TREE COMMUNITY STRUCTURE AND CARBON STOCK OF A SECONDARY FOREST IN UNIVERSITI TEKNOLOGI MALAYSIA CAMPUS

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This thesis specially dedicated to my husband, daughter and family.

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ABSTRACT

Recently, anthropogenic activities such as forest logging, plantation and urban development have influenced the growth of secondary forests throughout the tropics. In Universiti Teknologi Malaysia (UTM), secondary forest has emerged after the removal of rubber plantation, which has led this study to identify secondary forest composition, estimate the amount of carbon stock from the above-ground biomass (AGB), below-ground biomass (BGB) and soil organic carbon, and identify tree distribution based on soil, chemical and physical properties. In this study, 200 plots with an area of 100 m^2 each were established within UTM's secondary forest. The diameter at breast height (DBH), the tree height, coordinates for each tree species and soil samples were collected. Top-soil samples in 50 selected plots were collected and analysed for texture, pH, base cation and available nutrients, including Mg, P and K. Shannon diversity index was applied in measuring species diversity. Then, a satellite image acquisition from Pleiades and spectral radiometer data collection were carried out to compile spectral data of fresh leaves from 25 species. For species composition, a total of 1,917 tree stands, comprising 25 species from 17 genera and 15 families were enumerated in all the study plots. Euphorbiaceae is the largest family with a total basal area (BA) of 29.6 m^2/ha which contributes to the high density in UTM secondary forest. The Shannon Diversity Index in UTM secondary forest was 2.248 (H_{max}= 3.219) which is lower than for primary forest. The total tree biomass was 84.6 t/ha, which was composed of AGB of 61.3 t/ha and BGB of 23.3 t/ha. The amount of carbon stock in this forest was 40.1 t/ha for AGB (28.8 t/ha), BGB (11 t/ha), and in the soil (0.79 t/ha). The total amount of soil organic carbon in UTM was 37.39 t/ha. Finally, ordinations by using Canonical Correspondence Analysis (CCA) indicated that soil, chemical and physical factors had no relationship with vegetation distribution. According to supervised classification for carbon stock estimation, the total carbon stock from 173.80 hectares of secondary forest in UTM amounted to 11,731.5 tonnes of carbon. Therefore, the secondary forest in UTM should be conserved as a carbon reservoir.

ABSTRAK

Kebelakangan ini, aktiviti manusia seperti pembalakan hutan, perladangan dan pembangunan bandar telah mempengaruhi pertumbuhan hutan sekunder di kawasan tropika. Di Universiti Teknologi Malaysia (UTM), hutan sekunder telah muncul selepas pemansuhan ladang getah, dengan itu kajian ini menjurus kepada mengenalpasti komposisi hutan sekunder, menganggarkan jumlah simpanan karbon daripada biojisim atas dan bawah tanah serta karbon organik di dalam tanah, dan mengenalpasti taburan pokok berdasarkan ciri kimia dan fizikal tanah. Dalam kajian ini, sejumlah 200 plot berkeluasan 100 m^2 setiap satu telah dikenalpasti di hutan sekunder UTM. Diameter paras dada (DBH), tinggi pokok, koordinat bagi setiap pokok dan sampel tanah telah diambil. Sampel tanah atas di 50 plot terpilih daripada 200 plot telah diambil dan dianalisis terhadap tekstur, pH, bes kation dan nutrien tersedia termasuk Mg, P dan K. Indeks kepelbagaian Shannon telah digunakan bagi menganggarkan kepelbagaian spesies. Kemudian, imej satelit diperolehi daripada Pleiades dan data spektral radiometer dari daun segar telah dijalankan bagi mengumpulkan spektral data bagi 25 spesies. Bagi komposisi hutan, sejumlah 1,917 batang pokok, merangkumi 25 spesies daripada 17 genus dan 15 famili telah dikenalpasti dalam semua plot kajian. Jumlah keluasan pangkal pokok (BA) bagi famili Euphorbiaceae adalah 29.6 m^2/ha dalam kesemua plot sekaligus menjadi penyumbang tertinggi kepada kepadatan hutan. Indeks Kepelbagaian Shannon di hutan sekunder UTM adalah 2.248 (H_{max} = 3.219), lebih rendah dari hutan primer. Jumlah biojisim pokok adalah 84.6 t/ha, 61.3 t/ha dari AGB dan 23.3 t/ha dari BGB. Jumlah simpanan karbon di hutan sekunder UTM adalah 40.1 t/ha untuk AGB (28.8 t/ha), BGB (11 t/ha), dan di dalam tanah (0.79 t/ha). Jumlah simpanan organik karbon di UTM adalah 37.39 t/ha. Akhirnya, Analisis Kesepadanan Kanonikal (CCA) menunjukkan faktor kimia dan fizikal tanah tiada perkaitan dalam taburan tumbuhan. Berdasarkan kajian pengelasan untuk menganggarkan jumlah simpanan karbon adalah 11,731.5 tan karbon bagi 173.8 hektar hutan sekunder. Oleh itu, hutan sekunder perlu dipelihara sebagai takungan karbon.

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LIST OF ABBREVIATIONS

ANOVA	-	Analysis of Variance
a.s.l.	-	Above sea level
C	-	Carbon
cm	-	Centimetre
COP	-	Conference of Parties
CO_2	-	Carbon dioxide
DBH	-	Diameter at breast height
DN	-	Digital numbers
FAO	-	Food and Agriculture Organization of United Nations
FCCC	-	Framework Convention on Climate Change
FGV	-	FELDA Global Venture
FRA	-	Forest Resource Assessment
g	-	gram
GHG	-	Greenhouse Gases
GPS	-	Global Positioning System
Gt	-	Gigatonne
ha	-	Hectare
ha^{-1}	-	per hectare
HA	-	Humic acids
IPCC	-	Intergovernmental Panel on Climate Change
ITTO	-	International Tropical Timber Organization
IVI	-	Important Value Index
KBR	-	Khangchendzonga Biosphere Reserve
KWR	-	Krau Wildlife Reserve
m	-	Meter
M	-	Mega
MEA	-	Millennium Ecosystems Assessment

meq	-	milliequivalents
Mg	-	Megagram
ml	-	Millilitre
MLC	-	Maximum Likelihood Classifier
Mt	-	Megaton
NPP	-	Net Primary Productivity
Pg	-	Petagram
ppm	-	Parts per million
PVC	-	Polyvinyl Chloride
REDD	-	Reduced Emission from Deforestation and Forest Degradation
RH	-	Relative Humidity
RM	-	Ringgit Malaysia
SIC	-	Soil Inorganic Carbon
SOC	-	Soil Organic Carbon
t/ha	-	tonne per hectare
UHI	-	Urban Heat Island
UNFCCC	-	United Nation Framework on Climate Change
UPM	-	Universiti Putra Malaysia
USD	-	United State Dollar
USDA	-	United State Department of Agriculture
UTM	-	Universiti Teknologi Malaysia
yr^{-1}	-	per year

LIST OF SYMBOLS

±	-	Plus-minus
°C	-	Degree Celsius
%	-	Percent
Al^{3+}	-	Aluminium Ion
Ca^{2+}	-	Calcium Ions
CH_4	-	Methane
H^+	-	Hydrogen Ion
K+	-	Potassium Ion
M	-	Molar
Mg^{2+}	-	Magnesium Ions
Na^+	-	Sodium Ion
P	-	Phosphate

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Tropical forests play an important role in the global carbon cycle. They contain 40% of the global terrestrial carbon, which accounts for more than half of the global gross primary productivity, and they keep large amounts of CO_2 from the atmosphere (Ngo *et al*., 2013). Rapid urban and industrial development, which commenced in the 1970s, may account for the prevalent formation of secondary forests in Malaysia. Deforestation happens when more space is needed by humans for farming and other developments, and this has resulted in forests being made to serve non-forest functions, such as housing, plantations and industrial activities. Tropical secondary forests are continuously increasing due to the increase in anthropogenic pressure along with the population migration to urban centres (Ngo *et al*., 2013).

Malaysia is not the only nation confronted with secondary forest formation issues, as other countries within the ASEAN region are facing similar issues. One such country is Thailand, where the country's primary forests were recently made into secondary forests due to prevalent farming activities practised by various ethnic groups in the country (Podong and Poolsiri, 2013). In addition, the Indonesian tropical forests were extensively logged from the year 2000 through to 2010, which resulted in the formation of 23 million hectares of secondary forests, and they accounted for 80% of the country's yearly emission of greenhouse gases (Rutishauser *et al*., 2013; Kartawinata *et al*., 2001). Although secondary forests are of less concern, it is noteworthy that these forests play a crucial role after most of the primary forests have been changed into secondary forest landscapes.

In 1995, there was a shortage of supply in forest resources in Malaysia, i.e., an insufficient hardwood supply, which could not support the increasing demand for wood products (Ang *et al*., 2014). Most of the pioneer species within secondary forests are generally classified as less known wood species (LKS), including Mahang (*Macaranga* sp.), Sesenduk (*Endospermun* sp.) and Terap (*Artocarpus* sp.). Although, these woods are available in massive amounts in secondary forests, wood-based industries in Malaysia are reluctant to use these LKS due to their poor properties, such as dimensional instability, inferior mechanical strength, and low durability. Thus, these tree species require some wood modifications, for instance, bulking, internal coating or crosslinking, to upgrade low quality timbers for potential applications (Ang *et al*., 2014). However, conserving secondary forests is a major task since the decline in primary forests contributes high concentrations of CO_2 into the atmosphere, which leads to climate change and global warming (Lasco and Cardinoza, 2006). In Article 1 of the United Nations Framework Convention on Climate Change (FCCC), climate change is defined as a change of climate that is attributed directly or indirectly to human activity which alters the composition of the global atmosphere and which is in addition to the natural climate variability observed over comparable time periods (United Nations, 1992). Climate change also reportedly results in the disappearance or reversal of the putative terrestrial carbon sink by approximately 1.6 Pg per year, which is equal to 1.6×10^9 tonnes (White *et al*., 1999).

In recent years, tropical forests have been under threat due to the massive impact of human activities, such as illegal logging, deforestation, and farming. In the year 2000 alone, approximately 10% of Malaysian land was covered by palm trees, and the west coast of Peninsular Malaysia was mostly planted with these trees due to its soil fertility and productive areas (Henson, 2005). An equal increase of the population in towns and cities also caused high land area demands for urban development. In 2009, the world’s forest cover was at 4 billion hectares, but this number soon dwindled as a result of deforestation and forest degradation (Fonseca *et* *al*., 2011). Food and Agriculture Organisation of the United Nations (FAO) defines forest degradation as the reduction of a forest capacity to provide goods and services (FAO, 2011). Forest degradation has many and varied perceptions, depending on the driver of degradation and the goods or most interested services. For example, a manager who replaces a natural forest with a plantation to supply desired wood products is unlikely to perceive his forest as degraded. On the other hand, his plantation is capable of providing many goods and services that a fully functioning natural forest would provide on the same site, partly because of the reduced biodiversity that is generally associated with a plantation, which would otherwise constitute a degraded site. Meanwhile, deforestation is defined as the conversion of forest to other land use or the long-term reduction of the tree canopy cover below the minimum 10% threshold (FAO, 2010). Moreover, deforestation implies long-term or permanent forest cover loss and transformation into another land use. Such a loss can only be caused and maintained by a continued human-induced or natural perturbation.

Changes in land use may also have an impact on carbon cycling through the emission of CO_2 as a major greenhouse gas. Tropical deforestation accounted for almost 12% of anthropogenic CO_2 emissions in 2008 and keeps increasing every year (Morton *et al*., 2011). Approximately 1.8 gigatons of carbon were released into the atmosphere, which resulted from deforestation. However, only 1.1 to 1.8 gigatons of carbon can be sequestered in 50 years (Heng and Tsai, 1999).

A similar scenario was observed in tropical countries, including Malaysia, in which the total annual deforestation rate between 2005 and 2010 was at 0.41% (Aisyah *et al*., 2015). Large amounts of green areas were made to serve non-forest functions, which resulted in an increase of carbon accumulation in the atmosphere. Carbon is retained in different natural stocks available in the environment. Natural stocks refer to oceans, fossil fuel deposits, terrestrial systems and the atmosphere. As mentioned earlier, a tree is one of the carbon stocks for the terrestrial system; it sequesters carbon from the atmosphere during photosynthesis (Suryawanshi *et al*., 2014). Moreover, from a resource management perspective, sequestering carbon in trees is viewed as relatively safer, environmentally more acceptable, aesthetically more appealing, and in many cases, more cost-effective in reducing additional atmospheric CO_2 (Merry *et al*., 2013). Moreover, secondary forests play a crucial role as contributors in carbon stocking by replacing the primary forests. According to Poorter *et al*. (2016), newly grown rainforest, which refers to secondary forest, can absorb 11 times as much carbon from the atmosphere as older forests. From their study in the Neotropics, it was proven that secondary forests play an important role in sequestering carbon. Therefore, it is important to estimate the amount of carbon stock which remains inside the secondary forest, including those located in the Universiti Teknologi Malaysia (UTM).

Although trees are well known for mitigating the amount of carbon in the atmosphere during photosynthesis, there is a continued increase in deforestation activities. In many cases, deforestation has altered the primary forests into secondary forests, and these forests are mostly located in urban areas, especially in developing countries. From 1990 to 2005, the forest cover in Malaysia reportedly was decreasing by 1,486,000 ha annually and was predicted to result in 6.64% of the total Malaysian forest area (Amlin *et al*., 2014). Primary rainforest in Kalimantan, Indonesia also faced a similar issue, where the primary forest was lost through exploitation, large scale fires and conversion into agricultural use. Forests naturally encounter challenges, but on relatively small scales, such as tree fall because of diseases associated with trees. In summary, forests in developing countries, including Malaysia, are facing large scale disturbances which are mostly from human interventions for large scale developments (Verburg *et al*., 2001).

Generally, forest gap formation is due to human disruption that stimulates the growth of secondary forest species: the bigger the gap, the greater the amount of solar radiation reaching the forest floor. This process initiates the seeds of pioneer species to grow since they are tolerant of high temperatures and poor nutrient conditions (Swaine and Whitmore, 1988). On the other hand, their seeds are shade intolerant, so they require direct access to sunlight to germinate, and once they establish themselves in the secondary areas, they will partially fill the forest gaps and create a forest canopy (Schnitzer *et al*., 1991). Secondary forests are also relatively higher in relation to the photosynthesis rate since much nitrogen accumulates after forests are damaged (Okuda *et al*., 2003; Kenzo *et al*., 2010). Moreover, pioneer species in secondary forests contain higher photosynthetic pigments; therefore, the photosynthesis rate is much higher than in primary forests (Silvestrini *et al*., 2007).

After primary forests are disturbed, they enter a new phase of regeneration. Secondary forests, which replace primary forests, consist of pioneer species that fill forest gaps. This regeneration is important because it determines the future tropical forest structure, dynamics and composition (Brokaw *et al*., 1987). Moreover, the heterogeneity of a forest depends on gap dynamics in tropical forests especially in relation to light quality and intensity (Silvestrini *et al*., 2007).

The increase in the amount of carbon dioxide from 280 ppm to 387 ppm in the atmosphere after the Industrial Revolution in 1760 had a crucial impact on the equilibrium of natural greenhouse gases (Hemati *et al*., 2014). This situation became worse after researchers revealed that the higher amount of carbon dioxide had contributed to the increase in the global temperature (Heimann and Reichstein, 2008). Then, carbon dioxide was classified as a primary greenhouse gas, which was mostly emitted from human activities. The concentration of carbon dioxide kept increasing after anthropogenic activities degraded the forest areas for urbanisation and development purposes. Initially, Global Forest Resource Assessment (FRA), the United Nation Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol of 1997 concentrated only on climate change issues. It was only after they started to notice the amount of carbon dioxide having a severe impact on global temperature that they decided to reveal the changes observed in the carbon pool.

The urban temperature is slightly higher than the temperature in rural areas. This phenomenon is called the urban heat island (UHI) effect and was first discovered in 1818 by the meteorologist Luke Horward (Bristow *et al*., 2010). Since early 1818, the global temperature started to increase due to the Industrial Revolution and deforestation, which influenced the temperature in urban areas. Carbon emissions increased in the atmosphere, and at the same time, humans were removing forests as the carbon pool, which resulted in a warmer environment in urban areas. Therefore, increasing the secondary forest landscape protects the Earth by controlling local temperatures, especially in urban areas, where it can reduce the UHI effect.

Wang (2013) stated that urbanisation, economic development and growth lead to land use and land cover change (LULCC). This LULCC increases tree mortality, which affects terrestrial carbon sinks and sources (Ren *et al*., 2012). As mentioned before, trees play a crucial role in reducing the amount of carbon in the atmosphere without any cost by means of their daily natural process, that is, photosynthesis.

1.2 Research Background

Global carbon emissions of carbon dioxide had increased by 18% and had reached the highest level since 1750 (Chavan and Ganesh, 2012). Attempts by certain quarters to exploit lands to the advantage of human use have largely affected the environment, natural phenomena, and ecological processes, including soil condition and carbon sequestration (Cheng *et al*., 2007). As shown in Table 1.1, a study by Malaysia National Communication in the UNFCCC showed that Land Use, Land Use Change and Forestry (LULUCF) was the second largest sector that contributed to the emission of greenhouse gases for the year 2000.

Table 1.1: Greenhouses gases inventory in Malaysia for the year of 2000

Sector	Emissions (Mt CO_2 eq)
Energy	147.00
Industrial Processes	14.13
Agriculture	5.91
LULUCF	29.59
Waste	26.36
Total	222.99

Source: Malaysia National Communication to the UNFCCC (2000)

Sequestration is defined as the net removal of carbon dioxide from the atmosphere into long-lived carbon pools (Chavan and Ganesh, 2012). According to

IPCC (2000), carbon sequestration is defined as an increase in carbon stocks in any non-atmospheric reservoir. Carbon sequestration by trees from the atmosphere is a function of land use, time for growing, and technological progress (Baral and Guha, 2004). Trees help to reduce carbon emissions in two ways. One is direct carbon sequestration by reforestation and afforestation that yields a stock of carbon in standing trees. The second way is by using forest products as substitutes for fossil fuels or fossil fuel intensive goods, such as steel and concrete. Carbon sequestration through forestry has the potential to play a significant role in improving environmental problems on a global scale, such as the atmospheric accumulation of greenhouse gases and climate change (Moura-costa, 1996; Kridiborworn *et al*., 2012). Forest ecosystems contribute approximately half of global net primary production (NPP). Therefore, they have a great influence on the terrestrial ecosystem's ability to accumulate carbon (Pregitzer *et al*., 2008). NPP is defined as the balance between the light energy fixed through photosynthesis (gross primary production) and the portion lost through respiration and mortality, which results in net carbon sequestration from the atmosphere by vegetation or trees (Zhao *et al*., 2010).

In recent years, the carbon cycle was out of a state of equilibrium as a result of two classes of major perturbations. According to Grace *et al*. (2014), the two classes of major perturbations, which were perpetrated by the rich countries of the world, are fossil fuel burning and the removal of forests in tropical countries. Therefore, alteration of primary forests into secondary forests will change the carbon cycle in an ecosystem. Currently, secondary forests have emerged close to human territory and act as a carbon reservoir instead of primary forests. Moreover, pioneer species grow naturally, are fast-growing and require a lower cost compared to street trees, which are cultivated. In Malaysia, these forests are widely available or located in both new towns and on institutional campuses. Therefore, it is significant to estimate the carbon stock in institutional campuses since there are more than 20 public universities in Malaysia.

Further, estimating carbon, particularly estimating the changes in different carbon pools, is highly relevant for the international conventions and processes related to climate change. The international conventions, such as the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol, are interested in empirical reports that may assist them in estimating carbon stock and stock changes in tree biomass, including above ground biomass (AGB) and below-ground biomass (BGB).

In managing carbon dioxide emissions, a few organisations were formed at both local and international levels. This was evidenced from the development of the Kyoto Protocol in 1997 for the international level and Local Agendas for the local level. This committee is responsible for overseeing the carbon dioxide emissions and ensuring the non-excessive volume of this gas. The Kyoto Protocol is one of the important agreements that aim to reduce anthropogenic greenhouse gases; it was prepared by the United Nations in the Framework of Convention on Climate Change which specifies the Clean Development Mechanism (CDM). Malaysia has also been part of this agreement since 1997. The Kyoto Protocol was adopted to achieve a greater reduction in greenhouse gases in the post-2000 period. Countries participating in this protocol have a legally binding commitment to reducing six greenhouse gases between 2008 and 2012 to at least 5%, based on the 1990s levels. As spelt out in Article 3.3 of the Kyoto Protocol, carbon credits may be claimed for any net increase in the carbon stock by means of direct human-induced activities arising from LULUCF (Beets *et al*., 2011). Consequently, monitoring carbon stocks is an advantage mainly for developing countries, as it allows them to claim carbon credits.

In order to plan for a low carbon society (LCS) in Malaysia, it is more effective to examine urban areas, as they are the engines of economic growth as well as the main contributors of CO_2 emissions (Universiti Teknologi Malaysia *et al*., 2009). Moreover, the World Bank (2010) stated that cities all around the world that serve as centres of settlements and economic activities are responsible for consuming two-thirds of the world’s energy and thus generating an estimated 70% of global carbon emissions. Indeed, in 2012, carbon dioxide emissions in urban and metropolitan areas contributed more than 80% of the volume of standard global emissions (Chen and Chen, 2012), and the total carbon emissions in urban areas are increasing every year.

Another plan in mitigating climate change is the Local Agenda 21 (LA21). It was implemented in Malaysia after the United Conference on Environment and Development, commonly known as the Earth Summit, which was held in June, 1992, in Rio de Janeiro. During the Earth Summit declaration, it was reported that an increasing amount of global carbon dioxide emissions had led to global warming and climate change (Chavan and Ganesh, 2012). Therefore, LA21 was developed at the Earth Summit as a supportive action after the declaration for a local sustainable development was made.

The Copenhagen Summit in 2009 was another United Nations' Climate Change Conference; it was held at the Bella Centre in Copenhagen, Denmark, between 7 and 18 December. The conference included the 15th Conference of the Parties (COP 15) to the United Nations Framework Convention on Climate Change (UNFCCC) and the 5th Meeting of the Parties (MOP 5) to the Kyoto Protocol. According to recent reports on the Copenhagen UNFCCC, held on the 26 December 2009, a report from Asian Developing Bank (ADB) revealed that Southeast Asia, of which Malaysia is a part, may suffer from more climate change than observed elsewhere in the world. Southeast Asia emitted over 1 billion metric tons (bt) of carbon dioxide in 2008, i.e., approximately 4% of global energy-related emissions.

In 2004, the Ministry of Natural Resources and Environment (MNRE) was established in Malaysia to address climate change issues (Ministry of Natural Resources and Environment Malaysia, 2000a). Later, in November 2009, the Malaysian cabinet endorsed the Malaysian Policy on Climate Change (Salahudin *et al*., 2013). These actions reflect a serious commitment by the government with regard to the environment, especially climate preservation. Currently, in the Eleventh Malaysian Plan, two principle outcomes were established. The first is to reduce the intensity of GHGs emissions of GDP by up to 40% compared to the 2005 levels by 2020. This is parallel to the voluntary target announced by the Malaysian Prime Minister at the 15th Conference of the Parties to the UNFCC (Economic Planning

Unit, 2015). The second is to conserve at least 17% of terrestrial and inland water areas, as well as 10% of coastal and marine areas, as protected areas in line with the Aichi Biodiversity Targets. Therefore, it is now quite clear that mitigating the effect of greenhouse gases is an important task, considering that the issue was discussed in the Eleventh Malaysia Plan for the time period of 2016 through to 2020.

Other tasks that were carried out by MNRE in 2010 included a program to plant 26 million trees, which is equal to one tree per Malaysian by the year 2015. In addition, the Malaysian government allocated funds under NRE to establish the replanting project, that is, the National Tree Planting Program, along the coastal areas of Peninsular Malaysia, Sabah and Sarawak (Ibrahim *et al*., 2007). Therefore, this effort by NRE shows the importance of trees in reducing carbon and avoiding climate change. The ability to estimate forest carbon stocks is essential and can be achieved by means of Reducing Emissions from Deforestation and Forest Degradation (REDD+) mechanisms developed under UNFCCC to establish reliable National Reference Emission Levels (NREL) and to estimate carbon stock changes (Rutishauser *et al*., 2013). Furthermore, REDD+ seeks to reward actors for keeping or restoring forests as a means of reducing carbon emissions (Karsenty *et al*., 2014).

Many actions have been considered in reducing carbon and simultaneously reducing climate change, which affects humans and the environment. Reducing the amount of carbon is the most important task, as it may help in making the environment stable, that is, no annual increase in temperature, even of 0.1°C. Therefore, conserving forests at the local level can make a contribution to reducing carbon.

1.3 Research Problem

The average surface air temperature was globally reported to have increased by 0.5°C in the 20th century, and it is expected to increase further by 1.5°C to 4.5°C by 2100 (Kanniah *et al*., 2014). In 2015, the Paris Climate Conference (COP21) aimed to achieve a legal binding and universal agreement on climate to keep global warming below 2°C (United Nations Framework Convention on Climate Change 2015). In a similar vein, IPCC predicts that anthropogenic emissions of greenhouse gases will raise the global mean surface temperature from 1.4°C to 5.8°C over the next century (Pala *et al*., 2013). Carbon sequestration in forests can be affected by changes in surface temperature, which has increased by 0.8°C in the last 100 years, and is now reportedly increasing at a rate of 0.2°C per decade (Dai *et al*., 2014a).

In recent years, tropical rainforests have been transformed into secondary forests due to conversion of land from serving its original forest functions into non-forest functions, such as residential, plantation, and industrial purposes. Tropical forest stores large amounts of carbon; indeed, approximately 40% to 50% of carbon is retained in terrestrial biomass (Martin and Thomas, 2011). An acre of tropical forest is capable of removing approximately 100 tons of carbon dioxide from the atmosphere (Webb, 1998). This clearly indicates that trees play an important role in sequestering carbon. On a global scale, the secondary forest landscape constitutes approximately 40% of forest cover (Brown and Lugo, 1990). In 1986, observations indicated that secondary forests of various sizes and phases were found throughout Kuala Lumpur, Malaysia (Ang, 1986). Moreover, most of the housing development projects in the 1970s took place in secondary forestland comprising abandoned rubber and oil palm plantations (Webb, 1998). The conservation and management of secondary forests is crucial since such forests provide valuable resources to the human community, retain significant amounts of biodiversity, and relieve the pressure on primary forests.

For ease of reference, a list of previous studies regarding estimating carbon stocks is presented in Table 1.2; estimating the biomass in tropical forests began as early as the 1980s (Brown and Lugo, 1984). At that time, researchers had already recognised the rise of CO_2 concentration in the atmosphere, and CO_2 is now being released into the atmosphere much faster than at any time in the past 80,000 years (Vashum, 2012). Based on the literature listed in the table, studies in estimating carbon stock have been increasing since 2000. However, the studies have concentrated on estimating the carbon stocks in primary forests at oil palm and rubber plantations (Terakunpisut *et al*., 2007; Thenkabail *et al*., 2004; Petsri *et al*., 2013). Therefore, this study is considered important, as to the researcher's knowledge, studies exploring forest structure and estimating carbon stocks in secondary forests located within a university campus are scarce. Moreover, secondary forests are recognised for their biodiversity conservation values and as important carbon sinks (Thompson *et al*., 2012).

Research on commercially valued trees is now of more concern compared to non-commercial trees. Most Dipterocarpaceae species, such as *Shorea*, *Hopea*, and *Dryobalanops* are well studied (Saner *et al*., 2012; Okuda *et al*., 2004; Ch *et al*., 2011; Okuda *et al*., 2003). This study aimed to identify the potential of tree species in secondary forests to store carbon from their dendrometric characteristics (trunk diameter and height of the tree) by using a non-destructive methods of measurement to understand the factors that influence the occurrence of vegetation in relation to soil physical and chemical factors, which are described in Chapter 4.

Table 1.2: List of literature study in estimating carbon stock

Source	Location	Carbon stock estimation site or specific tree
Lasco *et al.* (2004)	Philippines	Secondary forest at mountain areas
Terakunpisut *et al.* (2007)	Thailand	Tropical rain forest, dry evergreen forest and mixed deciduous
Kenzo *et al.* (2009)	Sarawak, Malaysia	Tropical secondary forests
Eckert *et al.* (2011)	Madagascar	Two types of degraded forests: low degraded and degraded forest
Njomgang *et al.* (2011)	Cameroon	Six land use types: virgin forest, secondary forest, forest fallow, mixed crop field and old cocoa plantations
van Breugel *et al.* (2011)	Panama canal watershed	Secondary forest
Saner *et al.* (2012)	Sabah, Malaysia	Tropical lowland dipterocarp forest
Warren *et al.* (2012)	Sumatra	Tropical peat soil
Dirocco (2012)	Malaysia	Tropical dipterocarp forest
Pragasan and Karthick (2013)	India	Eucalyptus plantation and mixed species plantation in Bharathiar University campus at Coimbatore
Rathore and Jasrai (2013)	India	Sixty tree species in Gujarat University
Orihuela-Belmonte *et al.*	Mexico	Secondary forest

(2013)		
Pala *et al.* (2013)	India	Reserve and community forest
Rutishauser *et al.* (2013)	Indonesia	Unmanaged dipterocarp forest
Ekoungoulou *et al.* (2014)	Republic of Congo	Secondary forest and Gallery forest of Congo
Dai *et al.* (2014b)	Mexico	Secondary dry forest

Secondary forests are formed as a result of human activities, especially in developing countries, including Malaysia. It has recently been reported that secondary forests dominate 40% of tropical forest cover (Li *et al*., 2005). Formerly, primary forests used to be major carbon stock reservoirs compared to secondary forests. However, the capability of storing carbon decelerates after the trees become older because respiration begins to be either equal to or exceed primary production (Baral *et al*., 2004).

Regenerating secondary forests was reported to have the potential to assimilate and store large quantities of carbon (Kueh *et al*., 2014); this information helped to quantify their role in carbon storage and sequestration. However, there was lack of information on biomass accumulation by the secondary species that dominate early successional processes, especially in tropical Asia. To date, very few studies (Chokkalingam and Jong, 2001) have been carried out on tree species in secondary forests to determine their potential in carbon stocking, especially within the secondary forests located on institutional campus grounds.

UTM, one of the institutional campuses located within urban areas to have secondary forests, was selected to identify the secondary forest structure, measure its AGB and BGB and carbon stock, and finally, to identify the relationship between the soil and the tree community. The secondary forest in UTM emerged after the abandonment of rubber and oil palm plantations, development and unmanaged green areas, which in combination contributed towards creating a suitable environment for tree species to grow. The abandoned area, which consists of pioneer species, is well adapted with direct access to sunlight and without any forest cover.

1.4 Research Aim

The aim of this research is to identify the secondary forest composition in an institutional campus. The next step is to estimate the amount of carbon stock in UTM secondary forest tree species from AGB and BGB, and soil organic carbon. The final step is to identify tree distribution according to the soil physical and chemical properties at UTM secondary forest.

1.5 Research Objectives

The present research aimed to achieve the following three research objectives:

1) to determine tree community structure of UTM secondary forest
2) to estimate the amount of tree carbon stock and soil organic carbon of UTM secondary forest
3) to identify tree distribution based on soil physical and chemical properties between tree communities

1.6 Research Questions

In relation to the abovementioned research objectives, the aim is to answer the following four research questions:

1) How many secondary forest species have emerged in UTM secondary forest?
2) How much AGB and BGB is stored in UTM secondary forest?
3) How much is carbon stock is accumulated from UTM secondary forest tree species?
4) What is the relationship between tree distribution and soil physical and chemical properties based on CCA analysis?

1.7 Scope of the Study

The focus of this study is to identify forest structure and to estimate carbon stock in AGB and BGB, which includes soils and roots in UTM secondary forest. All trees in the established plot were measured. This study also examined tree distribution based on soil physical and chemical properties. Moreover, this study determined the relationship between tree communities and soil variables by using a multivariate analysis. The tree distribution was mapped using satellite images according to the spectral reflectance from each species. UTM was selected as the study area since it comprised a secondary forest. UTM secondary forest was formed from an abandoned plantation and unmanaged greenery.

1.8 Significance of Study

Secondary forests have replaced areas which were previously dominated by primary forests. Since UTM consists of a large green area, remote sensing should be applied to assist in estimating the carbon stock for the whole green area in UTM. Satellite imagery also helps to map tree distribution in UTM secondary forest. The findings of this study will help UTM management in conserving trees in the secondary forest and trees that were replanted. More importantly, to the researcher's knowledge, the literature is devoid of any studies that explore carbon stock within secondary forests located on campuses of higher educational institutions. Moreover, the findings also revealed the factors that influenced the occurrence of vegetation in relation to the soil factors.

Estimating carbon stock at UTM is an advantage because it gains monetary values, such as carbon credits. In the United Nations Conference on Environment and Development (UNCED) in Rio in 1992, forest management in developing countries attracted much attention, while carbon stock management in forests among developing countries received similar attention during the Kyoto Protocol in 1997. The Kyoto Protocol also started with the idea of carbon credits where it was stated under Article 12 of the CDM (Kim Phat *et al.*, 2004). Carbon credits is a proposed solution to tropical forest degradation (Dirocco, 2012). A credit is a measure representing one megaton, a mass equal to 1000 kg of carbon dioxide. Later, in 2005, REDD) also recommended similar actions to slow down the deforestation rates and help safeguard threatened forest species, as these actions may enhance the opportunities for providing substantial economic benefits for developing countries (Laurance, 2007).

In 2010, at the COP15, as set out in the Cancun Agreement, REDD was made into REDD+ to reflect the addition of a new component. REDD+ is used as a broad term that encompasses a range of forest conservation and reforestation options and financing mechanisms which are being negotiated at both global and national levels to reduce deforestation and forest degradation (Evans *et al*., 2014). Furthermore, it also enhances forest carbon stocks to mitigate climate change. REDD+ is a policy that was developed under UNFCCC. During the REDD phase, UNFCCC provided financial incentives for developing countries that voluntarily reduced national deforestation rates and associated carbon emissions below the reference level (Venter *et al*., 2009). Current market value for carbon in a hectare of rainforest, if kept, could be worth approximately USD 400 to USD 8000 or more (Laurance, 2007). This value is considered higher compared to the costs involved in conserving the forest.

The price of carbon credits differs and may range from as low as USD 3.00 a tonne CO_2 equivalent (eq) to a high in excess of USD 40.00 a tonne. However, carbon prices for forestry-based activities range from USD 2.90 to USD 7.30 while the conservative price of USD 5.00 (RM 16) a tonne is usually assumed (Ministry of Natural Resources and Environment Malaysia, 2000b). Nevertheless, replanting a forest or plantation may cost RM 5000 per hectare, and may incur an additional cost of RM 150 per ha for maintenance (Ministry of Natural Resources and Environment Malaysia, 2000b). Therefore, to obtain a higher income in relation to carbon credits, these costs should be reduced. Considering this situation, secondary forest is potentially significant to contribute towards a good income in carbon credits. Meanwhile, secondary forest continues to exist naturally without any maintenance costs.

1.9 Structure of the Thesis

The thesis is divided into eight chapters. Chapter 1 introduces the research background, research problem, research gap, research aim, research objectives, research question, scope of study, and the study's significance. A comprehensive review of relevant and applicable literature is provided in Chapter 2. Next, Chapter 3 presents the general methodology and background of the study area, which includes the climate. Chapter 4 includes a discussion on the physical environment of UTM secondary forest, including soil physical and chemical properties. This is followed by Chapter 5, in which the floristic composition and diversity of trees from 200 established plots are described and compared with other previously similar or different studied habitats. Chapter 6 discusses the forest structure, biomass, and carbon stock of UTM secondary forest while Chapter 7 emphasises the tree distribution according to a supervised classification based on the spectral reflectant of each tree species and soil properties of the forest. This chapter also highlights the relationship between tree communities and soil variables by using a multivariate analysis. Finally, Chapter 8 provides the conclusion, implication and limitation of the study, including recommendations.

REFERENCES

Abbasi, M., Schaepman, M.E., Darvishsefat, A., Bartholomeus, H.M., Marvi Mohajer, M.R. & Sobhani, H. (2008). Spectroradiometric measurements of tree species in the caspian forests of Iran. In *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*. Beijing, 291–296.

Abdul Razak, S., Haron, N.W., H., Nuradnilaila & M., Azani. (2015). A phytosociological study on the community of Ayer Hitam Forest Reserve, Selangor, Malaysia. *Sains Malaysiana*, *44*(4).

Abd Rahman, K., Niiyama, K., Azizi, R., Appanah, S. & Iida, S. (2002). Species assembly and site preference in a primary Seraya-Ridge Forest of Peninsular Malaysia. *Journal of Tropical Forest Science, 14*(3), 287-303.

Adachi, M., Ito, A., Ishida, A., Kadir, W.R., Ladpala, P. & Yamagata, Y. (2011). Carbon budget of tropical forests in Southeast Asia and the effects of deforestation: An approach using a process-based model and field measurements. *Biogeosciences*, *8*(9), 2635–2647. Available at: http://www.biogeosciences.net/8/2635/2011/ [Accessed December 4, 2014].

Addo-Fordjour, P. & Rahmad, Z.B. (2013). Development of allometric equations for estimating above-ground liana biomass in tropical primary and secondary forests, Malaysia. *International Journal of Ecology*, 2013, 1–8. Available at: http://www.hindawi.com/journals/ijecol/2013/658140/.

Adzmi, Y., Suhaimi, W.C., Amir Husni, M.S., Mohd Ghazali, H., Amir, S.K. & Bailie, I. (2010). Heterogeneity of soil morphology and hydrology on the 50 ha long-term ecological research plot at Pasoh, Peninsular Malaysia. *Journal of Tropical Forest Science, 22*(1), 21-35.

Ahmad, A. & Quegan, S. (2012). Analysis of maximum likelihood classification on multispectral data. *Applied Mathematical Sciences*, *6*(129), 6425–6436.

Ahmad Fitri, Z. (2013). *Community Structure, Species Diversity and Relationship of Tree Communities with Soil Factors in an Upper Hill Dipterocarp Forest of*

Perak State, Peninsular Malaysia. Universiti Kebangsaan Malaysia.

Aisyah, A., Shahrul, A.B., Zulfahmie, M.Z.M., Sharifah Mastura, S.A. & Mokhtar, J. (2015). Deforestation analysis in Selangor, Malaysia between 1989 and 2011. *Journal of Tropical Forest Science, 27*(1), 3–12.

Akbar, M.H., Ahmed, O.H., Jamaluddin, A.S., Nik Ab. Majid, N.M., Abdul-Hamid, H., Jusop, S., Hassan, A., Yusof, K.H. & Arifin Abdu. (2010). Differences in soil physical and chemical properties of rehabilitated and secondary. *American Journal of Applied Sciences*, *7*(9), 1200–1209.

Akbari, H. & Kalbi, S. (2017). Determining Pleiades satellite data capability for tree diversity modeling. *IForest, 10*(1), 348–352.

Allaby, M. (2006). *Biomes of the Earth: Tropical Forest*. New York: Chelsea House.

Alves, L.F., Vieira, S.A., Scaranello, M.A., Camargo, P.B., Santos, F.A.M., Joly, C.A. & Martinelli, L.A. (2010). Forest structure and live aboveground biomass variation along an elevational gradient of tropical Atlantic moist forest (Brazil). *Forest Ecology and Management*, *260*, 679–691.

Amlin, G., Suratman, M.N. & Isa, N.N.M. (2014). Soil chemical analysis of secondary forest 30 years after logging activities at Krau Wildlife Reserve, Pahang, Malaysia. *APCBEE Procedia*, *9,* 75–81. Available at: http://linkinghub.elsevier.com/retrieve/pii/S2212670814000153 [Accessed January 15, 2015].

Analytical Spectral Devices, I., 2002. *FieldSpec ® UV / VNIR HandHeld Spectroradiometer User's Guide*. USA: Analytical Spectral Devices, Inc.

Ang, A.F., Zaidon, A., Bakar, E.S., Mohd Hamami, S., Anwar, U.M.K. & Jawaid, M. (2014). Possibility of improving the properties of mahang wood (*Macaranga* sp.) through phenolic compreg technique. *Sains Malaysiana*, *43*(2), 219–225.

Ang, L. (1986). *Comparison of Floristic Composition of Kenny Hill secondary vegetation and Bukit Nanas forest stand and their implications on urban forestry.* Universiti Pertanian Malaysia.

Arévalo-Gardini, E., Canto, M., Alegre, J., Loli, O., Julca, A. & Baligar, V. (2015). Changes in soil physical and chemical properties in long term improved natural and traditional agroforestry management systems of cacao genotypes in Peruvian Amazon. *PLoS ONE, 10*, 1–29.

Ashton, P.S. (1964). Ecological studies in the mixed dipterocarp forests of Brunei State. *Oxford Forestry Memoir* 45. Oxford: University of Oxford.

Ashton, P.S. (1976). Mixed dipterocarp forest and its variation with habitat in the Malayan lowlands: A re-evaluation at Pasoh. *Malay. Forester, 39,* 56-72.

ASTRIUM, 2012. *Pléiades Imagery User Guide*, Available at: http://blackbridge.com/geomatics/upload/airbus/Pleiades User Guide.pdf.

Atmopawiro, V. & Hussin, Y.A. (2004). Sub-pixel and maximum likelihood classification of Landsat ETM+ images for detecting illegal logging and mapping tropical rain forest cover types in Berau, East Kalimantan, Indonesia. *The XX Congress of ISPRS,* 933–942. Available at: http://www.isprs.org/proceedings/XXXV/congress/comm7/papers/182.pdf.

Azhar, N., Maimon, M.Y., Mohd Hizamri, Y., Rosaizan Haryani, R., Abdul Wahab, B., Ahamd Ashrin, M.B., Paul Leo, L., Ismail, P., Kamuruddin, M.N., Ahmad Azhar, M., Almizi, I. & Burhanuddin, M.N. (2010). *FRA 2010*. Available at: papers3://publication/uuid/C311B35B-28D3-4BC2-8DFA-3358A59E0DE3.

Azlan, A., Aweng, E.R., Ibarhim, C.O. & Noorhaidah, A. (2012). Correlation between soil organic matter, total organic matter and water content correlation between soil organic. *Journal Applied Science Environment Management, 16*(4), 353–358.

Bailie, I. C., Ashton, P.S., Chin, S.P., Davies, S.J., Palmiotto, P.A., Russo, S.E. & Tan, S. (2006). Spatial associations of humus, nutrients and soils in mixed dipterocarp forest at Lambit, Sarawak, Malaysian Borneo. *Journal of Tropical Ecology, 22,* 543-553.

Baral, A. & S. Guha, G. (2004). Trees for carbon sequestration or fossil fuel substitution: The issue of cost vs. carbon benefit. *Biomass and Bioenergy*, 27(1), 41–55. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0961953403002046 [Accessed August 13, 2013].

Barnes, B.V., Zak, D.R., Denton, S.R. & Spurr, S.H. (1998). *Forest Ecology*. 4th ed. USA: John Wiley & Sons.

Barbosa, J.M. Melendez-Pastor, I., Navarro-Pedreño, J. & Bitencourt, M.D. (2014). Remotely sensed biomass over steep slopes: An evaluation among successional stands of the Atlantic Forest, Brazil. *ISPRS Journal of Photogrammetry and Remote Sensing*, *88,* 91–100.

Barbosa, J.M., Broadbent, E.N. & Bitencourt, M.D. (2014). Remote sensing of aboveground biomass in tropical secondary forests: A review. *International Journal of Forestry Research*, *2014,* 1–14. Available at: http://www.hindawi.com/journals/ijfr/2014/715796/.

Basuki, T.M., van Laake, P.E., Skidmore, A.K. & Hussin, Y.A. (2009). Allometric equations for estimating the above-ground biomass in tropical lowland Dipterocarp forests. *Forest Ecology and Management*, *257*(8), 1684–1694. Available at: http://linkinghub.elsevier.com/ retrieve/pii/S0378112709000516 [Accessed July 10, 2014].

Batista, N.D.A., Bianchini, E., Carvalho, E.D.S. & Pimenta, J.A. (2014). Architecture of tree species of different strata developing in environments with the same light intensity in a semideciduous forest in southern Brazil. *Acta Botanica Brasilica,* *28*(1), 34–45. Available at: http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0102-33062014000100004&lng=en&nrm=iso&tlng=en.

Beets, P.N., Brandon, A.M., Goulding, C.J., Kimberley, M.O., Paul, T.S.H. & Searles, N. (2011). The inventory of carbon stock in New Zealand's post-1989 planted forest for reporting under the Kyoto protocol. *Forest Ecology and Management*, *262*(6), 1119–1130. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0378112711003641 [Accessed April 24, 2013].

Bhat, D.M., Murali, K.S. & Ravindranath, N.H. (2001). Formation and recovery of secondary forests in India: A particular reference to Western Ghats in South India. *Journal of Tropical Forest Science, 13,* 601–620.

Ter Braak, C.J.F. (2009). Program CANOCO Version 4.56. *Biometric - Quantitative Methods in the Life and Earth Sciences.*

Ter Braak, C.J.F. (1995). Ordination. In R. H. G. Jongman, C. J. F. Ter Braak, & O. F. R. Van Tongeren (eds.), *Data Analysis in Community Landscape Ecology*. Netherlands, Pudoc Wageningan, 91–173.

Borchert, R. (1994). Soil and stem water storage determine phenology and distributions of tropical dry forest trees. *Ecology, 75,* 1437-1449.

Borota, J. (1991). *Tropical forests: some African and Asian case studies of composition and structure*. Development in Agricultural and managed forest Ecology 22. Czechoslovakia: Elsevier.

Brearley, F.Q., Prajadinata, S., Kidd, P.S., Proctor, J. & Suriantata. (2004). Structure and floristics of an old secondary rain forest in Central Kalimantan, Indonesia, and a comparison with adjacent primary forest. *Forest Ecology and Management*, *195*, 385–397.

Breugel, M. V. Bongers, F. & Martinez-Ramos, M. (2011). Estimating carbon stock in secondary forests: Decisions and uncertainties associated with allometric biomass models. *Forest Ecology and Management*, *262*(8), 1648–1657. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0378112711004579 [Accessed May 9, 2014].

Breugel, M. V., Bongers, F. & Mart, M. (2007). Species dynamics during early secondary forest succession: Recruitment, mortality and species turnover. *Biotropica*, *35*(5), 610–619.

Bristow, R.S., Blackie, R. & Brown, N. (2010). Parks and the urban heat island : A longitudinal study in Westfield, Massachusetts. In *The 2010 Northeastern Recreation Research Symposium*, 224–230.

Brokaw, A.N.V.L. (1987). Gap-phase regeneration of three pioneer tree species in a tropical forest. *Journal of Ecology*, *75*(1), 9–19.

Brower, J.E., Zar, Jerrold, H. & von Ende, Carls, N. (1997). *Field and Laboratory Methods for General Ecology* (3rd ed.). United States: Wm. C. Brown.

Brown, S. & E. Lugo, A. (1984). Biomass of tropical forests: A new estimate based on forest volumes. *Science*, *223*(4642), 1290–1293.

Brown, S. & Lugo, A.E. (1990). Tropical secondary forests. *Journal of Tropical Ecology*, *6*, 1–32.

Brown, T.C., Bergstrom, J.C. & Loomis, J.B. (2007). Defining, valuing and providing ecosystem goods and services. *Natural Resources Journal*, *47,* 329–376. Available at: http://heinonlinebackup.com/hol-cgi-bin/get_pdf.cgi?handle=hein.journals/narj47&section=19.

Bu, W., Zang, R. & Ding, Y. (2014). Field observed relationships between biodiversity and ecosystem functioning during secondary succession in a tropical lowland rainforest. *Acta Oecologica*, *55*, 1–7. Available at: http://dx.doi.org/10.1016/j.actao.2013.10.002.

Buringh, P. (1984). Organic carbon in soils of the world. In G. M. Woodwell (ed.), *The Role of Terrestrial Vegetation in the Global Carbon Cycle: Measurement by Remote Sensing*. John Wiley & Sons Ltd, 91–110.

Burnham, C.P. (1984). The forest environment: Soils. In: Whitmore, T.C. *Tropical*

Rain Forests of the Far East, 137-154. Oxford: Clarendon Press.

Cairns, M. A., Helmer, E.H. & Baumgardner, G. A. (1997). Root biomass allocation in the world as upland forests. *Oecologia*, *111*, 1–11.

Carter, M.R. & Gregorich, E.G. (eds.) (2006). *Soil Sampling and Methods of Analysis*. Boca Raton, USA: Tailor and Francis Group.

Ch, H., Ahmed, O.S. & Majid, N.M.A. (2011). Assessment of soil carbon storage in a tropical rehabilitated forest. *International Journal of the Physical Sciences*, *6*(26), 6210–6219.

Chan, Y. (2008). Increasing soil organic carbon of agricultural land. *New South Wales Dep. of Primary Industries* (January). Available at: http://www.soilcare.org.au/Increasing soil organic carbon Prime Fact.pdf [Accessed January 29, 2015].

Chavan, B. & Ganesh, R. (2012). Total sequestered carbon stock of mangifera indica. *Journal of Environment and Earth Science*, *2*(1), 37–49.

Chave, J., Rejou-Mechain, M., Burquez, A., Chidumayo, E., Colgan, M.S., Delitti, W.B.C., Duque, A., Eid, T., Fearnside, P.M., Goodman, R.C., Henry, M., Martinez-Yrizar, A., Mugasha, W.A., Muller-Landau, H.C., Mencuccini, M., Nelson, B.W., Ngomanda, A., Noguiera, E.M., Ortiz-Malavassi, E., Pelissier, R., Ploton, P., Ryan, C.M., Saldarriaga, J.G. & Vieilledent, G. (2014). Improved allometric models to estimate the aboveground biomass of tropical trees. *Global Change Biology*, *20*, 3177–3190.

Chen, S.Q. & Chen, B. (2012). Determining carbon metabolism in urban areas though network environ theory. *Procedia Environmental Sciences*, *13*(2011), 2246–2255. Available at: http://linkinghub.elsevier.com/retrieve/pii/S1878029612002149 [Accessed March 13, 2013].

Cheng, C.-M., Wang, R.-S. & Jiang, J.-S. (2007). Variation of soil fertility and carbon sequestration by planting Hevea brasiliensis in Hainan Island, China. *Journal of Environmental Sciences (China)*, *19*(3), 348–52. Available at: http://www.ncbi.nlm.nih.gov/pubmed/17918599.

Chidumayo, E.N. (2002). Changes in miombo woodland structure under different land tenure and use systems in central Zambia. *Journal of Biogeography*, *29*, 1619–1626.

Chokkalingam, U. & Jong, W.I.L.D.E. (2001). Secondary forest : A working definition and typology. *International Forestry Review*, *3*(1), 19–26.

Clark, D.B., Palmer, M.W. & Clark, D.A. (1999). Edaphic factors and the landscape scale distributions of tropical rain forest trees. *Ecology, 80*(8), 2662-2675.

Corner, E.J.H. (1997). *Wayside Trees of Malaya* (Volume I a.). Kuala Lumpur, Malaysia: The Malayan Nature Society.

Curtis, J.T. & McIntosh, R.P. (1951). An upland forest continuum in the prairie-forest border region of Wisconsin. *Ecology, 32*(3), 476–496. Available at: http://www.jstor.org/stable/1931725.

Dai, Z., Birdsey, R.A., Johnson, K.D., Dupuy, J.M., Hernandez-Stefanomi, J.L. & Richardson, K. (2014). Modeling carbon stocks in a secondary tropical dry forest in the Yucatan Peninsula, Mexico. *Water, Air, & Soil Pollution, 225,* 1925. Available at: http://link.springer.com/10.1007/s11270-014-1925-x.

Davies, S.J., Nur Supardi, M.N., La Frankie, J.V. & Ashton, P.S. (2003). The Trees of Pasoh Forest: Stand Structure and Floristic Composition of the 50-ha Forest Research Plot. In: Okuda, T., Manokaran, N., Matsumoto, Y., Niiyama, K., Thomas, S.C. & Ashton, P.S. (eds). Pasoh: *Ecology of a Lowland Rain Forest in Southeast Asia*. Japan: Springer.

Davies, S.J. & Semui, H. (2005). Competitive dominance in a secondary successional rain-forest community in Borneo. *Journal of Tropical Ecology, 22*(1), 53. Available at: http://www.journals.cambridge.org/abstract_S0266467405002944 [Accessed April 7, 2014].

Davies, Z.G., Dallimer, M., Edmondson, J.L. & Leake, J.R. (2013). Identifying potential sources of variability between vegetation carbon storage estimates for urban areas. *Environmental pollution (Barking, Essex : 1987)*, *183*, 133–42. Available at: http://www.ncbi.nlm.nih.gov/pubmed/23906971 [Accessed April 13, 2014].

Davy, J.B. (1938). *The Classification of Tropical Woody Vegetation Types*. Institute Paper Cabidirect.org.

Dawkins, H. (1959). The volume increment of natural tropical high-forest and limitations to improvements. *Empire Forest Review, 38,* 705–726.

Debski, I., Burslem, D.F.R.P., Palmiotto, P.A., Lafrankie, J.V., Lee, H.S. & Manokaran, N. (2002). Habitat preferences of Aporosa in two Malaysian forests: Implications for abundance and coexistence. *Ecology, 83*(7), 2005-2018.

Deilami, B.R., Ahmad, B., Saffar, M.R.A. & Umar, H.A. (2014). Using remote sensing and GIS to detect and monitor land use and land cover change in Iskandar Malaysia During 2007 – 2014. *Middle-East Journal of Scientific Research*, *22*(3), 390–394.

Dirocco, T.L. (2012). A thorough quantification of tropical forest carbon stocks in Malaysia. *Carbon Stocks of Tropical Forests*, 1–18.

Doi, R., 2012. Quantification of leaf greenness and leaf spectral profile in plant diagnosis using an optical scanner. *Ciencia e Agrotecnologia*, *36*(3), 309–317.

Duivenvoorden, J.F. (1996). Patterns of tree species richness in rain forests of the middle Caqueta area, Colombia, NW Amazonia. *Biotropica, 29,* 142-158.

Dwivedi, P., Rathore, C.S. & Dubey, Y. (2009). Ecological benefits of urban forestry: The case of Kerwa Forest Area (KFA), Bhopal, India. *Applied Geography*, *29*(2), 194–200. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0143622808000507 [Accessed March 17, 2013].

Eastman, J.R. (2001). Introduction to remote sensing and image processing. *Clark University, USA*, *1*, 17–34.

Eckert, S., Ratsimba, H.R., Rakotondrasoa, L.O., Rajoelison, L.G. & Ehrensperger, A. (2011). Deforestation and forest degradation monitoring and assessment of biomass and carbon stock of lowland rainforest in the Analanjirofo region, Madagascar. *Forest Ecology and Management*, *262*(11), 1996–2007. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0378112711005330 [Accessed March 28, 2014].

Economic Planning Unit, P.M.D. (2015). *Eleventh Malaysia Plan: 2016-2020*, Malaysia. Available at: http://rmk11.epu.gov.my/book/eng/Elevent-Malaysia-Plan/RMKe-11 Book.pdf.

Ekanayake, S., Fernando, S. & Bambaradeniya, C. (2012). *Baseline assessment of sequestered standing carbon stock in Mahausakande*.

Ekoungoulou, R., Liu, X., Ifo, S.A., Loumeto, J.J. & Folega, F. (2014). Carbon stock estimation in secondary forest and gallery forest of Congo using allometric equations. *International Journal of Scientific and Technology Research*, *3*(3), 465–474.

Engelbrecht, B.M.J., Dalling, J.W., Pearson, T.R.H., Wolf, R.L., Ga'lvez, D.A., Koehler, T., Tyree, M.T. & Kursar, T.A. (2006). Short dry spells in the wet season increase mortality of tropical pioneer seedlings. *Oecologia*, *148,* 258-269.

Engelbrecht, B.M.J., Comita, L.S., Condit, R., Kursar, T.A., Tyree, M.T., Turner, B.L. & Hubbell, S.P. (2007). Drought sensitivity shapes species distribution patterns in tropical forests. *Nature, 447,* 80-83.

Ervan, R. (2005). Dynamics of a drought-tolerant tree species in lowland dipterocarp forest: habitat association and regeneration patterns of *Dimorphocalyx muricatus*. Diploma Thesis. Unievrsity of Neuchatek-LEVP, Switzerland. (unpublished).

Escobedo, F.J., Kroeger, T. & Wagner, J.E. (2011). Urban forests and pollution mitigation: analyzing ecosystem services and disservices. *Environmental pollution (Barking, Essex : 1987)*, *159*(8–9), 2078–87. Available at: http://www.ncbi.nlm.nih.gov/pubmed/21316130 [Accessed August 26, 2013].

Evans, K., Murphy, L. & de Jong, W., (2014). Global versus local narratives of REDD: A case study from Peru's Amazon. *Environmental Science & Policy*, *35,* 98–108.

Faidi, M. A., Hamzah, K.A., Misman, M.A. & Yaakub, S.Y. (2014). Assessment of peat swamp forest cover of Malaysia using remote sensing. *35th Asian Conference on Remote Sensing 2014, ACRS 2014: Sensing for Reintegration of Societies*.

FAO (2011). *Assessing forest degradation:Towards the development of globally applicable guidelines*.

FAO (2012). *FRA 2015: Terms and Definitions*, Rome.

FAO (2010). *Global Forest Resources Assessment 2010*.

Faridah Hanum, I., Norhisyam, T.M., Sabri, M., Mohamad Azani, A., Moktharuddin, A.M., Maswar, Mohd. Kamil, Y., Majid, N.M. & Kobayashi, S. (2001). Tree species composition and above ground biomass of a 15-year-old logged-over forest at Pasoh, Negeri Sembilan, Peninsular Malaysia. In S. Kobayashi et al. (eds). *Rehabilitation of Degraded Tropical Forest Ecosystems*. Bogor, Indonesia, 81–86.

Field, M., Ecology, C. & Guide, O.A. (1998). *Bulk Density/Moisture/Aeration - Soil Quality Kit*.

Fisher, B., Turner, R.K. & Morling, P. (2009). Defining and classifying ecosystem services for decision making. *Ecological Economics*, *68*(3), 643–653. Available at: http://dx.doi.org/10.1016/j.ecolecon.2008.09.014.

Fonseca, W., Rey Benayas, J.M. & Alice, F.E. (2011). Carbon accumulation in the biomass and soil of different aged secondary forests in the humid tropics of Costa Rica. *Forest Ecology and Management*, *262*(8), 1400–1408. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0378112711003987 [Accessed December 30, 2014].

Foody, G.M. (2002). Status of land cover classification accuracy assessment. *Remote Sensing of Environment*, *80,* 185–201.

Fujii, K. (2014). Soil acidification and adaptations of plants and microorganisms in Bornean tropical forests. *Ecological Research*, *29,* 371–381.

Gadow, K.V., Zhang, C.H., Wehenkel, C., Pommerening, A., Corral-Rivas, J., Korol, M., Myklush, S., Hui, G.Y., Kiviste, A. & Zhao, X.H. (2003). Forest Structure and Diversity. In *Managing Forest Ecosystems* 23. 6.

Goldsmith, G.R., Comita, L.S. & Chua, S.C., (2011). Evidence for arrested succession within a tropical forest fragment in Singapore. *Journal of Tropical Ecology*, *27*(3), 323–326. Available at: http://www.journals.cambridge.org/abstract_S0266467411000010 [Accessed March 28, 2014].

Gonzalez, P., Kroll, B. & Vargas, C.R. (2014). Tropical rainforest biodiversity and aboveground carbon changes and uncertainties in the Selva Central, Peru. *Forest Ecology and Management*, *312,* 78–91. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0378112713006865 [Accessed January 21, 2014].

Gotelli, N.J. & Chao, A. (2013). *Measuring and estimating species richness, species diversity and biotic similarity from sampling data*, Elsevier Ltd. Available at: http://www.sciencedirect.com/science/article/pii/B9780123847195004032.

Grace, J., Mitchard, E. & Gloor, E. (2014). Perturbations in the carbon budget of the tropics. *Global Change Biology*, *20,* 3238–3255. Available at: http://doi.wiley.com/10.1111/gcb.12600.

Guariguata, M.R. & Ostertag, R. (2001). Neotropical secondary forest succession: Changes in structural and functional characteristics. *Forest Ecology and Management*, *148,* 185–206.

Harms, K.E., Condit, R., Hubbell, S.P. & Foster, R.B. (2001). Habitat associations of trees and shrubs in a 50-ha neotropical forets plot. *Journal of Ecology*, *89*(6), 947-959).

Hashim, N.O.R.R. & Hughes, F.M.R. (2010). The responses of secondary forest tree seedlings to soil enrichment in Peninsular Malaysia : An experimental approach. *Tropical Ecology*, *51*(2), 173–182.

Hattori, D., Kenzo, T., Yamauchi, N., Irino, K.O., Kendawang, J.J., Ninomiya, I. & Sakurai, K. (2013). Effects of environmental factors on growth and mortality of *Parashorea macrophylla* (Dipterocarpaceae) planted on slopes and valleys in a degraded tropical secondary forest in Sarawak, Malaysia. *Soil Science and Plant Nutrition*, *59*(2), 218–228.

Hattori, D., Kenzo, T., Irino, K.O., Kendawang, J.J., Ninomiya, I. & Sakurai, K. (2013). Effects of soil compaction on the growth and mortality of planted dipterocarp seedlings in a logged-over tropical rainforest in Sarawak, Malaysia. *Forest Ecology and Management*, *310*, 770–776. Available at: http://dx.doi.org/10.1016/j.foreco.2013.09.023.

Heimann, M. & Reichstein, M., (2008). Terrestrial ecosystem carbon dynamics and climate feedbacks. *Nature*, *451*(7176), 289–92. Available at: http://www.ncbi.nlm.nih.gov/pubmed/18202646 [Accessed November 6, 2013].

Help, C.H.R., Herman, P.M.J. & Soetaert, K., 1998. Indices of diversity and evenness *. *Oceanis*, *24*(2459), 61–87.

Hemati, Z., Hossain, M., Emenike, C.U. & Rozainah, M.Z. (2014). Rate of Carbon Storage in Soil of Natural and Degraded Mangrove Forest in Peninsular Malaysia. *CLEAN - Soil, Air, Water*, 42(9999), p.n/a-n/a. Available at: http://doi.wiley.com/10.1002/clen.201400034 [Accessed November 27, 2014].

Heng, R.K. & Tsai, L.I.M.M. (1999). An Estimate of Forest Biomass in Ayer Hitam Forest Reserve. *Pertanika Journal Tropical Agriculture Science*, *22*(2), 117–123.

Henson, I.E. (2005). An assessment of changes in biomass carbon stocks in tree crops and forests in Malaysia. *Journal of Tropical Forest Science*, *17*(2), 279–296.

Heryati, Y., Abdu, A., Mahat, M.N., Abdul-Hamid, H., Jusop, S., Majid, N.M., Heriansyah, I., Ajang, L. & Ahmad, K. (2011). Comparing the fertility of soils under Khaya ivorensis plantation and regenerated degraded secondary forests. *American Journal of Applied Sciences*, *8*(5), 472–480.

Hikmat, A. & Latiff, A. (2009). Biomass and Carbon Storage of Three Virgin Jungle

Reserves in Peninsular. *The Malayan Forester*, *72*(2), 195–208.

Ho, C.C., Newbery, D.M. & Poore, M.E.D. (1987). Forest composition and inferred dynamics in Jengka Forest Reserve, Malaysia. *Journal of Tropical Ecology*, *3*(1), 25.

Hoshizaki, K., Niiyama, K., Kimura, K., Yamashita, T., Bekku, Y., Okuda, T., Quah, E.S. & Md. Noor, N.S. (2004). Temporal and spatial variation of forest biomass in relation to stand dynamics in a mature, lowland tropical rainforest, Malaysia. *Ecological Research*, *19*(April 2003), 357–363.

Houghton, R. A. (2005). Aboveground forest biomass and the global carbon balance. *Global Change Biology*, *11*(6), 945–958. Available at: http://doi.wiley.com/10.1111/j.1365-2486.2005.00955.x [Accessed April 28, 2014].

Hunter, M.O., Keller, M., Victoria, D. & Morton, D.C. (2013). Tree height and tropical forest biomass estimation. *Biogeosciences*, *10*(12), 8385–8399. Available at: http://www.biogeosciences.net/10/8385/2013/ [Accessed July 14, 2014].

Husch, B., Beers, T.W. & Kershaw, J.A. (2003). *Forest Mensuration Fourth*, New Jersey: John Wiley & Sons Ltd.

Ibrahim, K., Jusoh, K. & Md Isa, N.N. (2007). A study of forest structure, diversity index and above-ground biomass at Tok Bali Mangrove Forest, Kelantan, Malaysia. In *Environment, Ecosystems and Development*. Tenerife, Spain, 269–276.

Immitzer, M., Atzberger, C. & Koukal, T. (2012). Tree species classification with random forest using very high spatial resolution 8-band worldview-2 satellite data. *Remote Sensing*, *4*(12), 2661–2693. Available at: http://www.mdpi.com/2072-4292/4/9/2661/ [Accessed January 29, 2015].

Inada, T., Kitajima, K., Kanzaki, M., Ano, W., Hardiwitono, S., Sadono, R., Setyanto, P.E. & Saminto. (2015). Neighboring tree effect on the survival and growth of Shorea johorensis under a line planting system in a Bornean dipterocarp forest. *Tropics*, *24*(1), 23–31.

Ingram, J.C., Dawson, T.P. & Whittaker, R.J. (2005). Mapping tropical forest structure in southeastern Madagascar using remote sensing and artificial neural networks. *Remote Sensing of Environment*, *94*, 491–507.

Ioki, K., Imanishi, J. & Sasaki, T. (2011). Vegetation mapping of urban forest using airborne laser scanning in Kyoto City, Japan. In *Waste and Biomass Valorization*. Skiathos, 1049–1054. Available at: http://link.springer.com/article/10.1007/s12649-012-9158-y.

IPNI. The International Plant Name Index. (Http://www.ipni.org/).

Ipor, I., Jusoh, I., Wasli, M.E. & Seman, I.A. (2013). Composition and diversity of plant seedlings and saplings at early secondary succession of fallow lands in Sabal, Sarawak. *Acta Biologica Malaysiana*, *2*(3), 85–94.

ITTO, (2002). *ITTO Guidelines for the Restoration, Management and Rehabilitation of Degraded and Secondary ITTO Guidelines for the Restoration, Management and Rehabilitation.*

Jandl, R., Schuler, S., Schindlbacker, A. & Tomiczek, C. (2013). Forests, carbon pool, and timber production. In R. Lal et al. (eds). *Ecosystem Services and Carbon Sequestration in the Biosphere*. Dordrecht: Springer Netherlands, 101–130. Available at: http://link.springer.com/10.1007/978-94-007-6455-2 [Accessed August 29, 2013].

Jepsen, M.R. (2006). Above-ground carbon stocks in tropical fallows, Sarawak, Malaysia. *Forest Ecology and Management*, *225*(1–3), 287–295. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0378112706000132 [Accessed August 8, 2013].

Jeyanny, V., Husni, M.H.A., Wan Rasidah, K., Siva Kumar, B., Arifin, A. & Kamarul Hisham, M. (2014). Carbon stocks in different carbon pools of a tropical lowland forest and a montane forest with varying topography. *Journal of Tropical Forest Science*, *26*(4), 560–571.

Jong, W. De, Chokkalingam, U. & Smith, J., (2001). Tropical secondary forests in asia : Introduction and synthesis. *Journal of Tropical Forest Science*, *13*(4), 563–576.

John, R., Dalling, J.W., Harms, K.E., Yavitt, J.B., Stallard, R.F., Mirabello, M., Hubbell, S.P., Valencia, R., Navarrete, H., Vallejo, M & Foster, R.B. (2007). Soil nutrients influence spatial distributions of tropical tree species. *Proceedings of National Academy of Science, 104,* 864-869.

Jusoff, K., (2010). Individual species crown mapping in Taman Rimba Ilmu, University Malaya using airborne hyperspectral imaging. *American Journal of Applied Sciences*, *7*(4), 493–499. Available at: http://www.thescipub.com/abstract/10.3844/ajassp.2010.493.499.

Jusoff, K., Hassan, C.H. & Hamzah, K.A., (2007). Tropical peat swamp forest ecosystem and floristic diversity in Pahang , Malaysia. *International Journal of Systems Applications, Engineering & Development*, *3*(1), 41–44.

Kamaruzaman, J., Malek, M.Y. & Nurul Hidayah, M.A. (2010). Spectral signatures of leaf fall diseases in Hevea Brasiliensis using a handheld spectroradiometer. *Modern Applied Science*, *4*(2), 78–84.

Kanniah, K.D., Muhamad, N. & Kang, C.S. (2014). Remote sensing assessment of carbon storage by urban forest. *IOP Conference Series: Earth and Environmental Science*, *18,* 12151. Available at: http://stacks.iop.org/1755-1315/18/i=1/a=012151?key=crossref.8cafcc92c448080d8a6a35dee6f9f9a6 [Accessed April 3, 2014].

Kardevan, P. (2007). Reflectance spectroradiometry - a new tool for envicronmental mapping. *Carpth. J. of Earth and Environmental Sciences*, *2*(2), 29–38.

Karsenty, A., Vogel, A. & Castell, F. (2014). Carbon rights, REDD+ and payments for environmental services. *Environmental Science & Policy*, *35,* 20–29. Available at: http://linkinghub.elsevier.com/retrieve/pii/S1462901112001463 [Accessed March 25, 2014].

Kartawinata, K., Riswan, S., Gintings, A.N. & Puspitojati, T. (2001). An overview of post-extraction secondary forests in Indonesia. *Journal of Tropical Forest Science*, *13*(4), 621–638.

Kartawinata, K. (1994). The Use of Secondary Forest Species in Rehabilitation of Degraded Forest Lands. *Journal of Tropical Forest Science*, *7*(1), 76–86.

Kauffman, J.B., Cummings, D.L., Ward, D.E. & Babbitt, R. (1995). Fire in the Brazilian Amazon: 1. Biomass, nutrient pools, and losses in slashed primary forests. *Oecologia*, *104,* 397–408.

Kauffman, S., Sombroek, W. & Mantel, S. (1998). Soils of rainforests:characterization and major constraint of dominant forest soils in humid tropics. In. Schulte, A. & Ruhiyat, D. (eds). *Soils of tropical ecosystems*, pp. 9-20. Berlin: Springer.

Kenzo, T., Ichie, T., Hattori, D., Itioka, T., Handa, C., Ohkubo, T., Kendawang, J.J., Nakamura, M., Sakaguchi, M., Takahashi, N., Okamoto, M., Sakurai, K., et al. (2009). Allometric equations for accurate estimation of above-ground biomass in logged-over tropical rainforests in Sarawak, Malaysia. *Journal of Forest Research*, *14,* 365–372.

Kenzo, T., Ichie, T., Hattori, D., Kendawang, J.J., Sakurai, K. & Ninomiya, I. (2010). Changes in above- and belowground biomass in early successional tropical secondary forests after shifting cultivation in Sarawak, Malaysia. *Forest Ecology and Management*, *260*(5), 875–882. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0378112710003294 [Accessed April 7, 2014].

Kenzo, T., Ichie, T., Hattori, D., Itioka, T., Handa, C., Ohkubo, T., Kendawang, J.J., Nakamura, M., Sakaguchi, M., Takahashi, N., Okamoto, M., Tanaka-Oda, A., et al. (2009). Development of allometric relationships for accurate estimation of above- and below-ground biomass in tropical secondary forests in Sarawak, Malaysia. *Journal of Tropical Ecology*, *25*(4), 371. Available at: http://www.journals.cambridge.org/abstract_S0266467409006129 [Accessed December 2, 2014].

Kessler, M., Kebler, P.J.A., Gradstein, S.B., Bach, K., Schmull, M. & Pitopang, R. (2005). Tree diversity in primary forest and different land use systems in Central Sulawesi, Indonesia. *Biodiversity and Conservation*, *14*, 547–560.

Khairil, M., Wan Juliana, W.A., Nizam, M.S. & Faszly, R. (2011). Community Structure and Biomass of Tree Species at Chini. *Sains Malaysiana*, *40*(11), 1209–1221.

Khali, A.H., Ismail, P., Abd Rahman, K., Che Hashim, H., Grippin, A. & Nizam, M.S. (2009). Ecological characteristics of a Gonystylus bancanus-rich area in Pekan Peat swamp forest (PSF). *Tropical Life Sciences Research*, *20*(2), 15–27.

Kim Phat, N., Knorr, W. & Kim, S. (2004). Appropriate measures for conservation of terrestrial carbon stocks - Analysis of trends of forest management in Southeast Asia. *Forest Ecology and Management*, *191*(1–3), 283–299. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0378112704000428 [Accessed March 5, 2013].

Kindermann, G.E., McCallum, I., Fritz, S. & Obersteiner, M. (2008). A global forest growing stock, biomass and carbon map based on FAO statistics. *Silva Fennica*, *42*(3), 387–396.

Kochummen, K.M. & LaFrankie J V, J. (1990). Floristic composition of Pasoh Forest Reserve, a lowland rain forest in Peninsular Malaysia. *Journal of Tropical*, (October). Available at: http://www.cabdirect.org/abstracts/ 19930667132.html.

Kridiborworn, P., Chidthaisong, A., Yuttitham, M. & Tripetchkul, S. (2012). Carbon sequestration by mangrove forest planted specifically for charcoal production in Yeesarn, Samut Songkram. *Journal of Sustainable Energy & Environment*, *3*, 87–92.

Kueh, R., Onichandran, S., Mohamad Suhailiee, K.M., Sait, M., Sam, S. & Empin, G.B. (2014). Estimation of the aboveground biomass in a Dillenia suffruticosa stand, Malaysia. *Taiwan Journal Forest Science*, *29*(November 2012), 69–78.

Kuijk, M.V., Anten, N.P.R., Oomen, R.J., Bentum, D.W.V. and Werger, M.J.A. (2008). The limited importance of size-asymmetric light competition and growth of pioneer species in early secondary forest succession in Vietnam. *Oecologia*, *157*(1), 1–12. Available at: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2469597&tool=pmcentrez&rendertype=abstract [Accessed January 8, 2015].

Kurnianto, S., Warren, M., Talbot, J., Kauffman, B., Murdiyarso, D. & Frolking, S. (2014). Carbon accumulation of tropical peatlands over millennia: A modeling approach. *Global Change Biology*, 431–444.

Kuruneri-Chitepo, C. & Shackleton, C.M., (2011). The distribution, abundance and composition of street trees in selected towns of the Eastern Cape, South Africa. *Urban Forestry & Urban Greening*, *10*(3), 247–254. Available at: http://linkinghub.elsevier.com/retrieve/pii/S1618866711000434 [Accessed April 2, 2013].

Lajuni, J. & Latiff, A. (2013). Biomass and floristic composition of Bangi permanent forest reserve, a twice-logged lowland dipterocarp forest in Peninsular Malaysia. *Sains Malaysiana*, *42*(10), 1517–1521.

Lasco, R.D. & Cardinoza, M.M. (2006). Baseline carbon stocks assessment and projection of future carbon benefits of a carbon sequestration project in East Timor. *Mitigation and Adaptation Strategies for Global Change*, *12*(2), 243–257. Available at: http://link.springer.com/10.1007/s11027-005-9011-8 [Accessed February 24, 2014].

Latif, Z.A., Zamri, I. & Omar, H. (2012). Determination of tree species using Worldview-2 data. *2012 IEEE 8th International Colloquium on Signal Processing and its Applications*, 383–387. Available at: http://ieeexplore.ieee.org/lpdocs/epic03/wrapper.htm?arnumber=6194754.

Laurance, W. (2007). A new initiative to use carbon trading for tropical forest conservation. *Biotropica*, *39*(1), 20–24.

Lawal, D.U., Matori, A.N., Chandio, I.A. & Balogun, A.L. (2011). Framework for recreational park suitability. *International Journal of Civil & Environmental Engineering*, *11*(1).

Leng, L.Y., Ahmed, O.H., Ab Majid, N.M. & Jalloh, M.B. (2009). Organic matter, carbon and humic acids in rehabilitated and secondary forest soils. *American Journal of Applied Sciences*, *6*(5), 824–828.

Leps, J. & Smilauer, P. (2003). *Multivariate Analysis of Ecological Data using CANOCO*, United Kingdom: Cambridge Univeristy Press.

Lepun, P. (2002). *Tree species composition and distribution in Ayer Hitam Forest Reserve, Puchong, Selangor*. MSc. Thesis, Universiti Putra Malaysia, Serdang. (unpublished).

Lewis, O.T., Ewers, R.M., Lowman, M.D. & Mathi, Y. (2013). Conservation of tropical forests: maintaining ecological integrity and resilience. In: McDonald, D.W. & Willis, K.J. (eds). *Key topics in conservation biology 2*. 1st ed. United Kingdom: John Wiley & Son.

Li, Y., Xu, M., Zou, X., Shi, P. & Zhang, Y. (2005). Comparing soil organic carbon dynamics in plantation and secondary forest in wet tropics in Puerto Rico. *Global Change Biology*, *11*(2), 239–248. Available at: http://doi.wiley.com/10.1111/j.1365-2486.2005.00896.x [Accessed February 4, 2015].

Li, Y., Xia, Y., Lei, Y., Deng, Y., Chen, H., Sha, L., Cao, M. & Deng, Xl. (2015). Estimating changes in soil organic carbon storage due to land use changes using a modified calculation method. *iForest - Biogeosciences and Forestry*, *8*(1), 45–52. Available at: http://www.sisef.it/iforest/?doi=ifor1151-007 [Accessed February 2, 2015].

Liao, C., Luo, Y., Fang, C. & Li, B. (2010). Ecosystem carbon stock influenced by plantation practice: Implications for planting forests as a measure of climate change mitigation. *PLoS ONE, 5.*

Longman, K.A. & Jenik, J. (1987). *Tropical Forest and Its Environment* (2nd edition). London: Longman and Scientific & Technical.

Lorenz, K. (2013). Ecosystem carbon sequestration. In R. Lal et al. (eds.). *Ecosystem Services and Carbon Sequestration in the Biosphere*. Dordrecht: Springer Netherlands, 39–62. Available at: http://link.springer.com/10.1007/978-94-007-

6455-2 [Accessed August 29, 2013].

Lovejoy, T.E., Bierregaard, Jr., RO., Rankin, J.M. & Schubart, H.O. (1983). Ecological dynamics of tropical forest fragments. In. Sutton, L., Whitmore, T.C. & Chadwick, A.C. (eds). *Tropical Rain Forest: Ecology and Management*, pp.377-384.

Lu, D., Mausel, P., Brondizio, E. & Moran, E. (2003). Classification of successional forest stages in the Brazilian Amazon basin. *Forest Ecology and Management, 181*, 301–312.

Luis Hernandez-Stefanoni, J. & Ponce-Hernandez, R. (2004). Mapping the spatial distribution of plant diversity indices in a tropical forest using multi-spectral satellite image classification and field measurements. *Biodiversity and Conservation*, *13*(Forman 1995), 2599–2621.

Magurran, A.E. (1988). *Ecological Diversity and Its Measurement*, London: Chapman and Hall.

Magurran, A.E. & McGill, B. (eds.) (2011). *Biological Diversity: Frontiers in measurement and assessment*. New York: Oxford University Press.

Makido, Y., Dhakal, S. & Yamagata, Y. (2012). Relationship between urban form and CO2 emissions: Evidence from fifty Japanese cities. *Urban Climate*, *2,* 55–67. Available at: http://linkinghub.elsevier.com/retrieve/pii/ S2212095512000132 [Accessed March 9, 2013].

Mardan, M., Hakeem, K.R., Faridah Hanum, I. & Saari, N.S. (2013). Tree species composition and diversity in one ha forest,Ulu Muda Forest Reserve, Kedah. *Sains Malaysiana*, *42*(10), 1409–1424.

Martin, A.R. & Thomas, S.C. (2011). A reassessment of carbon content in tropical trees. *PloS One*, *6*(8), p.e23533. Available at: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3157388&tool=pmcentrez&rendertype=abstract [Accessed November 17, 2014].

Martin, P.A, Newton, A.C. & Bullock, J.M. (2013). Carbon pools recover more quickly than plant biodiversity in tropical secondary forests. *Proceedings. Biological Sciences / The Royal Society*, *280*(1773), 20132236. Available at: http://www.ncbi.nlm.nih.gov/pubmed/24197410.

Matricardi, E.A.T., Skole, D.L., Pedlowski, M.A., Chomentowski, W. & Fernandes, L.C. (2010). Assessment of tropical forest degradation by selective logging and fire using Landsat imagery. *Remote Sensing of Environment*, *114*(5), 1117–

1129. Available at: http://linkinghub.elsevier.com/retrieve/pii/ S0034425710000234 [Accessed April 9, 2014].

Mat-Salleh, K., Tami, R. & Latiff, A. (2003). Ecology and conservation value of Tanjung Tuan, the myrtaceae-dominated coastal forest reserve of Malaysia. *Journal of Tropical Forest Science, 15*(1), 59-73.

Mazlin, K. (2014). *Struktur Komuniti Pokok, Taburan dan hubungan dengan Faktor Tanah dalam Hutan Pusingan Kedua di Jengka, Pahang*. Universiti Kebangsaan Malaysia.

Merry, K., Siry, J., Bettinger, P. & Bowker, J.M. (2013). Efficient assessments of urban tree planting potential within or near the southern Piedmont region of the United States. *Computers, Environment and Urban Systems*, *39,* 39–47. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0198971513000136 [Accessed June 27, 2013].

Ministry of Natural Resources and Environment Malaysia (2000a). *Malaysia Second National Communication to The UNFCCC*.

Ministry of Natural Resources and Environment Malaysia (2000b). *Second National Communication to UNCFFF*, Malaysia.

Morton, D.C., Sales, M.H., Souza, C.M. & Griscom, B. (2011). Historic emissions from deforestation and forest degradation in Mato Grosso, Brazil: 1) source data uncertainties. *Carbon Balance and Management*, *6*, 18.

Motz, K., Sterba, H. & Pommerening, A. (2010). Sampling measures of tree diversity. *Forest Ecology and Management*, *260*(11), 1985–1996. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0378112710005177 [Accessed January 18, 2015].

Moura-costa, P. (1996). Tropical forestry practices for carbon sequestration. In A. Schulte & D. Schone (eds.). *Dipterocarp Forest Ecosystems - Towards Sustainable Management*. Singapore: World Scientific, 279–283.

Mucha, A.P., Vasconcelos, M.T.S.D. & Bordalo, A. A., (2003). Macrobenthic community in the Douro estuary: Relations with trace metals and natural sediment characteristics. *Environmental Pollution*, *121,* 169–180.

Mucha, A.P., Vasconcelos, M.T.S.D. & Bordalo, A. A. (2004). Vertical distribution of the macrobenthic community and its relationships to trace metals and natural sediment characteristics in the lower Douro estuary, Portugal. *Estuarine, Coastal and Shelf Science*, *59,* 663–673.

Muthulingam, U. & Thangavel, S. (2012). Density, diversity and richness of woody plants in urban green spaces: A case study in Chennai metropolitan city. *Urban Forestry & Urban Greening*, *11*(4), 450–459. Available at: http://linkinghub.elsevier.com/retrieve/pii/S1618866712000908 [Accessed March 4, 2013].

Nagy, M.T., Janssens, I.A., Yuste, J.C., Carrara, A. & Ceulemans, R. (2006). Footprint-adjusted net ecosystem CO2 exchange and carbon balance components of a temperate forest. *Agricultural and Forest Meteorology*, *139*(3–4), 344–360. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0168192306002346 [Accessed January 27, 2014].

Nelson, R.F., Kimes, D.S., Salas, W.A. & Routhier, M. (2000). Secondary forest age and tropical forest biomass estimation using thematic mapper imagery. *BioScience*, *50*(5), 419.

Neto, V., Ahmad Ainuddin, N., Wong, M.Y. & Ting, H.L. (2012). Contributions of forest biomass and organic matter to above-and belowground carbon contents at Ayer Hitam Forest Reserve, Malaysia. *Journal of Tropical Forest Science*, *24*(2), pp.217–230.

Neumann-Cosel, L., Zimmermann, B., Hall, J.S., Breugel, V.M. & Elsenbeer, H. (2011). Soil carbon dynamics under young tropical secondary forests on former pastures—A case study from Panama. *Forest Ecology and Management*, *261*(10), 1625–1633. Available at: http://linkinghub.elsevier.com/retrieve/pii/S037811271000407X [Accessed December 30, 2014].

Ngo, K.M., Turner, B.L., Muller-landau, H.C., Davies, S.J., Larjavaara, M., Nik Hassan, N.F. & Lum, S. (2013). Carbon stocks in primary and secondary tropical forests in Singapore. *Forest Ecology and Management*, *296*, 81–89. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0378112713000984 [Accessed March 27, 2013].

Niiyama, K., Kajimoto, T., Matsuura, Y., Yamashita, T., Matsuo, N., Ripin, A., Kassim, A.B. & Noor, N.S. (2010). Estimation of root biomass based on excavation of individual root systems in a primary dipterocarp forest in Pasoh Forest Reserve, Peninsular Malaysia. *Journal of Tropical Ecology*, *26*, 271.

Nizam, M.S., Fakhrul-Hatta & A. L. (2006). Diversity and tree species community in the Krau Wildlife Reserve, Pahang, Malaysia. *Malaysian Applied Biology*, *35*(2), 81–85.

Nizam, M.S., Jeffri, A. R. & Latiff, A. (2013). Structure of tree communities and their association with soil properties in two fan-palm dominated forests of east coast Peninsular Malaysia. *Tropical Ecology*, *54*(2), 213–226.

Nizam, M.S., Rohani, S. & Wan Juliana, W. A. (2012). Floristic variation of tree communities in two distinct habitats within a Forest Park in Pahang, Peninsular Malaysia. *Sains Malaysiana*, *41*(1), 1–10.

Nizam M.S., Norziana, J., Sahibin, A.R. & Latiff, A. (2006). Edaphic relationships among tree species in the national park At Merapoh, Pahang, Malaysia. *Journal of Bioscience*, *17*(2), 37–53. Available at: http://www.usm.my/bio/bioscience/2006-17-02_files/17-2-05Nizam.pdf.

Njomgang, R., Yemefack, M., Nounamo, L., Moukam, A. Katto-Same, J. (2011). Dynamics of shifting agricultural systems and organic carbon sequestration in Southern Cameroon. *Tropicultura*, *29*, 176–182.

Nowak, D.J., Greenfield, E.J., Hoehn, R.E. & Lapoint, E. (2013a). Carbon storage and sequestration by trees in urban and community areas of the United States. *Environmental Pollution (Barking, Essex : 1987)*, *178C*, 229–236. Available at: http://www.ncbi.nlm.nih.gov/pubmed/23583943 [Accessed April 21, 2013].

Nowak, D.J. & Crane, D.E., (2002). Carbon storage and sequestration by urban trees in the USA. *Environmental Pollution*, *116*(3), 381–9. Available at: http://www.ncbi.nlm.nih.gov/pubmed/11822716.

Numata, S., Yasuda, M., Okuda, T., Kachi, N. & Nur Supardi, M.N. (2006). Canopy gap dynamics of two different forest stands in a Malaysian lowland rain forest. *Journal of Tropical Forest Science*, *18*(2), 109–116.

Nurfazliza, K., Nizam, M.S. & Suparpardi, M.N.N. (2012). Association of liana communities with their soil properties in a lowland forest of negeri sembilan, Peninsular Malaysia. *Sains Malaysiana*, *41*(6), 679–690.

Okuda, T., Suzuki, M., Adachi, N., Quah, E.S., Hussien, N.A. & Manokaran, N. (2003). Effect of selective logging on canopy and stand structure and tree species composition in a lowland dipterocarp forest in peninsular Malaysia. *Forest Ecology and Management*, *175*(1–3), 297–320. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0378112702001378.

Okuda, T., Suzuki, M., Numata, S., Yoshida, K., Nishimura, S., Adachi, N., Niiyama, K., Manokaran, N. & Hashim, M. (2004). Estimation of aboveground biomass in logged and primary lowland rainforests using 3-D photogrammetric analysis. *Forest Ecology and Management*, *203,* 63–75.

Oliveira Filho, A.T., Carvalho, D.A., Vilela, E.A., Curi, N. & Fontes, M.A. (2004). Diversity and structure of the tree community of a fragment of tropical secondary forest of the brazilian Atlantic Forest domain 15 and 40 years after logging. *Revista Brasileira de Botânica*, *27,* 685–701.

Olschewski, R. & Benítez, P.C. (2005). Secondary forests as temporary carbon sinks? The economic impact of accounting methods on reforestation projects in the tropics. *Ecological Economics*, *55*(3), 380–394. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0921800904004215 [Accessed January 6, 2015].

Omar, H., Ismail, M.H. & Abu Hassan, M.H. (2013). Optimal Plot Size for Sampling Biomass in Natural and Logged Tropical Forests. In *Conference on Forestry and Forest Products*.

Orihuela-Belmonte, D.E., de Jong, B.H.J., Vega, J.M., der Wal, J.V., Pellat, F.P., Pinto, L.S. & Sandoval, A.F. (2013). Carbon stocks and accumulation rates in tropical secondary forests at the scale of community, landscape and forest type. *Agriculture, Ecosystems and Environment*, *171,* 72–84. Available at: http://dx.doi.org/10.1016/j.agee.2013.03.012.

Osman, K.T. (2014). *Forest Soils*.

Osman, K.T. (2013). Forest soils: Properties and management. *Forest Soils: Properties and Management*, 1–217.

Othman, Y. & Shamshuddin, J. (1982). *Sains Tanah*. Kuala Lumpur, Malaysia: Dewan Bahasa dan Pustaka.

Pala, N. A., Negi, A.K., Gokhale, Y., Aziem, S., Vikrant, K.K. & Todaria, N.P. (2013). Carbon stock estimation for tree species of Sem Mukhem sacred forest in Garhwal Himalaya, India. *Journal of Forestry Research*, *24*(3), 457–460. Available at: http://link.springer.com/10.1007/s11676-013-0341-1 [Accessed November 10, 2014].

Paoli, G.D., Curran, L.M. & Zak, D.R. (2006). Soil Nutrients and Beta Diversity in the Borneon Dipterocarpaceae: Evidence for Niche Partitioning by Tropical Rain Forest Trees. *Journal of Ecology, 94*(1), 157-170.

Peña-claros, M. (2003). Changes in forest structure and species composition during secondary forest succession in the Bolivian Amazon. *Biotropica*, *35*(4), 450–461.

Pinedo, A., Wehenkel, C., Hernandez-Diaz, J.C. & Vazquez, G. (2011). Remote sensing application in forest assessment. *Bulletin of the Transilvania University*, *4*(53), 71–76. Available at: http://www.tropecol.com/pdf/open/PDF_43_1/43105.pdf.

Pires, J.M. (1978). The forest ecosystems of the Brazilian Amazon: description, functioning and research needs. In: *Tropical Forest Ecosystems. A state of knowledge report prepared by UNESCO/UNEP/FAO*. pp 607-627. France: UNESCO-UNEP.

Podong, C. & Poolsiri, R. (2013). Forest structure and species diversity of secondary forest after cultivation in relation to various sources at lower northern Thailand. In *Proceedings of the International Academy of Ecology and Environmental Sciences*, 208–218.

Poorter, L. (1999). Growth responses of 15 rain-forest tree species to a light gradient: the relative importance of morphological and physiological traits. *Functional Ecology*, *13*(3), 396–410. Available at: http://doi.wiley.com/10.1046/j.1365-2435.1999.00332.x.

Poorter, L., Bongers, F. & Aide, T.M. (2016). Biomass resilience of neotropical secondary forests. *Nature*, *530*, 211–227.

Post, W.M. & Kwon, K.C. (2000). Soil carbon sequestration and land-use change: processes and potential. *Global Change Biology*, *6*, 317–327. Available at: http://doi.wiley.com/10.1046/j.1365-2486.2000.00308.x.

Potts, M.D., Ashton, P.S., Kauffman, L.S. & Plotkin, J.B. (2002). Habitat patterns in tropical rainforests: a comparison of 105 plots inNorthwest Borneo. *Ecology, 83,* 2782-2797.

Pouyat, R., Groffman, P., Yesilonis, L. & Hernandez, L. (2002). Soil carbon pools and fluxes in urban ecosystems. *Environmental Pollution, 116,* S107–S118. Available at: http://www.ncbi.nlm.nih.gov/pubmed/11833898.

Pragasan, L., A. & Karthick, A. (2013). Carbon stock sequestered by tree plantations in university campus at Coimbatore, India. *International Journal of Environmental Sciences, 3*(5), 1700–1710.

Pregitzer, K.S., Burton, A.J., King, J.S. & Zak, D.R. (2008). Soil respiration, root biomass, and root turnover following long-term exposure of northern forests to elevated atmospheric CO2 and tropospheric O3. *New Phytologist*, *180*, 153–161.

Rabiatul Khairunnisa & Mohd Hasmadi (2012). Biomass and carbon in mangrove: Measuring and managing through remote sensing technique. In *Malaysia Geospatial Forum*.

Radhiah, Z. (2015). *Ecological Characteristics of Vegetation Communities in a Semi-deciduous Forest at Perlis State Park, Perlis, Peninsular Malaysia*. Universiti Kebangsaan Malaysia.

Rathore, A. & Jasrai, Y.T. (2013). Urban green patches as carbon sink : Gujarat university campus, Ahmedabad. *Indian Journal of Fundamental and Applied Life Sciences*, *3*(1), 208–213.

Rautiainen, M. (2005). *The Spectral Signature of Coniferous Forests: The Role of Stand Structure and Leaf Area Index*. University of Helsinki. Available at: http://metla.eu/dissertationes/df6.pdf.

Razafimbelo, T., Chevallier, T., Albrecht, A., Lardy, L.C., Rakotondrasolo, F.N., Michellon, R., Rabeharisoa, L. & Bernoux, M. (2013). Texture and organic carbon contents do not impact amount of carbon protected in Malagasy soils. *Scientia Agricola*, *70*(June), 204–208. Available at: http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0103-90162013000300009&lng=en&nrm=iso&tlng=en.

Reese, H. (2011). *Classification of Sweden's Forest and Alpine Vegetation using Optical Satellite and Inventory Data*. Swedish Univeristy of Agricultural Sciences. Available at: http://pub.epsilon.slu.se/8349/.

Ren, Y., Yan, J., Wei, X., Wang, Y., Yang, Y., Hua, L., Xiong, Y., Niu, X. & Song, X. (2012). Effects of rapid urban sprawl on urban forest carbon stocks: Integrating remotely sensed, GIS and forest inventory data. *Journal of Environmental Management*, *113*, 447–55. Available at: http://www.ncbi.nlm.nih.gov/pubmed/23122621 [Accessed April 24, 2013].

Reyes, G., Brown, S. & Chapman, J. (1992). Wood densities of Tropical tree species. *Technical report*, 1–18.

Rita Diana (2007). Akumulasi karbon pada beberapa jenis pioner pada hutan sekunder dan hutan tanaman industri di Kalimantan Timur. *RIMBA Kalimantan Fakultas Kehutanan Unmul*, *12*(1), 51–55.

Rohani, S. (2007). *Struktur Komuniti Variasi Flora dan Biojisim di Taman Rimba*

Kenong, Kuala Lipis, Pahang. Universiti Kebangsaan Malaysia.

Rossiter, D.G. (2004). *Technical Note: Statistical Methods for Accuracy Assesment of Classified Thematic Maps*, Enschede, Netherlands: Department of Earth Systems Analysis, Universitiy of Twente, Faculty of Geo-Information Science & Earth Observation (ITC). Available at: http://www.itc.nl/personal/rossiter/teach/R/R_ac.pdf.

Rutishauser, E., Noor'an, F., Laumonier, Y., Halperin, J., Rufi'ie, Hergoualc'h, K. & Verchot, L. (2013). Generic allometric models including height best estimate forest biomass and carbon stocks in Indonesia. *Forest Ecology and Management*, *307,* 219–225. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0378112713004453 [Accessed May 7, 2014].

Sadeghi, S.M. & Razali, W.A.N. (2014). Tree composition and diversity of a hill dipterocarp forest after logging. *Malayan Nature Journal*, *66*(4), pp.1–15.

Saiful, I. (2002). *Effect of selective logging on tree species diversity, stand structure and physical environment of tropical hill dipterocarp forest of Peninsular Malaysia*. PhD Thesis. Universiti Kebangsaan Malaysia, Bangi. (unpublished).

Salahudin, S., Abdullah, M. & Newaz, N. (2013). Emissions: Sources, policies and development in Malaysia. *International Journal of ...*, *1*(7), 1–12. Available at: http://www.ijern.com/journal/July-2013/31.pdf.

Sanchez, P. (1989). Soil ecosystems of the world. *The tropical rainforest ecosystem*. USA: Elsevier Science Publication B.V.

Saner, P., Loh, Y.Y., Ong, R.C. & Hector, A. (2012). Carbon stocks and fluxes in tropical lowland dipterocarp rainforests in Sabah, Malaysian Borneo. *PloS one*, *7*(1), e29642. Available at: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3250468&tool=pmcentrez&rendertype=abstract [Accessed November 25, 2014].

Sang, P.M., Lamb, D., Bonner, M. & Schmidt, S. (2013). Carbon sequestration and soil fertility of tropical tree plantations and secondary forest established on degraded land. *Plant and Soil*, *362,* 187–200.

Schnitzer, S. A., Mascaro, J. & Carson, W.P. (1991). Treefall gaps and the maintenance of plant species diversity in tropical forests. *Ecology*, *82*(1947), 913–919. Available at: http://wolfweb.unr.edu/~ldyer/classes/396/schnitzer.pdf.

Schrumpf, M., Schulze, E.D., Kaiser, K. & Schumacher, J. (2011). How accurately can soil organic carbon stocks and stock changes be quantified by soil inventories? *Biogeosciences*, *8*(5), 1193–1212. Available at: http://www.biogeosciences.net/8/1193/2011/ [Accessed November 10, 2014].

Schuck, A., Paiivinen, R., Hytonen, T. & Pajari, B. (2002). *Compilation of Forestry Terms and Definitions*, Finland.

Selaya, N.G., Anten, N.P.R., Oomen, R.J., Matthies, M. & Werger, M.J.A. (2007). Above-ground biomass investments and light interception of tropical forest trees and lianas early in succession. *Annals of botany*, *99*(1), 141–51. Available at: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=2802976&tool=pmcentrez&rendertype=abstract [Accessed December 11, 2014].

Shamshuddin, J. & Che Fuziah, I. (2010). *Weathered tropical soils the ultisols and oxisols*. Serdang: Universiti Putra Malaysia.

Shono, K., Davies, S.J. & Kheng, C.Y. (2006). Regeneration of native plant species in restored forests on degraded lands in Singapore. *Forest Ecology and Management*, *237*(1–3), 574–582. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0378112706010231 [Accessed March 28, 2014].

Sierra, C. A, Del Valle, J.I. & Restrepo, H.I. (2012). Total carbon accumulation in a tropical forest landscape. *Carbon Balance and Management*, 7(1), 12. Available at: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3732086&tool=pmcentrez&rendertype=abstract.

Silvestrini, M., Valio, I.F.M., & De Mattos, E.R. (2007). Photosynthesis and carbon gain under contrasting light levels in seedlings of a pioneer and a climax tree from a Brazilian Semideciduous Tropical Forest. *Revista Brasileira de Botânica*, *30*(3), 463–474.

Singh, M., Evans, D., Tan, B.S. & Nin, C.S. (2015). Mapping and characterizing selected canopy tree species at the Angkor world heritage site in Cambodia using aerial data. *PLoS ONE, 10,* 1–26.

Slik, J.W.F. (2005). Assessing tropical lowland forest disturbance using plant morphological and ecological attributes. *Forest Ecology and Management, 205*(1–3), 241–250. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0378112704007200 [Accessed May 11, 2014].

Smith, R.L. (1992). *Elements of Ecology 3rd ed*. New York: Harper Collins

Publishers.

Sollin, M. (1998). Factors influencing species composition in tropical lowland forest:does soil matter? *Ecology, 79,* 23-30.

Sreenivas, B. & B. Narasimha Chary (2011). Processing of satellite image using digital image processing. In *Dimensions and Directions of Geospatial Industry*. India: Geospatial World Forum.

Stas, S.M. (2011). *Aboveground Biomass and Carbon Stocks in a Secondary Forest in Comparison with Adjacent Forest on Limestone in Seram, Moluccas, Indonesia*.

Strohbach, M.W. & Haase, D. (2012). Above-ground carbon storage by urban trees in Leipzig, Germany: Analysis of patterns in a European city. *Landscape and Urban Planning*, *104*(1), 95–104. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0169204611002891 [Accessed March 23, 2013].

Sundarapandian, S.M. & Swamy, P. S. (2000). Forest ecosystem structure and composition along an altitudinal gradient in the Western Ghats, South India. *Journal of Tropical Forest Science, 12*(1),104-123.

Suryatmojo, H. (2014). Recovery of forest soil disturbance in the intensive forest management system. *Procedia Environmental Sciences*, *20,* 832–840. Available at: http://www.sciencedirect.com/science/article/pii/S1878029614001029.

Suryawanshi, M.N., Patel, A.R., Kale, T.S. & Patil, P.R. (2014). Carbon sequestration potential of tree species in the environment of North Maharashtra University Campus, Jalgaon (MS) India. *Bioscience Discovery*, *5*(2), 175–179.

Swaine, M.D. & Whitmore, T.C. (1988). On the definition of ecological species groups in tropical rain forests. *Vegetatio*, *75*(1–2), 81–86. Available at: http://link.springer.com/10.1007/BF00044629.

Swaine, M.D. (1996). Rainfall and soil fertility as factors limiting forest species distributions in Ghana. *Journal of Ecology, 84,* 419-428.

Symington, C.F. (1943). Foresters Manual of Dipterocarps. *Malayan Forest Records No.16*.

Tange, T., Yagi, H., Sasaki, S., Niiyama, K. & Abd Rahman, K. (1998). Relationship between topography and soil properties in a hill dipterocarp forest dominated by *Shorea curtisii* at Semangkok Forest Reserve, Peninsular Malaysia. *Journal of Tropical Forest Science, 10*(3), 398-409.

Terakunpisut, J., Gajaseni, N. & Ruankawe, N. (2007). Carbon sequestration potential in aboveground biomass of Thong Pha Phum national forest. *Applied Ecology and Environment Research*, *5*(2), 93–102.

The World Bank (2010). *World Development Report 2010: Development and Climate Change*, Washington.

Thompson, I., Ferreira, J., Gardner, T., Guariguata, M., Koh, L.P., Okabe, K., Pan, Y., Schmitt, C.B. & Tylianakis, J. (2012). Forest biodiversity, carbon and other ecosystem services: Relationships and impacts of deforestation and forest degradation. In *Understanding Relationships between Biodiversity, Carbon, Forests and People: The Key to Achieving REDD+ Objectives*, 21–50.

Turner, I. M. (1989). An enumeration of one hectare of Pantai Aceh Forest Reserve, Penang. *The Garden's Bulletin Singapore*, *42*(1), 29-44.

Turner, I.M. (1995). A catalogue of the vascular plant of Malaya. *The Garden's Bulletin Singapore, 47*(1-2), 1-757.

Turner, I. (2001). *The Ecology the Tropical Rainforest*. Cambridge, UK: Cambridge University Press.

United Nations (1992). *United Nations Framework Convention on Climate Change*. Available at: http://doi.wiley.com/10.1111/j.1467-9388.1992.tb00046.x.

United Nations Framework Convention on Climate Change (2015). *Adoption of the Paris Agreement. Proposal by the President.* Available at: http://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf.

Universiti Teknologi Malaysia. (2009). *Low Carbon City 2025 - Sustainable Iskandar Malaysia*, Malaysia and Japan.

Vashum, K. & S. Jayakumar (2012). Methods to estimate above-ground biomass and carbon stock in natural forests - a review. *Journal of Ecosystem & Ecography*, 2(4), 1–7. Available at: http://www.omicsonline.org/2157-7625/2157-7625-2-116.digital/2157-7625-2-116.html [Accessed October 10, 2014].

Venkanna, K., Mandal, U.K., Solomon Raju, A.J., Sharma, K.L., Adake, R.V., Pushpanjali, Reddy, B.S., Masane, R.N., Venkatravamma, K. & Babu, B.P. (2014). Carbon stocks in major soil types and land-use systems in semiarid tropical region of southern India. *Current Science*, *106*(4), 604–611.

Venter, O., Meijaard, E., Possingham, H., Dennis, R., Sheil, D., Wich, S., Hovani, L. & Wilson, K. (2009). Carbon payments as a safeguard for threatened tropical mammals. *Conservation Letters, 2,* 123–129. Available at:

http://doi.wiley.com/10.1111/j.1755-263X.2009.00059.x.

Verburg, R., Slik, F., Heil, G., Roos, M. & Baas, P. (2001). Secondary forest succession of rainforests in east kalimantan : A preliminary data analysis. In *The Balance between Biodiversity Conservation and Sustainable Use of Tropical Rain Forests*, 151–160.

Viña, A., Gitelson, A.A., Nguy-Robertson, A.L. & Peng, Y. (2011). Comparison of different vegetation indices for the remote assessment of green leaf area index of crops. *Remote Sensing of Environment*, *115*(12), 3468–3478. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0034425711002926 [Accessed March 21, 2014].

Vohland, M., Stoffels, J., Hau, C. & Schuler, G. (2007). Remote sensing techniques for forest parameter assessment : Multispectral classification and linear spectral mixture analysis. *Silva Fennica*, *41*(3), 441–456.

Wang, B. & Niu, X. (2013). Biomass and carbon stock in moso bamboo forests in subtropical China: Characteristics and implications. *Journal of Tropical Forest Science*, *25*(1), 137–148.

Wang, Q. (2013). Effects of urbanisation on energy consumption in China. *Energy Policy*, pp.1–8. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0301421513010239 [Accessed November 12, 2013].

Warren, M.W., Kauffman, J.B., Murdiyarso, D., Anshari, G., Hergoualc'h, K., Kurnianto, S., Purbopuspito, J., Gusmayanti, E., Afifudin, M., Rhajoe, J., Alhamd, L., Limin, S. & Iswandi, A. (2012). A cost-efficient method to assess carbon stocks in tropical peat soil. *Biogeosciences*, *9*(11), 4477–4485. Available at: http://www.biogeosciences.net/9/4477/2012/ [Accessed November 22, 2014].

Webb, R. (1998). Urban forestry in Kuala Lumpur, Malaysia. *Arboricultural Journal*, *22*(January), 287–296. Available at: http://www.tandfonline.com/doi/abs/10.1080/03071375.1998.9747211.

Wei, C., Lau, A.M.S. & Kanniah, K.D. (2016). Multi-level adaptive support vector machine classification for tropical tree species (January).

West, W.P. (2004). *Tree and Forest Measurement*, New York: Springer Berlin Heidelberg.

Wetland International (2010). *A Quick Scan of Peatlands in Malaysia*. Petaling Jaya, Malaysia.

White, A., Cannell, M. & Friend, A. (1999). Climate change impacts on ecosystems and the terrestrial carbon sink: A new assessment. *Global Environmental Change*, *9*, S21–S30. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0959378099000163.

Whitmore, T.C. (1990). *An Introduction to Tropical Rainforest,* New York: Oxford University Press.

Whitmore, T.C. (1973). *Tree Flora of Malaya. Volume Two*, Kuala Lumpur, Malaysia: Longman Malaysia Sdn. Berhad.

Whitmore, T.C. (1984). *Tropical Rain Forests of the Far East.* 2nd ed. Oxford: University Press.

Whitmore, T.C. (1998). *An Introduction to Tropical Rain Forests.* 2nd ed. Oxford: University Press.

William, C.N. & Joseph, K.T. (1970). *Climate, Soil and Crop Production in the Humid Tropics*. Kuala Lumpur: Oxford University Press.

Witmer, F.D.W. & O'Loughlin, J. (2009). Satellite data methods and application in the evaluation of war outcomes: Abandoned agricultural land in Bosnia-Herzegovina after the 1992–1995 conflict. *Annals of the Association of American Geographers*, *99*(5), pp.1033–1044. Available at: http://www.tandfonline.com/doi/full/10.1080/00045600903260697.

Wyatt-Smith, J. (1964). A preliminary vegetation map of Malaya with descriptions of the vegetation types. *Journal of Tropical Geography*, *18*, 200-213.

Wyckoff, P.H. & Clark, J.S. (2005). Tree growth prediction using size and exposed crown area. *Canadian Journal of Forest Research*, *35*, 13–20.

Yamashita, T., Kasuya, N., Kadir, W.R., Wan Chik, S., Seng, Q.E. & Okuda, T. (2003). Soil and belowground characteristics of Pasoh Forest Reserve. In T. Okuda et al. (eds.). *Pasoh Ecology of a Lowland Rain Forest in South East Asia*. Kuala Lumpur, Malaysia: Forest Research Institute Malaysia, pp. 89–109. Available at: http://link.springer.com/10.1007/978-4-431-67008-7.

Yashiro, Y., Kadir, W.R., Okuda, T. & Koizumi, H. (2008). The effects of logging on soil greenhouse gas (CO2, CH4, N2O) flux in a tropical rain forest, Peninsular Malaysia. *Agricultural and Forest Meteorology*, *148*(5), 799–806. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0168192308000348 [Accessed April 30, 2013].

Yong Shin, M., Miah, D.M. & Lee, K.H. (2007). Potential contribution of the forestry sector in Bangladesh to carbon sequestration. *Journal of environmental management*, *82*(2), 260–76. Available at: http://www.ncbi.nlm.nih.gov/pubmed/16630685 [Accessed June 27, 2013].

Yule, C.M., Lim, Y.Y. & Lim, T.Y., (2016). Degradation of tropical Malaysian peatlands decreases levels of phenolics in soil and in leaves of Macaranga pruinosa. *Frontiers in Earth Science*, *4*(April). Available at: http://journal.frontiersin.org/Article/10.3389/feart.2016.00045/abstract.

Zakaria, R., Nik Rosely, N.F., Mansor, M. & Zakaria, M.Y. (2008). The distribution of macaranga, Genus (Family Euphorbiaceae) in Penang Island, Peninsular Malaysia. *Journal of Bioscience*, *19*(2), 91–99.

Zanne, A.E., Lopez-Gonzalez, G., Jansen, S., Ilic, J., Lewis, S.L., Miller, R.B., Swenson, N.G., Wiemann, M.C. & Chave, J. (2009). *Data from: Towards a worldwide wood economics spectrum*. Dryad Digital Repository.

Zen, I.S., Bandi, M., Zakaria, R. & Saleh, A.B. (2013). The UTM Sustainable Campus: lnstitutionalize Sustainability, The Living Lab Approach and Sustainable Energy Management Program. *International Workshop on Ul Greenmatric*, *8*, 53–60.

Zhang, C. & Qiu, F. (2012). Mapping individual tree species in an urban forest using airborne lidar data and hyperspectral imagery. *Photogrammetric Engineering & Remote Sensing*, *78*(10), 1079–1087. Available at: http://home.fau.edu/czhang3/web/2012ZhangQiu_PERS.pdf.

Zhao, J., Kang, F., Wang, L., Yu, X., Zhao, W., Song, X., Zhang, Y., Chen, F., Sun, Y., He, T. & Han, H. (2014). Patterns of biomass and carbon distribution across a chronosequence of chinese pine (Pinus tabulaeformis) forests. *PLoS ONE*, *9*(4).

Zhao, M., Kong, Z.H., Escobedo, F.J. & Gao, J. (2010). Impacts of urban forests on offsetting carbon emissions from industrial energy use in Hangzhou, China. *Journal of Environmental Management*, *91*(4), 807–13. Available at: http://www.ncbi.nlm.nih.gov/pubmed/19914765 [Accessed August 27, 2013].

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