UNIVERSITI PUTRA MALAYSIA

ESTIMATION OF CARBON STOCK AND EMISSION, AND LIFE CYCLE ASSESSMENT OF MALAYSIAN HEVEA FOR ESTABLISHING NATIONAL CARBON INVENTORY

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ESTIMATION OF CARBON STOCK AND EMISSION, AND LIFE CYCLE ASSESSMENT OF MALAYSIAN *HEVEA* FOR ESTABLISHING NATIONAL CARBON INVENTORY

By

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The study utilises two computer spreadsheet models to estimate both carbon sequestered by Malaysian rubber plantation ecosystems, and carbon stocks and emissions from harvested rubber wood products (furniture, medium density fibreboard, rubber gloves and tyres). Changes in the net carbon balance in Malaysian rubber ecosystems are related to the total rubber hectarage, age class structure, age class dynamics, and total biomass, rate of harvesting and production and utilization of the products. The Carbon Sequestration Model and Harvested Wood Products Model were used to estimate the carbon budget of the ecosystem and also the carbon fate in the latex and wood products throughout their life span. From the life cycle assessment of one-hectare of rubber, we project that carbon storage in biomass and products could last up to 63 years before it returns to a carbon neutral situation. At the national level, the rate of carbon stocks were projected to decrease from 241,748 kTC in 1991 to 231,541 kTC in 1996. The declining trend (between 1991 and 1996) was estimated to continue in the projected years (2004 to 2020). Carbon stocks registered at 105,354 kTC (year 2013), followed by 90,748 kTC (year 2017) and eventually amounted to 80,797 kTC (year 2020). Harvested rubber products played an important role in the process of delaying the return of the carbon to the atmosphere. Net emission could be minimized through appropriate pollution control technologies in landfills, increasing product use efficiency, recycling and increasing product longevity. Stock to emission ratio (SER) is described and proven to be a useful measure to determine the longevity of an industry.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

ANGGARAN STOK KARBON DAN PELEPASANNYA, DAN LCA HEVEA DI MALAYSIA UNTUK PEMANTAPAN INVENTORI KARBON NASIONAL

Oleh

IRENE CHUNG

Jun 2004

Pengerusi: Profesor Madya Mohd. Ismail Yaziz, Ph.D.

Fakulti : Sains dan Pengajian Alam Sekitar

Kajian ini telah mengutilasikan dua stimulasi perisian komputer, Carbon Sequestration Model dan Harvested Wood Product Model untuk menganalisasi kemampuan penanaman getah di Malaysia dengan membandingkan kadar penyerapan dan pelepasan karbon dalam ekosistem tanaman getah berserta hasil produknya (perabot, MDF, sarung tangan getah dan tayar). Perubahan keseimbangan ini adalah berkait rapat dengan jumlah keluasan tanaman, pengkelasan tanaman mengikut peringkat umur, jumlah berat kering tanaman, kadar penuaian tanaman serta jumlah produktiviti dan penggunaan produk tanaman getah. Melalui kajian kitaran satu hektar, dapat disimpulkan bahawa simpanan karbon yang terdapat di ekosistem dan produk tanaman akan berlanjutan sehingga 63 tahun sebelum keadaan menjadi karbon neutral semula. Apabila konsep stimulasi diaplikasikan ke senario sebenar penanaman getah di Malaysia, kajian mendapati jumlah stok karbon adalah berkurangan dari 241,748 kTC pada tahun 1991

hingga 231,541 kTC pada tahun 1996. Kadar penurunan ini juga akan mempengaruhi jumlah stok karbon sehingga tahun 2020. Dari 105,354 kTC pada tahun 2013, jumlah stok berkurangan sehingga 90,748 kTC pada tahun 2017 dan akhirnya pada tahun 2020, jumlah stok adalah 80,792 kTC. Produk hasil dari tanaman getah memainkan peranan penting dalam melengahkan masa pengembalian karbon ke atmosfera. Kadar pelepasan karbon ke atmosfera dapat dikurangkan melalui penggunaan teknologi kawalan pencemaran di tapak pelupusan, peningkatan peratus utilasi produk, kitar semula serta peningkatan jangka hayat produk. Pengiraan nisbah antara jumlah stok dengan pelepasan karbon adalah penting dalam menentukan kepanjangan sesuatu industri.

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LIST OF SYMBOLS AND ABBREVIATION

C	carbon
CDM	Clean Development Mechanism
CERs	Certified Emission Reduction
CH_4	methane
CO_2	carbon dioxide
COMAP	Comprehensive Mitigation Assessment Process
EWPs	engineered wood products
Gg	gigagram
GHG	greenhouse gasses
GWP	Global Warming Potential
HFCs	hydrofluorocarbons
HWPs	Harvested Wood Products
IPCC	International Panel on Climate Change
kT	kilo tonne
LTC	latex timber clone
LVL	laminated veneer lumber
MDF	medium density fibreboard
MRB	Malaysian Rubber Board
N_2O	nitrous oxide
PFCs	perfluorocarbons
RRIM	Rubber Research Institute of Malaysia
SER	stock to emission ratio
UNFCCC	United Nations Framework Convention on Climate Change

CHAPTER I

INTRODUCTION

1.1 Global Climate Change

Climate change is a widely considered to be one of the largest threats to the sustainability of the Earth's environment, and the well being of its people. Most scientists agree that the Earth's climate is changing from the buildup of greenhouse gases (GHG), principally carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) that result from anthropogenic activities such as electricity generation, transportation, and agriculture (Houghton et al., 1990). CO_2 is the primary GHG and its concentration in the atmosphere has been increasing steadily since 1958 (Keeling et al., 1989). Predictions of future climate change caused by increasing atmospheric CO_2 and its potential effects on human environment and health have led to international concerns about the production of GHG (Houghton et al., 1995).

The global carbon cycle is the most important process linking forests to climate change. Forests play an important role in the global carbon cycle because they store a large amount of carbon in vegetation and soil, exchange carbon with the atmosphere through photosynthesis and respiration, are atmospheric (sinks during regrowth after disturbance, and become a carbon source when they are disturbed by human activity or natural causes (e.g., forests fires, insect outbreaks, harvesting) (Dixon et al., 1994, Steffan et al., 1998). Through forest management, people can change (the amount of carbon stored in a) forest ecosystem (pools and fluxes), and thus affect atmospheric CO_2 concentrations (Apps and Price, 1996).

The international response to climate change includes the United Nations Framework Convention on Climate Change (UNFCCC). Agreed to in 1992, the Convention is a framework for action to limit or reduce GHG emissions. In 1997, 159 countries signed the Kyoto Protocol, committing industrialized countries to reducing their GHG emissions.

Article 12 of the Kyoto Protocol allows developed countries and countries with economics in transition, so-called Annex I (see Table 1.1), to meet their greenhouse gas reduction commitments by engaging in what is called the "Clean Development Mechanism (CDM)". Developing countries that have ratified the Kyoto Protocol, or non-Annex I countries, can benefit from these CDM projects to promote sustainable development. Annex I countries receive certified emission reduction (CERs) credits for investing in projects that result in additional reductions in the emissions of GHG in developing countries. Ideally, CDM projects should involve the transfer of and investment in environmentally safe technologies and practices.

Greenhouse gases mix evenly in the atmosphere making it possible to reduce emissions at any point on the planet and have the same effect. This fact enables countries to pursue GHG reductions wherever they can be reduced at lower costs. CDM projects allow developed countries that have ratified the Kyoto Protocol to invest in projects that reduce GHGs in developing countries while contributing to sustainable development. Approved and certified projects can earn certified emission reductions (CERs) that developed countries can use to meet their Kyoto Protocol GHG reduction commitments and to contribute to the overall goal of mitigating climate change. CDM projects help developed and developing countries work together to achieve sustainable development and decrease GHG emissions through the Kyoto Protocol.

Table 1.1: Annex I Countries To The United Nations Framework Convention on Climate Change

Annex I or Investor Countries*			Sectors	Greenhouse Gases and Gas Classes
Australia Austria Belarus Belgium Bulgaria Canada Croatia Czech Republic Denmark Europe Estonia Finland France Germany	Greece Hungary Iceland Ireland Italy Japan Latria Liechtenstein Lithuania Luxembourg Monaco Netherlands New Zealand Norway	Poland Portugal Romania Russian Federal Slovakia Spain Sweden Switzerland Turkey Ukraine United Kingdom United States of America	Energy Industrial Processes Solvent and other product use Waste Land use, land use change, forestry	Carbon dioxide (CO_2) Methane (CH_4) Nitrous oxide (N_2O) Hydrofluorocarbons (HFCs) Perfluorocarbons (PFCs) Sulphur herafluorid (SFs)

*These countries need to ratify the K.P in order to use the CDM mechanism, Entities in these countries – whether public or private- constitute the investors in CDM
Source: Kyoto Protocol, Annex A

1.2 Carbon Sinks

The term "sink" is commonly used to describe the carbon taken from the atmosphere by plants and stored in living and dead organic matter both above and below ground in land-based (or *terrestrial*) ecosystems.

Forests remove CO_2 from the atmosphere and store carbon in plant material and soil. This natural process is part of the carbon cycle and is known as sequestration. Approximately half of a tree's dry mass is carbon, so large amounts of carbon are stored in forests and they are the largest store of terrestrial carbon. (Apps and Price, 1996). Depending upon the particular forest, the amount of carbon stored in it may be; increasing – making the forest a carbon sink, decreasing – a carbon source, or in carbon balance – a carbon store.

Other ecosystems such as savannas and woodlands are also significant sinks. In most ecosystems, the majority of the carbon is stored below ground, either as roots and decaying biomass or as organic carbon in soil (De Jong et al., 2000).

Forests can absorb CO_2 from the atmosphere and thereby assists us by temporarily stabilizing greenhouse gasses in the atmosphere. However, half of the world's forests have already been cleared and those that remain have largely been degraded. We have therefore reduced the capacity of the world's forests to slow climate change.

1.3 Importance of Carbon Sinks

According to a report by Houghton et al., (1998), the concentration of CO_2 in the atmosphere is increasing. Human activity has continued to release large amounts of CO_2, largely from the burning of fossil fuels (oil, gas and coal) and from activities such as clearing forests. Each year, human activities are thought to add an extra 7 billion tonnes of CO_2 to the atmosphere.

Because CO_2 traps heat in the atmosphere, increasing concentrations of CO_2 will lead to global climate change. Many scientists predict that climate change will result in more extreme weather patterns – more cyclones, floods and droughts. With such changes in our climate, rising sea levels will threaten coastal environments, it will be harder to grow food successfully, and the rate of species extinction will increase.

Houghton et al., (1998) also stated that, to reduce the impacts of climate change, it is necessary to stabilize atmospheric CO_2 concentrations. In the 250 years since the industrial revolution, the amount of CO_2 in the atmosphere has increased by 30%. To stabilize CO_2 at current levels, we need to reduce emissions by 50% - 70% now. To stabilize CO_2 at twice pre-industrial levels, emissions need to be reduced by 30% now. Forest carbon sinks can help us to do this through the natural absorption and storage of carbon dioxide.

An international agreement, the UN Framework Convention on Climate Change (UNFCCC) was ratified in 1994. The UNFCCC aims to stabilize atmospheric Kyoto Protocol pursues action (if and when ratified), to combat global warming by managing greenhouse gas sources and sinks.

Under the Kyoto Protocol, developed countries have set emissions reduction targets that are on average 5% below 1990 levels. There are a number of mechanisms in the Protocol, including carbon trading that can help Annex I countries reach their emissions reduction targets

1.4 Rubber and Carbon Sinks

Carbon sequestration by agricultural land has generated international interest because of its potential impact on and benefits for agriculture and climate change where proper soil and residue management techniques are implemented, agriculture can be one of many potential solutions to the problem of greenhouse gas emissions. Additionally, agricultural conservation practices such as the use of different cropping and plant residue management, as well as organic management farming, can enhance soil carbon storage. Farmers, as well as the soil and environment, receive benefits from carbon sequestration.

Lal et al., (1995) reported that agricultural ecosystems represent an estimated 11% of the earth's land surface and include some of the most productive and carbon rich soils.

As a result, they play a significant role in the storage and release of carbon within the terrestrial carbon cycle.

Hevea like other green plants can be considered as a plant factory for solar energy conversion and a carbon sink by virtue of the process of photosynthesis. The maximum rate of photosynthesis, which differs between clones, has been recorded with a range from 1.14 mg m^{-2} s^{-1} in clone PR 107 to 0.36 mg m^{-2} s^{-1} in clone RRIM 623 (Cuelemans et al., 1984).

A monoculture of Hevea has been reported to be a relatively efficient converter of solar energy into dry matter. According to Templeton (1969), the rate of dry matter production of 5 ¼ and 6 ¾ years stand of RRIM 501 was 35.5 tonnes/hectare/year, a relatively high value among tree species. At this rate of dry matter production, the efficiency of utilization of solar radiation in a stand of Hevea trees with a closed canopy was calculated to be about 2.8% (Templeton, 1969).

Naimah, Zainol and Yoon (1992) also reported that Hevea trees have the highest photosynthetic productivity and with a capacity to fix 90 million tonnes of carbon per year. It would appear that a rubber plantation would be nearly as effective during photosynthesis as a virgin forest in consuming the products of fossil fuel burning as well as producing life sustaining oxygen.

The influence of the rubber trees on the atmospheric carbon balance is also indicated by the amount stored in biomass. The amount of biomass estimated for humid tropical forests in various countries ranged between 210 t/ha in Mulu, Malaysia and 664 t/ha in Pasoh, Malaysia. Rubber ecosystem at tappable maturity attain a relatively much lower biomass level than a mature forest ecosystem. However, with time the value for the rubber ecosystem increases. It reaches comparable levels at an age of beyond 30 years. The biomass potential of a 33 year old stand of tapped trees was 444.9 t/ha, a value nearing those obtained for forest ecosystems in Brazil and Malaysia, or even higher than those recorded in Thailand and New Guinea (K. Sivanadyan and Norhayati, 1992).

1.5 The Carbon Budget and Life Cycle Assessment of a Rubber Plantation

A carbon budget (sometimes called carbon balance) shows the inventory of carbon in carbon pools and the balance of exchange between the pools. The rate of exchange between the pools is called carbon flux. The most direct method of tracking the amount of carbon ecosystems for policy analysis is the calculation of carbon budgets based on biomass inventories. Many researches had considered rubber tree as a plant factory for solar energy conversion and carbon sink by virtue of the process of photosynthesis.

The influence of the rubber trees on the atmospheric carbon budget is also indicated by the amount stored in the biomass, with values comparable to that of forest ecosystems, particularly beyond a certain age of growth.

Rubber plantation plays an important role with regard to carbon contribution to the environment. In recent years, net addition or sequestration carbon in Malaysia in one hectare of a 27 year-old stand of rubber trees is 72.36 tonnes. The total amount of carbon sequestered in one hectare of rubber trees made up of tree biomass, latex produced and leaf litter is computed to be 319 tonnes (Sivakumaran et. al., 1992).

Life-cycle assessment evaluates a product or activity through all of its stages, from raw material access through manufacturing to consumer use and waste management (recycling or disposal). This concept is often referred to as a cradle-to-grave assessment. Life-cycle assessment require detailed data on production, extraction (harvesting) and processing of raw materials, manufacturing, use and disposal.

Rubber products also play a crucial role in offsetting these emissions by sequestering carbon, which helps to mitigate carbon buildup in the atmosphere. Carbon in wood harvested or latex from rubber plantation ends up in a variety of uses, from being sequestered in lumber in buildings or furniture for a century or more, to quickly being released into the atmosphere after the lifetime ends during decay process. It is consider four general categories for the fate of rubber end products: furniture, Medium Density Fibreboard, gloves and tyres. Figure 1.1 shows the carbon emission of rubber tree and rubber end products.