15
1010209	Shorea ovalis	4	1	39.75	0.10	1.35	0.29	1.64	0.82
1010211	Shorea parvifolia	5	1	55.3	0.24	3.74	0.90	4.63	2.32
1010300	Shorea	20	3	42.74	0.63	9.27	2.14	11.41	5.70
1010301	Shorea assamica	5	1	30.64	0.10	1.52	0.36	1.88	0.94
1010303	Shorea bracteolata	3	1	41.06667	0.07	1.02	0.22	1.23	0.62
1010400	Shorea	27	5	44.36667	0.98	14.99	3.80	18.79	9.40
1010402	Shorea dolichocarpa	4	1	33.375	0.09	1.39	0.33	1.72	0.86
2010500	Shorea	7	1	31.48571	0.14	1.93	0.45	2.37	1.19
2010508	Shorea guiso	1	0	11.9	0.00	0.01	0.00	0.02	0.01
2010600	Anisoptera	6	1	42.68333	0.19	2.71	0.63	3.34	1.67
2010700	Dipterocarpus	25	4	40.86	0.76	11.25	2.66	13.91	6.95
2010703	Dipterocarpus cornutus	1	0	18.1	0.00	0.04	0.01	0.04	0.02
2010800	Dipterocarpus	2	0	46.8	0.06	0.84	0.18	1.01	0.51
2010900	Dryobalanops spp.	36	6	30.76667	0.54	7.00	1.45	8.45	4.23
2010901	Dryobalanops aromatica	18	3	34.55556	0.38	5.42	1.22	6.64	3.32
2011000	Hopea	19	3	26.35789	0.21	2.54	0.52	3.06	1.53
2011200	Neobalanocarpus sp.	3	1	19.8	0.02	0.16	0.03	0.18	0.09
2011300	Parashorea	7	1	52.47143	0.31	4.69	1.14	5.83	2.91
2011400	Vatica	17	3	33.84706	0.32	4.25	0.91	5.16	2.58
3050400	Campnosperma spp.	1	0	36.3	0.02	0.21	0.04	0.26	0.13
3050800	Mangifera spp.	9	2	29.3	0.12	1.56	0.32	1.88	0.94
3060000	Annonaceae	171	29	20.9	1.18	13.00	2.57	15.57	7.78
3062500	Xylopia spp.	18	3	21.1	0.12	1.20	0.23	1.43	0.72
3070300	Dyera sp.	4	1	24.0	0.04	0.43	0.08	0.51	0.26
3110300	Durio spp.	3	1	17.2	0.01	0.11	0.02	0.13	0.06
3110500	Neesia spp.	1	0	17.3	0.00	0.03	0.01	0.04	0.02

3130000	Burseraceae	114	19	22.5	1.00	11.97	2.45	14.41	7.21
3130400	Santiria sp.	2	0	26.8	0.02	0.20	0.04	0.24	0.12
3370100	Calophyllum spp.	14	2	28.0	0.18	2.26	0.47	2.73	1.36
3400100	Cratoxylum spp.	2	0	39.9	0.06	0.80	0.18	0.98	0.49
3452100	Pithecellobium sp.	14	2	17.1	0.06	0.52	0.10	0.61	0.31
3452101	Pithecellobium bubalinum	1	0	17.7	0.00	0.04	0.01	0.04	0.02
3452600	Sindora spp.	19	3	48.4	0.81	12.54	3.13	15.68	7.84
3770000	Sapotaceae	62	10	27.8	0.92	12.55	2.79	15.34	7.67
3770900	Payena sp.	2	0	17.2	0.01	0.07	0.01	0.08	0.04
3831000	Scaphium spp.	11	2	32.2	0.21	3.01	0.68	3.68	1.84
3880200	Gonystylus spp.	3	1	36.7	0.06	0.88	0.19	1.07	0.53
4270100	Dillenia spp.	11	2	22.6	0.09	1.07	0.21	1.28	0.64
4451300	Koompassia sp.	9	2	42.8	0.29	4.22	0.97	5.19	2.60
4451302	Koompassia malaccense	1	0	18.5	0.00	0.04	0.01	0.05	0.02
4530200	Artocarpus spp.	45	8	36.9	1.10	15.92	3.70	19.61	9.81
4530209	Artocarpus int.f.silvestris	1	0	37.1	0.02	0.22	0.04	0.27	0.13
4530211	Artocarpus lanceifolius	5	1	19.6	0.03	0.26	0.05	0.31	0.16
4530214	Artocarpus rigidus	2	0	18.8	0.01	0.10	0.02	0.12	0.06
4690300	Carallia spp.	3	1	24.2	0.02	0.25	0.05	0.30	0.15
4690800	Pellacalyx sp.	15	3	25.3	0.15	1.84	0.37	2.21	1.11
4830300	Heritiera spp.	9	2	31.9	0.14	1.75	0.36	2.10	1.05
5450600	Cynometra spp.	1	0	20.0	0.01	0.05	0.01	0.06	0.03
5450800	Dialium spp.	10	2	47.1	0.38	5.75	1.39	7.15	3.57
5451200	Intsia palembanica	3	1	23.5	0.02	0.25	0.05	0.29	0.15
6050000	Anacardiaceae	11	2	25.7	0.16	2.23	0.51	2.74	1.37
6050700	Gluta spp.	2	0	19.4	0.01	0.12	0.02	0.15	0.07
6050900	Melanochyla sp.	1	0	17.7	0.00	0.04	0.01	0.04	0.02
6051600	Swintonia spp.	7	1	42.4	0.21	2.97	0.67	3.64	1.82
6280100	Diospyros spp.	50	8	20.3	0.34	3.86	0.77	4.63	2.31
6340000	Fagaceae	18	3	29.3	0.27	3.58	0.79	4.37	2.19
6340100	Castanopsis spp.	13	2	38.0	0.32	4.62	1.06	5.68	2.84
6340200	Lithocarpus sp.	3	1	28.1	0.04	0.58	0.12	0.70	0.35
6430000	Lauraceae	173	29	27.9	2.41	31.82	7.10	38.92	19.46
6530200	Artocarpus	5	1	29.3	0.07	0.95	0.20	1.15	0.58
6550000	Myristicaceae	97	16	23.3	0.88	10.58	2.20	12.78	6.39
6550400	Myristica spp.	11	2	19.9	0.07	0.71	0.14	0.85	0.42
6610300	Ochanostachys amentacea	48	8	28.1	0.64	8.27	1.76	10.03	5.02
6610400	Scorodocarpus sp.	2	0	51.1	0.07	0.96	0.20	1.16	0.58
6610500	Strombosia sp.	10	2	21.5	0.07	0.79	0.15	0.94	0.47
6680100	Xanthophyllum spp.	26	4	30.1	0.40	5.17	1.10	6.27	3.13
6700000	Rosaceae	1	0	29.5	0.01	0.13	0.02	0.15	0.08
6751500	Pometia spp.	61	10	28.6	0.86	11.17	2.36	13.53	6.76
6890600	Pentace spp.	11	2	24.2	0.15	2.04	0.48	2.52	1.26
7050000	Anarcadiaceae	8	1	18.2	0.04	0.39	0.07	0.46	0.23
7050200	Bouea sp.	4	1	31.8	0.07	0.88	0.18	1.07	0.53
7050300	Buchanania sp.	1	0	27.2	0.01	0.11	0.02	0.13	0.06
7060400	Cyathocalyx sp.	4	1	23.9	0.03	0.34	0.06	0.41	0.20

7110100	Bombax sp.	1	0	12.7	0.00	0.02	0.00	0.02	0.01
7160500	Kokoona spp.	9	2	46.2	0.41	6.66	1.79	8.45	4.22
7160600	Lophopetalum spp.	2	0	53.4	0.07	1.06	0.23	1.29	0.64
7180200	Terminalia spp.	6	1	26.4	0.09	1.21	0.27	1.48	0.74
7330800	Baccaurea sp.	10	2	25.2	0.10	1.18	0.23	1.42	0.71
7332300	Elateriospermum	60	10	31.4	0.94	12.17	2.53	14.69	7.35
7334200	Phyllanthus sp.	4	1	25.2	0.04	0.39	0.08	0.47	0.23
7334300	Pimeliodendron sp.	5	1	24.7	0.05	0.58	0.12	0.70	0.35
7350300	Flacourtia sp.	1	0	12.4	0.00	0.01	0.00	0.02	0.01
7350600	Hydnocarpus spp.	3	1	20.2	0.02	0.16	0.03	0.19	0.09
7370200	Garcinia atroviridis	16	3	23.9	0.14	1.69	0.34	2.02	1.01
7370400	Mesua ferrea	4	1	31.4	0.06	0.70	0.14	0.84	0.42
7440100	Barringtonia spp.	20	3	19.4	0.12	1.29	0.25	1.54	0.77
7450100	Adenathera sp.	2	0	19.1	0.01	0.09	0.02	0.10	0.05
7451600	Milletia spp.	25	4	31.3	0.40	5.20	1.10	6.31	3.15
7451700	Ormosia sp.	1	0	16.2	0.00	0.03	0.01	0.03	0.02
7451800	Parkia spp.	10	2	32.0	0.15	1.89	0.38	2.27	1.14
7452400	Saraca sp.	4	1	18.9	0.02	0.19	0.04	0.23	0.11
7460200	Ixonanthes sp.	7	1	26.3	0.10	1.30	0.29	1.59	0.80
7510100	Aglaia spp.	3	1	32.2	0.05	0.75	0.16	0.92	0.46
7510800	Lansium sp.	4	1	16.1	0.01	0.12	0.02	0.15	0.07
7511000	Sandoricum sp.	1	0	21.2	0.01	0.06	0.01	0.07	0.03
7530500	Parartocarpus spp.	1	0	19.4	0.00	0.05	0.01	0.05	0.03
7530700	Streblus sp.	7	1	19.7	0.04	0.34	0.06	0.40	0.20
7570300	Eugenia spp.	487	81	24.7	5.11	63.29	13.26	76.55	38.28
7570800	Tristania spp.	1	0	20.8	0.01	0.05	0.01	0.06	0.03
7610500	Strombosia javanica	1	0	16.9	0.00	0.03	0.01	0.04	0.02
7640200	Sarcotheca sp.	1	0	26.6	0.01	0.10	0.02	0.12	0.06
7700800	Prunus sp.	1	0	17.4	0.00	0.03	0.01	0.04	0.02
7713400	Pertusadina sp.	23	4	32.7	0.48	6.86	1.62	8.49	4.24
7720400	Citrus sp.	1	0	118.9	0.19	3.18	0.91	4.09	2.05
7751300	Nephelium spp.	5	1	29.0	0.06	0.70	0.14	0.84	0.42
7751700	Xerospermum spp.	1	0	16.1	0.00	0.03	0.01	0.03	0.02
7800300	Eurycoma sp.	1	0	13.3	0.00	0.02	0.00	0.02	0.01
7810200	Sonneratia sp.	9	2	52.1	0.34	4.87	1.07	5.93	2.97
7830700	Pterocymbium spp.	1	0	11.5	0.00	0.01	0.00	0.01	0.01
7830800	Pterospermum spp.	5	1	21.0	0.03	0.37	0.07	0.44	0.22
7830900	Pterygota sp.	1	0	13.8	0.00	0.02	0.00	0.02	0.01
7880100	Aquilaria malaccensis	2	0	28.0	0.02	0.24	0.05	0.29	0.14
8070100	Alstonia spp.	1	0	17.6	0.00	0.04	0.01	0.04	0.02
8290100	Elaeocarpus sp.	5	1	20.1	0.03	0.29	0.05	0.34	0.17
8331100	Breynia sp.	13	2	20.9	0.08	0.85	0.16	1.01	0.50
8331200	Bridelia	3	1	15.7	0.01	0.08	0.01	0.09	0.05
8332400	Endospermum sp.	33	6	29.5	0.46	5.88	1.25	7.13	3.56

8333000	Glochidion sp.	1	0	20.2	0.01	0.05	0.01	0.06	0.03
8333500	Macaranga spp.	85	14	24.1	0.78	9.13	1.83	10.96	5.48
8333600	Mallotus sp.	2	0	33.6	0.03	0.41	0.08	0.50	0.25
8334600	Sapium sp.	20	3	33.7	0.36	4.82	1.03	5.85	2.92
8500200	Memecylon sp.	23	4	20.4	0.15	1.66	0.32	1.98	0.99
8500300	Pternandra sp.	12	2	19.0	0.06	0.57	0.11	0.68	0.34
8530300	Ficus sp.	9	2	28.4	0.13	1.67	0.36	2.03	1.01
8560300	Maesa ramentacea	2	0	30.1	0.03	0.37	0.08	0.45	0.22
8713000	Neolamarckia sp.	3	1	46.0	0.11	1.68	0.41	2.09	1.04
8713600	Porterandia sp.	20	3	18.5	0.10	1.00	0.19	1.19	0.59
8910200	Gironniera sp.	15	3	18.0	0.08	0.87	0.17	1.05	0.52
8930900	Vitex spp.	4	1	17.5	0.02	0.18	0.03	0.22	0.11
9000000	Unknown	1	0	20.7	0.01	0.05	0.01	0.06	0.03
	Unknown	3	1	17.0	0.01	0.10	0.02	0.12	0.06
	Total	**2430**	**405**	**28.3**	**33.64**	**446.89**	**99.21**	**546.09**	**273.05**