

CARBON STOCKS ASSESSMENT OF A SELECTIVELY LOGGED DIPTEROCARP FOREST AND WOOD PROCESSING MILL IN THE PHILIPPINES

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LASCO, R. D., MACDICKEN, K. G., PULHIN, F. B., GUILLERMO, I. Q., SALES, R. F. & CRUZ, R. V. O. 2006. Carbon stocks assessment of a selectively logged dipterocarp forest and wood processing mill in the Philippines. This study determined effects of selective logging on carbon (C) stocks of a dipterocarp forest in the Philippines. Biomass C was determined from fixed plots using a chronosequence of 1–21 years after logging. The total C budget within an existing timber concession in the area, including that in the wood processing mill, was analysed. Unlogged forests had mean C stocks of 258 Megagrams of C per hectare (Mg C ha^{-1}), of which 34% was in soil organic carbon (SOC). About 98% of above-ground biomass C was in trees ≥ 19.5 cm diameter-at-breast height. After logging, aboveground C stocks declined by about 50% (100 Mg C ha^{-1}). In between the cutting cycle of 35 years, logged forests sequester C at the rate of about $1.4 \text{ Mg C ha}^{-1} \text{ year}^{-1}$. Before the next harvest, forests recovered about 70% of the original biomass C. Changes in SOC showed no apparent relationship with the number of years after logging. About 40% of woody aboveground biomass C was converted to lumber and veneer/plywood or sold as logs. Most of the remaining 60% was emitted to the atmosphere as carbon dioxide through burning as fuel and decay.

Keywords: carbon budget, carbon sequestration, dipterocarp forest, selective logging

LASCO, R. D., MACDICKEN, K. G., PULHIN, F. B., GUILLERMO, I. Q., SALES, R. F. & CRUZ, R. V. O. 2006. Penilaian stok karbon di hutan dipterokarpa tebangan memilih dan kilang kayu di Filipina. Kajian ini menyelidiki kesan tebangan memilih terhadap stok karbon (C) di dalam hutan dipterokarpa di Filipina. Biojisim C ditentukan daripada plot tetap mengikut turutan kronologi dari 1 tahun hingga 21 tahun selepas pembalakan. Jumlah bajet C di dalam konsesi hutan yang sedia ada di kawasan itu termasuk kilang kayunya dianalisis. Hutan yang tidak dibalak mempunyai stok C sebanyak 258 Megagram C sehektar (Mg C ha^{-1}). Sejumlah 34% daripada stok C terdapat dalam bentuk karbon organik tanah (SOC). Kira-kira 98% daripada biojisim C di atas tanah terdapat dalam pokok berukuran ≥ 19.5 cm diameter aras dada. Selepas pembalakan, stok C di atas tanah menurun sebanyak 50% (100 Mg C ha^{-1}). Antara pusingan tebangan 35 tahun, hutan yang dibalak mensekuester C pada kadar sekitar 1.4 Mg C ha^{-1} . Dalam tebangan berikutnya, hutan akan memperoleh semula 70% daripada biojisim C yang asal. Tiada perkaitan antara SOC dengan bilangan tahun selepas pembalakan diperhatikan. Kira-kira 40% daripada biojisim C berkayu di atas tanah diubah kepada kayu gergaji dan venir/kayu lapis atau dijual sebagai balak. Kira-kira 60% yang tinggal dibebaskan ke atmosfera sebagai karbon dioksida akibat pembakaran bahan api dan pereputan.

INTRODUCTION

Climate change is one of the most pressing environmental concerns of the 21st century. Greenhouse gases (GHGs) such as carbon dioxide (CO_2), methane, nitrous oxides and

chlorofluorocarbons absorb thermal radiation emitted by the earth's surface. Rising concentration of GHGs in the atmosphere will very likely lead to a significant change in the

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world's climate before 2100 (IPCC 2001).

CO₂ is the most important GHG, accounting for more than 50% of radiative forces associated with anthropogenic GHG emissions. It is estimated that about 60 Petagrams of carbon (Pg C) is exchanged between terrestrial ecosystems and the atmosphere every year, with a net terrestrial uptake of 0.7 ± 1.0 Pg C (Schimel *et al.* 1995). The world's tropical forests cover 17.6 million km² and contain 428 Pg C in vegetation and soils. Landuse change and forestry activities, mainly tropical deforestation, are significant net sources of CO₂, accounting for 1.6 Pg year⁻¹ out of the total anthropogenic emissions of 6.3 Pg year⁻¹ (Houghton *et al.* 1996, Watson *et al.* 2000). However, tropical forests have the largest potential to mitigate climate change amongst the world's forests through conservation of existing carbon pools, expansion of C sinks and substitution of wood products for fossil fuels (Brown *et al.* 1996, Brown *et al.* 2000). In tropical Asia, it is estimated that forestation, agroforestry, regeneration and avoided deforestation activities have the potential to sequester 7.50, 2.03, 3.8–7.7 and 3.3–5.8 Pg C respectively, between 1995 and 2050 (Brown *et al.* 1996).

Modifications of forest harvest operations could play an important role in climate change mitigation by adopting sound logging practices such as reduced impact logging to reduce CO₂ release. While improved forest management in developing countries will not be eligible for carbon credits at least for the first commitment period of 2008–2010 under the Kyoto Protocol, it will however be considered for future commitment periods (Smith & Applegate 2002).

Logging activities by big companies have historically been the most important driving force in the formation of post-extraction secondary forests in the Philippines (Kummer 1992). Prior to the implementation of the Philippine Selective Logging System (PSLS) in 1954, only a crude diameter limit was used, resulting in degraded logged-over areas that were quickly occupied by shifting cultivators. The PSLS was designed to make possible another economic cut after cutting cycles of 30, 35 or 40 years depending on the growth conditions of the forest (Weidelt & Banaag 1982).

There is limited information on monitoring changes in the standing biomass of tropical

forest and therefore C accumulation over long periods under different management regimes (Smith & Applegate 2002). The main objective of this study was to assess the C stocks of a selectively logged dipterocarp forest and the C budget of the wood processing mill of the Surigao Development Corporation (SUDECOR) timber concession in the Philippines. Specifically, the study aimed to: (a) determine the aboveground and belowground C stocks of the various stages of forest cover after logging and (b) analyse the C budget of the sawmill and the veneer/plywood plant.

MATERIALS AND METHODS

Description of the study site

The study was conducted in the timber concession of SUDECOR located in Surigao del Sur province, island of Mindanao, Philippines at 125° 47' and 126° 09' E longitude and 8° 56' and 9° 14' N latitude. Mean annual rainfall is 3800 mm with more or less even distribution throughout the year. The most common soil in the study area is highly weathered, predominantly fine-textured, deep and well drained (SUDECOR 1999). The total area of forest cover in the concession is about 77 000 ha of which 49 000 ha are production forests.

Logging practice is regulated by the government under the PSLS, which permits only the harvest of mature, over mature and defective trees while leaving sufficient numbers to ensure sustainable harvest and site protection. There are five main phases in the PSLS: establishment of logging set-up, computation of marking goal (the number of trees to be left as residuals), timber harvesting, residual inventory and timber stand improvement. The cutting cycle is 35 years. The detailed activities for the PSLS are contained in the Handbook of Selective Logging (Bureau of Forestry 1970, Weidelt & Banaag 1982). On a per unit area basis, the volume harvested in the secondary forests (second cutting cycle) was much lower than the primary forests (Weidelt & Banaag 1982). This is in fact one of the reasons why the marking goal formula was revised in 1992 to reflect the smaller sizes of trees present.

Carbon stocks of forest cover

Field sampling

A systematic sampling design was used in plot establishment by the Sustainable Ecosystems International Corporation (SUSTEC) with funding from the International Tropical Timber Organization (ITTO) (Fernando *et al.* 1997, Revilla 1999). A maximum sampling error of 5% for total estimate was allowed. A total of 118 sample plots were stratified based on the number of years elapsed after logging (YEAL). The plots were distributed as follows: 1–5 YEAL (26 plots); 6–10 YEAL (10 plots); 11–15 YEAL (16 plots); 16–20 YEAL (16 plots); 21+ YEAL (22 plots) and pre-disturbance (28 plots).

Plot area was 0.1 ha (100 × 10 m) with nested subplots for measuring trees, understory/herbaceous vegetation and litter, and soil (Figure 1).

For calculating tree biomass and carbon density, all 118 ITTO plots and subplots for measuring trees (10 × 20 m) were included, while for the other C pools, subplots were established and distributed in selected ITTO plots. The number of samples collected from each stratum are presented in Table 1. Data collection was conducted from March till April 2000.

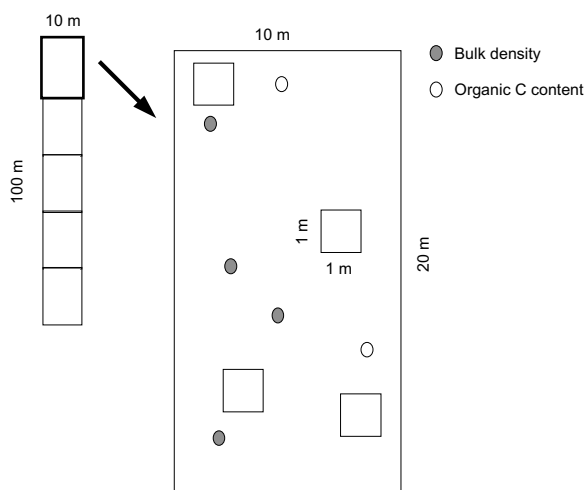


Figure 1 100 × 10 m plot with five subplots of 20 × 10 m for tree inventory

Calculation of biomass and carbon density

Tree biomass

Only trees with diameter-at-breast-height (dbh) ≥ 19.5 cm in the 118 plots were included in tree biomass determination. Data were gathered only for trees meeting this minimum diameter because the main concern was commercial size of trees.

Total aboveground biomass (including branches and leaves) of individual trees was determined using the allometric equation developed by Brown (1997) from destructive sampling of 170 trees of various species from the tropical moist forest zone (Holdridge 1967):

$$Y = \exp[-2.134 + 2.53 \ln D]$$

(range: 5–148 cm; n: 170; adjusted $r^2 = 0.97$) where Y = total aboveground biomass (kg) and D = dbh (cm)

Three wood samples from each of the 12 dominant tree species in the logging concession were analysed at the International Rice Research Institute Analytical Service Laboratory for C content using the ROBOPREP C-N Biological Sample Converter. These tree species include *Shorea negrosensis*, *S. palosapis*, *S. contorta*, *S. almon*, *S. astylosa*, *Cinnamomum mercadoi*, *Calophyllum blancoi*, *Syzygium brevistylum*, *Dipterocarpus grandiflorus*, *Teijsmanniodendron ahernianum*, *Diospyros mindanaensis* and *Albizia procera*. Average carbon content of the wood samples was used as conversion factor to estimate carbon contained in aboveground tree biomass.

Understorey vegetation and litter

Using methods described by MacDicken (1997), four 1 × 1 m plots were randomly established within the 10 × 20 m subplots. All understorey and herbaceous vegetation (< 2 cm) occurring in the plots were harvested, weighed and sub-samples of about 50 g obtained for oven drying to constant mass. Ground litter was carefully collected from the same plots, weighed and processed in the same manner.

Through composite sampling, 65 sub-samples each of understorey vegetation and ground litter were collected from the subplots, oven dried, and analysed for carbon content analysis. The average C content of the samples was multiplied

Table 1 Number of plots and samples for measuring understorey, litter and soil C pools

Years elapsed after logging (YEAL)	Sample plot (100 × 10 m)	Number of samples		
		Understorey/herbaceous vegetation and litter (1 × 1 m)	Soil bulk density	Soil organic carbon
1–5	2	40	40	20
6–10	2	40	40	20
11–15	2	40	40	20
16–20	3	60	60	30
21+	2	40	40	20
Mature	2	40	40	20
Total	13	260	260	130

with dry mass to estimate carbon storage in understorey and herbaceous vegetation and litter.

Soil carbon storage

Soil bulk density was determined through core sampling (MacDicken 1997, PCARR 1980) at depths of 0–30 cm in undisturbed areas inside the 20 × 10 m subplots. Soil samples were collected at depths of 0–30 cm and analysed for soil organic carbon (SOC) content using the Walkley-Black method (MacDicken 1997, PCARR 1980). Bulk density and SOC content were used to estimate SOC storage to a depth of 30 cm.

Carbon budget of processing mills

Carbon flow from wood and wood products was determined by tracking the amount of waste generated in processing lumber and in veneer and plywood mills. The volume of waste produced from processing was calculated as the difference between the total volume of industrial timber input to the sawmill, veneer and plywood mills and the total volume of lumber and veneer produced. Interviews with company staff revealed that wastes generated from milling were used as fuel for power generation. Monthly data collection was conducted from July 1999 till March 2000. Daily values of log input and lumber and veneer outputs for March 2000 were also examined.

The diameter and length of all log inputs to the sawmill were measured and individual log volumes computed using the Huber formula (Cailliez 1980):

$$\text{Volume of log (m}^3\text{)} = \pi/4 D^2 L$$

where

D = midpoint diameter, m

L = length of the log, m

Post-processing volume was determined using the formula:

$$\text{Volume of lumber (m}^3\text{)} = (L \times W \times T)/424$$

where

L = length, ft

W = width, ft

T = thickness, ft

424 = conversion factor board ft to m³

Volume of veneer was determined using the formula:

$$\text{Total volume of veneer produced} = (L \times W \times T) / 424 \times \text{no. of veneer sheets produced}$$

where

L = length, ft

W = width, ft

T = thickness, ft

424 = conversion factor board ft to m³

Veneer volume was converted to biomass by multiplying with 0.462 which is the average wood density of the various timber species processed in the sawmill, and veneer and plywood mills. To determine C storage, biomass was multiplied with the average C content of the wood samples collected at the mill. The amount of C lost through wastes from wood processing was estimated using the same procedure.

RESULTS AND DISCUSSION

Aboveground biomass and carbon stocks of forest cover

Biomass density in mature forests averaged 406 Mg ha⁻¹ (Table 2), which is at the lower end of estimates for similar forest types in the

Philippines. Biomass densities of old-growth forests in other parts of the Philippines derived from allometric equations similar to those used in this study showed a range of 446 to 1126 Mg ha⁻¹ (Lasco *et al.* 2000, 2002), while mature secondary forests at Mt. Makiling in Luzon island were reported to have 576 Mg ha⁻¹ (Lasco *et al.* 2004). Using destructive sampling, Kawahara *et al.* (1981) obtained a biomass density of only 265 Mg ha⁻¹ in a dipterocarp forest in Mindanao 20 years after logging. A possible reason for the lower value reported in this study was the inventory's use of larger-sized plots and sampling size compared with the previous studies (Lasco *et al.* 2000, 2002), which would better reflect the spatial heterogeneity in the forest (Brown *et al.* 1991). The Intergovernmental Panel on Climate Change (IPCC) estimated primary and logged forests in the Philippines to have biomass densities of 370–520 Mg ha⁻¹ and 300–370 Mg ha⁻¹ respectively (Houghton *et al.* 1997).

The results of the study are consistent with the data obtained from other Southeast Asian countries. Old growth forests in Indonesia have up to 500–700 Mg ha⁻¹ biomass (Murdiyarsa & Wasrin 1996, van Noordwijk *et al.* 2000, Hairiah & Sitompul 2000). In Malaysia, aboveground biomass estimates were 280–405 Mg ha⁻¹ for unlogged forests in Sarawak (Brown *et al.* 1991); 291–400 Mg ha⁻¹ (pre-logging) for a commercial logging reserve in Sabah (Pinard & Putz 1996), and > 500 Mg ha⁻¹ for a fully-stocked dipterocarp forest (Abu Bakar 2000). The result that most of the biomass (97–98%) were found in trees ≥ 19.5 cm dbh is likewise consistent with the general pattern that ≥ 96% of forest biomass is found in

trees ≥ 10 cm dbh (Gillespie *et al.* 1992).

Just after logging (1–5 YEAL), the biomass density declined to about 48% of pre-logging biomass, a result consistent with other studies in the region. Biomass of broadleaf tropical forests in Asia have been estimated to decline by 53 to 67% after logging (Brown & Lugo 1984). In Indonesia, logged forests contain 38–75% of the biomass of natural forests (Lasco 2001), with reduced impact logging (RIL) operations resulting in a 30% reduction in biomass (Sist & Bertault 1998, cited by Smith & Applegate 2002). The biomass density at ≥ 21 YEAL (292 Mg ha⁻¹) is similar to the value obtained by Kawahara *et al.* (1981) in a similarly-aged forest in Mindanao (265 Mg ha⁻¹). One year after logging, conventional and RIL areas in Sabah have biomass values that represented about 44 and 67% of pre-logging levels respectively (Pinard & Putz 1996). Total biomass generally increases with increasing number of years after logging which shows the ability of the forest to recover after timber harvesting. However, the total biomass more than 20 years after logging was still lower than the mature forest biomass.

The C density of aboveground biomass, which ranged from 93 to 139 Mg ha⁻¹, followed the same proportional pattern as total biomass (Table 3). Just like biomass density, C density declined to about 48% of pre-logging levels, which is lower than reported values of 59 (van Noordwijk *et al.* 2000) and 75% (Hairiah & Sitompul 2000) of pre-disturbance aboveground C stores for logged tropical forests in Indonesia. However, this value is comparable with that observed in Malaysia (Pinard & Putz 1997), where conventional

Table 2 Mean biomass and necromass densities in aboveground pools of dipterocarp forest at various YEAL

YEAL	Dry mass (Mg ha ⁻¹)				
	Trees (≥ 19.5 cm dbh)	Understorey (< 2 cm dbh)	Litter	Total	% in trees
Mature	399 (145)	1.9 (0.2)	5.8 (1.5)	406	98
1–5	191 (123)	1.5 (0.2)	3.8 (0.6)	196	97
6–10	238 (156)	1.1 (0.3)	3.9 (1.1)	242	98
11–15	204 (134)	0.6 (0.03)	3.8 (0.04)	209	98
16–20	235 (161)	1.6 (0.5)	5.0 (2.0)	242	97
≥ 21	287 (149)	1.0 (0.4)	4.7 (0.9)	292	98

Standard deviations in parentheses
YEAL = years elapsed after logging

logging techniques resulted in a decline in aboveground C from 196 to 86 Mg C ha⁻¹ or 44%.

One limitation of the study is the omission of contributions of coarse woody debris (fallen and standing dead woody material with diameter > 2 cm) and roots (dead and live), which could lead to an underestimation of C pools and losses from harvesting. Keller *et al.* (2000) reported coarse woody debris (CWD) mass varied from 49.7 to 59.9 Mg ha⁻¹ in mature forest sites in Eastern Amazonia, with fallen CWD (> 10 cm) containing as much as 16% of aboveground biomass. Delaney *et al.* (1998) found that dead wood with < 10 cm diameter contributed 33.3–42.3 Mg ha⁻¹ necromass in tropical moist and wet forest zones in Venezuela, which were 9.6–12.4% of the total aboveground biomass. In the study by Pinard and Putz (1997), the mean difference between conventional logging and RIL areas in necromass produced a year after logging was 37 Mg C ha⁻¹, with the greater number of trees destroyed during logging in conventional logging areas accounting for 62% of the difference between the two methods. Belowground biomass of forests in the same study represented 17% of aboveground biomass, which falls within the range reported in other studies relating belowground to aboveground biomass (Pinard & Putz 1997).

The results showed that the significant amount of C lost due to logging was about half of the original aboveground C. These C losses from the forest will have two general pathways: some will be stored in wood products, which lifetimes differ depending on the use (e.g. paper = 1 year, wood > 20 years) while the rest will be returned to the atmosphere at various time scales through burning and decay.

The amount of SOC ranged from 30–106 Mg C ha⁻¹ (Table 3), which was about 31–52% of total forest C (Figure 2). The level of SOC was

more variable, with no apparent relationship with the number of years following logging. This implies that the SOC is less sensitive to changes brought about by selective logging activities.

Assuming linear growth, it is estimated that between 1–5 and 15–20 YEAL or for a period of 15 years, the logged forest sequesters aboveground C at the rate of 1.43 Mg C ha⁻¹ year⁻¹. This is equal to about 3.02 Mg ha⁻¹ year⁻¹ of biomass accumulation. This is lower than the findings of Kawahara *et al.* (1981) for a forest in Mindanao 20 years after logging which grew at 5.2 Mg ha⁻¹ year⁻¹, and of Lasco and Pulhin (2000) for tree plantations in the Philippines which generally accumulate more than 9 Mg ha⁻¹ year⁻¹.

Using the C density obtained in this study, the total C stored in the forest concession was calculated by multiplying the C density with the total area under a particular YEAL. The total biomass stocks of the production forest at SUDECOR amounted to 13.0 Teragrams (Tg) equivalent to 6.2 Tg C in 49 104 ha of land area (Table 4). On the other hand, total C stocks including SOC is equal to 9.3 Tg C. For comparison, a 20 438 ha forest reservation surrounding a geothermal power plant in Leyte island has total C stocks of 3.8 Tg C in the biomass and soil (Lasco *et al.* 2002). Total Philippine net GHG emissions from all sources in 1994 amounted to about 101 Tg CO₂-equivalent (Government of the Philippines 1999). The total C stocks in the biomass of the SUDECOR concession was equal to 23 Tg CO₂-equivalent, which was about 23% of total Philippine emissions in 1994.

Carbon budget of wood processing mills

Average daily volume of logs used for lumber production was around 44 m³ with an equivalent

Table 3 Carbon density in above- and belowground pools of dipterocarp forest at various YEAL

YEAL	Dry mass (Mg ha ⁻¹)					
	Tree	Herb	Litter	Total aboveground pool	Soil organic carbon	Total
Mature	190	0.9 (0.1)	2.6 (0.8)	193	64.8 (24.3)	258
1–5	91	0.7 (0.1)	1.6 (0.2)	93	89.7 (13.2)	183
6–10	113	0.5 (0.1)	1.4 (0.5)	115	30.7 (9.4)	146
11–15	97	0.3(0.02)	1.5 (0.1)	99	106.2 (33.3)	205
16–20	112	0.6 (0.2)	2.1 (1.2)	115	43.1 (33.2)	158
≥ 21	136	0.4 (0.2)	1.8 (0.4)	139	60.1 (33.2)	199

Standard deviations in parentheses
YEAL = years elapsed after logging

C in biomass of 0.01 Mg. In terms of average monthly volume of input, about 979 m³ of logs were used, equivalent to 0.2 Mg of C in biomass. Volume of lumber produced averaged 14.13 m³ per day or 409 m³ per month, corresponding to 0.003 Mg and 0.09 Mg of C in biomass respectively.

In veneer production, daily average volume of logs used in March 2000 was 1361 m³ or 0.3 Mg of C in biomass, while daily average volume of veneer produced for the same month was 376 m³ or 0.083 Mg C in biomass. In terms of monthly production, around 2694 m³ of wood were used as log input producing an average of 1159 m³ of veneer. When converted to C in biomass, monthly volume of input amounted to 0.6 Mg of C while the volume of output was about 0.3 Mg C. Around 0.3 Mg of carbon became waste and served as fuel for the boiler. While C was released into the atmosphere when wastes were used as fuel, a substantial

amount of C emission was avoided because wood was used instead of fossil fuel, although in this study we were not able to quantify these avoided emissions.

Daily recovery rate in the sawmill plant for March 2000 averaged 32%, with specific values ranging from 20 to 48%. Average monthly recovery rate in lumber production was higher at 42% (range 32–46%) compared with daily recovery rates for March 2000. For veneer and plywood, recovery rate ranged from 26 to 61% or an average of 42%. Recovery rate varies each day or month because it is highly dependent on the quality of log input. If logs used are of low quality, recovery rate is likewise low. In SUDECOR, high quality logs are sold as raw materials to other wood processors and the 'next best' logs are processed into veneer and plywood. Logs used for lumber production are usually of low quality. As such, the 32% average recovery rate for such production is observed to be very low.

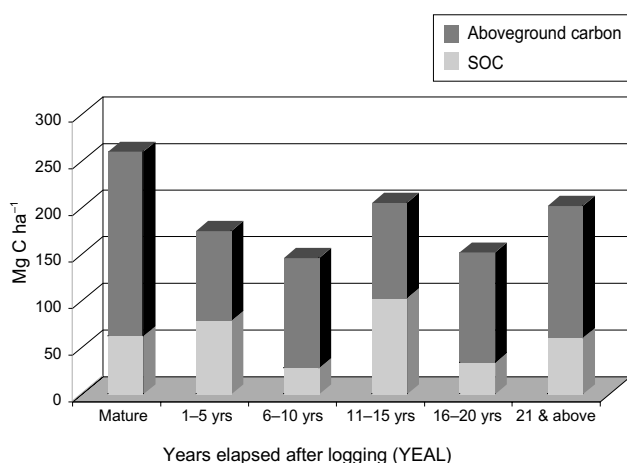


Figure 2 Aboveground C and SOC of dipterocarp forest at various YEAL

Total carbon flows in the timber concession

Figure 3 shows the estimated total flows of C within the timber concession from harvesting to finished wood products. Company records showed that about 32 244 m³ (18 379 Mg) of wood came out of the forest during the period covered by this study or an equivalent 8754 Mg C in biomass. Assuming a recovery factor of 70%, it is estimated that 12 506 Mg C were originally harvested as logs. Of the total estimated original harvest, 40% was converted to forest products (lumber and veneer/plywood) or sold as logs. The remaining 60% was mostly emitted to the atmosphere as CO₂ through burning as fuel and

Table 4 Total C stocks of the forest concession of SUDECOR, Surigao, Philippines

YEAL	Area (ha)	Forest C storage (Mg C)		
		SO C	Aboveground biomass	Total
Mature	1879	121 687	363 362	485 049
1-5	6177	554 262	575 658	1 129 920
6-10	3973	122 130	456 085	578 215
11-15	4647	493 465	460 437	953 902
16-20	7539	324 554	864 047	1 188 601
≥ 21	24 889	1 495 331	3 453 581	4 948 912
Total	49 104	3 111 430	6 173 170	9 284 600

decay. A small portion was used as construction materials by the company and local settlers but the exact amount of this is unknown.

CONCLUSIONS AND IMPLICATIONS

The study showed that immediately after selective logging in a dipterocarp forest the original C density in aboveground biomass was reduced by about 50%. Subsequently, the forest recovered up to about 70% of the original C just before the next cutting cycle begins. From a sustainability point of view, the results imply that the forest may not have sufficient time to regenerate the biomass it lost through harvesting. If this trend continues repeatedly, then it is expected that the harvest levels will progressively decline leading to forest degradation. There are two possible solutions to this problem. First, the volume of harvest can be reduced subject, however, to the regenerative capacity of the forest. Second, the cutting cycle can be lengthened from the current 35 years to allow the forest to recover its original biomass levels.

From a climate change point of view, selective logging of dipterocarp forests could release 50% of aboveground C stocks to the atmosphere right after logging or about 100 Mg C ha⁻¹ under Philippine conditions. Of the total biomass C harvested, about 60% will also be released to the atmosphere through decay in the forests and fuel burning. The rest will be stored for varying periods of time in wood products. Between logging activities, the forest can sequester C at the rate of about 1.4 Mg C ha⁻¹ year⁻¹. However, only about 70% of the original C density could be attained after 35 years or before the next cut.

This information could be used in estimating the climate change impacts of proposed logging

projects in the Philippines. It is required by law that all logging projects be subjected to an environmental impact assessment. One environmental impact that could be investigated is the effect on the global environment such as GHG emission of projects.

The results of the study are also useful whenever forestry projects are included under the Clean Development Mechanism (CDM) of the Kyoto Protocol. Specifically, the results could help in the initial estimation of C benefits from CDM projects. For example, the data obtained could be used to establish the baseline or reference case for avoided logging and RIL projects. Under an avoided logging project the C benefits will be equal to 50% of the standing biomass C (about 100 Mg C ha⁻¹). While for reduced impact logging, the goal will be to bring down the 50% C loss due to logging activities. In addition, the results of the study suggest that a C monitoring programme for CDM could be limited to aboveground biomass as the effect of logging activities on SOC appears not to be significant.

Finally, the study was confined to C budget of the forest ecosystem and wood processing mill. A full C accounting of logging and processing activities should also include GHG emissions from the use of fossil fuels.

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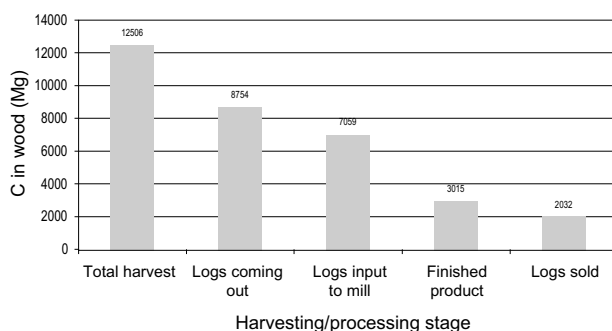


Figure 3 C stocks of wood at various stages of harvesting and processing

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