Vested Interests

Industrial logging and carbon in tropical forests

A Report by **Global Witness** | June 2009

Contents

Forest Definitions

*Primary natural forests:** Forests of native species, in which there are no clearly visible indications of human activity and ecological processes are not significantly disturbed. Also referred to in this report as *undisturbed* or *intact* forests.

*Modified natural forests:** Forests of naturally regenerated native species in which there are clearly visible indications of human activity. The typical modified forest is a tropical forest in which selective logging has taken place, but no silvicultural measures have influenced the natural regeneration of species. Also referred to in this report as *secondary* forests.

* Definitions from FAO's Global Forest Resources Assessment, 2005.

Acronyms

COP	Conference of the Parties
FAO	United Nations Food and Agriculture Organization
FSC	Forest Stewardship Council
HWP	Harvested wood products
IPCC	Intergovernmental Panel on Climate Change
REDD	Reducing emissions from deforestation and forest degradation
RIL	Reduced impact logging
UNFCCC	United Nations Framework Convention on Climate Change

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Front cover picture: Logs transported from a concession in Cameroon. © Global Witness *Back cover picture:* © Wetlands International

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Executive summary

A growing body of scientific literature demonstrates that even when industrial logging follows best practice guidelines to reduce its impact, immediate and substantial carbon emissions are caused by removing the largest trees and killing surrounding trees and vegetation through collateral damage. In concessions in the Amazon and Congo – one certified by the Forest Stewardship Council (FSC) and the other often cited as a model of "sustainable forest management" – for every tree harvested a further 6 - 10 trees are killed or severely damaged despite practicing "reduced impact" logging (RIL), and up to 10 tonnes of carbon is lost per hectare, most ending up in the atmosphere. In areas where logging is more intense, such as South East Asia, up to 80 tonnes can be lost per hectare. It can take centuries for the forest to fully recover, and then only if the logging ceases.

Studies comparing emissions from RIL with a business as usual scenario are not only misleading, they play to vested industry interests rather than help to solve climate change. Comparisons should be made against the carbon dynamics of the intact forest, not by comparing it with worst case logging operations.

Industrial logging puts the remaining forest on a path towards further degradation from fire, drought, insects and disease, illegal logging, poaching, and conversion to other land uses such as industrial agriculture – leading to yet more carbon emissions. In the Brazilian Amazon, for example, a third of the forest area that was "selectively" logged in the year 2000 was completely cleared by 2004. Roads exact a heavy price. Over a decade ago, the FAO drew attention to the link between roads and conversion. It found that, largely as a result of the access that roads provide, the deforestation rate due to conversion to agriculture was eight times higher overall in forests that have been logged than in undisturbed forests.

Fire multiplies the cost of logging. Degradation due to industrial logging is one of the major causes of increased fire susceptibility in tropical forests. Primary tropical forests are almost immune to fire, whereas logged forests are far more vulnerable. During the El Niño fires a decade ago, 60% of logged forests in Indonesian Borneo burned compared with 6% of primary forest.

At the same time, new research highlights that old-growth primary forests retain a vigorous carbon sequestering capacity for centuries and are much greater carbon stores than previously thought. Intact tropical forests pull an estimated 1.3 billion tonnes of carbon out of the atmosphere each year.

Claims that industrial logging can play a role in "sustainable forest management" in tropical forests appear to be based on faith and vested interests rather than on facts or scientific evidence. These vested interests are driving attempts to include "sustainable logging" within the scope of activities eligible for REDD benefits, while at the same time arguing for recognition of "harvested wood products" (HWP) as carbon stores. A simple life cycle analysis exposes the HWP argument as a myth, showing that the amount of carbon stored in wood products derived from natural tropical forests is negligible compared with the total emissions they entail. Most importantly though, the facts demonstrate that industrial logging in natural tropical forests is fundamentally incompatible with the goals of REDD. If REDD is to deliver meaningful and lasting reductions in emissions and provide a tool for adaptation to climate change, ending logging in natural tropical forests, including under the guise of sustainable forest management, must be part of the solution.

Tropical forests are not the only victims of industrial logging. Australia, Canada, Russia and the United States are still logging old growth forests. *Global Witness*

Key findings and recommendations

• If REDD is to be an effective mitigation tool, funds must not be used to benefit or subsidise industrial logging operations.

• Old-growth primary forests are not "carbon neutral" but continue to grow and sequester carbon from the atmosphere.

• There is no consensus on the meaning of "sustainable forest management". Many destructive logging practices have taken place under its name.

• Industrial logging in tropical forests, in all its forms, is not a sustainable option that helps to solve climate change. Rather, it is a major cause of degradation and a precursor to deforestation and conversion to other uses, such as industrial agriculture.

• "Selective" logging, even when utilising best practice or carried out in its "reduced impact" form, causes an immediate and significant release of carbon from direct and collateral damage and associated logging infrastructure.

• The carbon emissions from "reduced impact" logging (RIL) should always be assessed against the carbon dynamics of an intact forest, not by comparing it with worst-case destructive logging operations.

• It can take centuries for a logged forest's total carbon stock to return to pre-logged levels.

• Degradation due to industrial logging is one of the major causes of increased fire susceptibility in tropical forests. An increase in the severity and frequency of forest fires can be more devastating and release far more carbon than the logging operations themselves.

• The assumption that a forest logged selectively will remain a forest is incorrect. Selectively logged forests are, in fact, more likely to be converted to other land use than undisturbed forest.

• Logging roads open up remote areas of forest to agricultural conversion and illegal logging, and deplete wildlife by fragmenting habitat and facilitating increased levels of hunting driven by commercial trade, leading to "empty forest syndrome".

• The amount of carbon stored long-term in wood products derived from natural tropical forests is negligible compared with the carbon emissions resulting from the harvest, transport and processing of the wood.

• Introducing "harvested wood products" into accounting and reporting procedures under the UNFCCC would constitute a methodological nightmare and is best avoided.

Vested interests, motivated by short-term financial returns, are positioning themselves to benefit from REDD under the guise of "sustainable forest management".

Money –
...the only Harvested Wood Product the timber industry cares about.

Introduction

Industrial logging in the Congo Basin. *Global Witness*

When the UNFCCC and Kyoto Protocol were being negotiated, the problem of avoiding dangerous climate change did not seem as urgent as it does today. Insufficient work was done at that time to establish the true nature and extent of global emissions attributable to all forms of forest degradation, including its extreme form, deforestation. The latest IPCC report, however, estimates that deforestation, which is proceeding at a staggering 13 million hectares per year,[1] now accounts for some 17% of global emissions.[2]

There has been much debate over the scope of activities that should be included within a mechanism for reducing emissions from deforestation and forest degradation in developing countries (REDD), proposed as part of the post-2012 climate agreement due to be concluded at UNFCCC COP 15 in Copenhagen in December 2009. Proponents of industrial forestry have lobbied hard for the inclusion of forest management activities within REDD, with business-as-usual strategies in mind. As a result, the Bali Action Plan calls for consideration of '*the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries*' as well as *'Policy approaches and positive incentives on issues relating to reducing emissions from deforestation and forest degradation in developing countries'*.[3]

> The main underlying drivers of degradation and deforestation in tropical forests are industrial operations such as logging and large-scale agriculture along with globalised markets for commodities.

No attention has been paid so far in the UNFCCC negotiations to what is meant by "the role of sustainable management of forests". Despite extensive inter-governmental processes,[4] the concept of "sustainable forest management" or "SFM" means vastly different things to different people – including sustaining the industrial supply of commercial fibre, a "whole of landscape" approach to land use planning, and site-based activities aimed at reducing collateral damage from industrial logging operations. Today, the main underlying drivers of degradation and deforestation in tropical forests are industrial operations such as logging and large-scale agriculture along with globalised markets for commodities.[5] Strong vested interests in these industries, motivated by short-term financial returns, are positioning themselves to benefit from REDD under the guise of "sustainable forest management". There is a real danger that a vague or ambiguous REDD agreement will allow support for activities that increase deforestation and forest degradation, and therefore carbon emissions, both over the short and long term.

The logging industry and its supporters claim that incremental improvements in logging practices, such as the adoption of reduced impact logging techniques, will benefit the climate when applied on a large scale and should therefore be eligible for REDD funds. However, a growing body of evidence demonstrates that industrial logging in natural forests, regardless of the techniques used, inevitably results in the release of large amounts of carbon into the atmosphere. This report reviews scientific evidence concerning the impacts of industrial logging practices on the climate. It presents the case that for REDD to be effective as a mitigation and adaptation tool, it must not support industrial logging within primary or modified (i.e. previously logged) natural forests (*see* Forest Definitions, inside cover).

Key facts and figures

- Intact tropical forests pull an estimated 1.3 billion tonnes of carbon out of the atmosphere each year, equivalent to one-fifth of the global carbon emissions from burning fossil fuels.[6]

- Between 2000 and 2005, at least 20% of the forest biome in the world's tropical regions underwent some level of industrial logging.[7]

- Carbon stocks in commercially logged forests are 40-60% lower than in intact natural forests depending on the intensity of logging.[8]

- Even in the "best case" scenarios of "reduced impact" logging, 6 -10 trees are killed or severely damaged for every tree that is harvested.[9] Where logging is more intense, RIL can reduce the carbon content of a natural forest by nearly 40% during a single logging rotation – most of the lost carbon ends up in the atmosphere as CO_2.[10]

- Between 1999 and 2001, degradation from selective logging in the Brazilian Amazon released up to 80 million tonnes of carbon annually – which is more carbon than is released each year by the fourteen highest emitting coal-fired power plants in the United States.

- During the El Niño fires of 1997-98, 60% of logged forests in Indonesian Borneo burned compared with 6% of primary forest.[11] Across Indonesia, these fires emitted carbon equal to as much as 40% of global fossil fuel emissions over the same period.[12]

- FAO found that, due in large part to the access provided by roads, the deforestation rate due to conversion to agricultural land was eight times higher, overall, in forests that have been logged than in undisturbed forests.[13]

Conversion to palm oil plantations in Indonesia. *Steve Jackson*

- The Congo Basin has over 51,916 km of logging roads. Gabon alone has a network of 13,400 km of logging roads – more than the length of the German autobahn network.[14]

- Selective logging is a precursor to deforestation. In the Brazilian Amazon, 32% of "selectively" logged forests were cleared within four years.[15] In Papua New Guinea, 24% of logged forests were cleared between 1972 and 2002.[16] In Indonesia, 29% of the forest area designated for permanent timber production was deforested by 2005.[17]

- Less than 1% of the original standing tree may remain in use as a solid wood product after 100 years.[18]

Primary tropical forests: stable carbon reservoirs and still growing

The world's forests contain more carbon than the atmosphere – an estimated 638 billion tonnes.[19] If this carbon were released, it would be equivalent to roughly 90 years of global carbon dioxide emissions from the burning of fossil fuels and cement production (based on the average yearly global emissions from 2000-2005).[20] Much of the world's forest carbon is locked up in tropical forests, which contain 45% of all above-ground terrestrial biomass.[21]

Natural tropical forests, if left undisturbed, are vast and stable storehouses of carbon. These forests create their own micro-climates underneath dense canopies of vegetation, where daytime temperatures are reduced, humidity is higher and exposure to sunlight is limited.[22] Intact tropical forests are thus resistant to climate-related stresses such as seasonal drought as well as other natural disturbances.[23] Their micro-climates virtually eliminate the possibility of fire, whereas logging changes micro-climates and increases flammability.[24] The high levels of biodiversity in natural tropical forests make them resilient to disease and insects, and may increase the forests' ability to adapt to climate change.[25] A 2003 report from the Secretariat of the Convention on Biological Diversity stated that "biodiversity itself can play a potentially important role in enhancing ecosystem capacity to recover (resilience) and adapt to the impacts of climate change."[26]

Until recently, it was widely asserted that the world's old-growth primary forests were 'carbon neutral', releasing as much carbon as they absorb. However, new research has shown that primary forests of all types are continuing to grow and sequester large amounts of carbon from the atmosphere. A survey of forest carbon-flux estimates found that primary forests older than 200 years sequester on average 2.4 tonnes of carbon per hectare per year, with much of that contained in soil and root organic matter.[29] The total biomass of Amazonian old-growth forests has increased by as much as 1.22 tonnes per hectare per year over the past two decades.[30] A forty year-long study in Africa also found that primary tropical forests continue to grow and sequester carbon.[31] This study estimated that the world's tropical forests pull a combined total of 1.3 billion tonnes of carbon out of the atmosphere each year – equivalent to roughly one-fifth of global carbon emissions from fossil fuels.

Thus, not only do the world's primary forests contain vast amounts of carbon, they continue to accumulate it as well. Yet only 36% of the world's forests remain as primary forests,[32] while natural forests of all types are increasingly under the threat of degradation from the rapid expansion of industrial logging.

"Old-growth forests steadily accumulate carbon for centuries... carbon-accounting rules for forests should give credit for leaving old-growth forest intact."[28] *Global Witness*

"...biodiversity itself can play a potentially important role in enhancing ecosystem capacity to recover (resilience) and adapt to the impacts of climate change."
Secretariat of the Convention on Biological Diversity, 2003[27]

The real impact of "selective" and "reduced impact" logging: collateral damage and carbon emissions

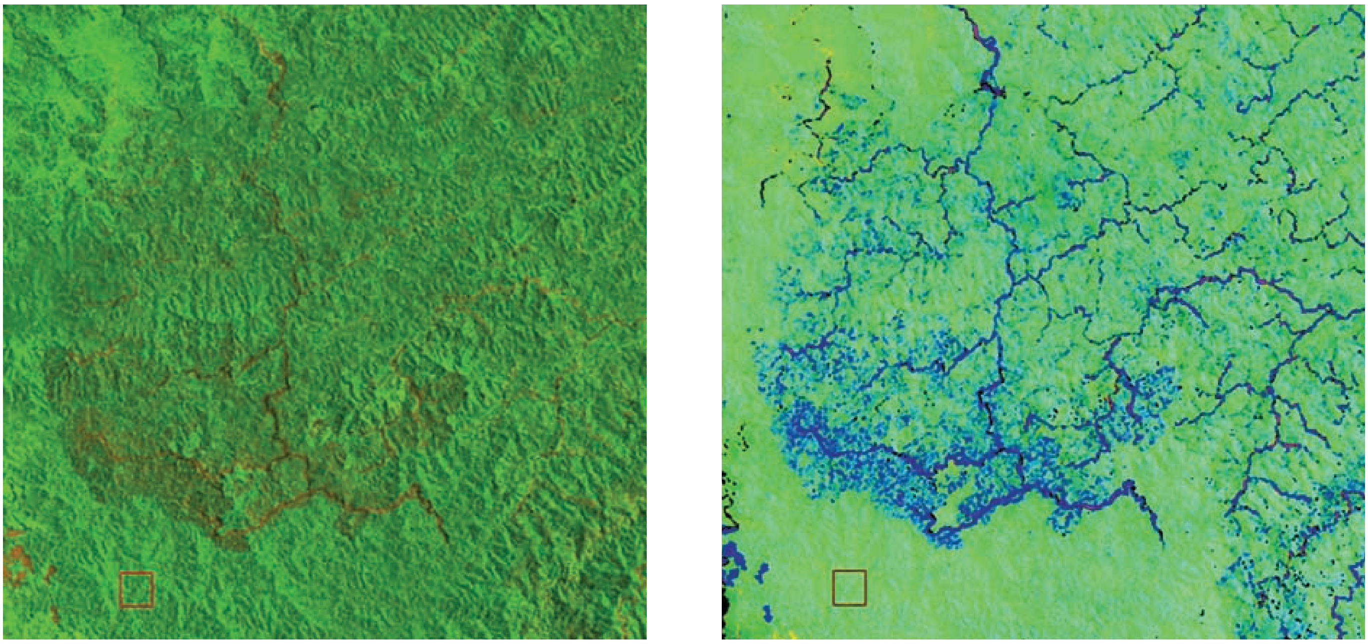
Selective logging, even in its "reduced impact" form, results in an immediate and significant release of carbon into the atmosphere through degradation (removal of targeted trees and collateral damage), and greatly increases the likelihood of complete deforestation whether through conversion or fire. Studies have shown that carbon stocks in commercially logged forests are 40-60% lower than in intact natural forests depending on the intensity of logging.[33]

Selective logging

The term "selective" logging is used to describe the practice of harvesting a subset of all the commercially valuable trees from a defined area or logging plot (also called a "coupe" in some countries). "Clear-cut" operations whereby all the trees are removed, usually to be chipped, are less common in the tropics. Between 2000 and 2005, selective logging was carried out over approximately four million km^2 of tropical forest – 20% of the total humid tropical forest biome, and 15 times greater than the area that was deforested over the same period.[34] The carbon emissions and potential ecological consequences of this level of logging activity are enormous.

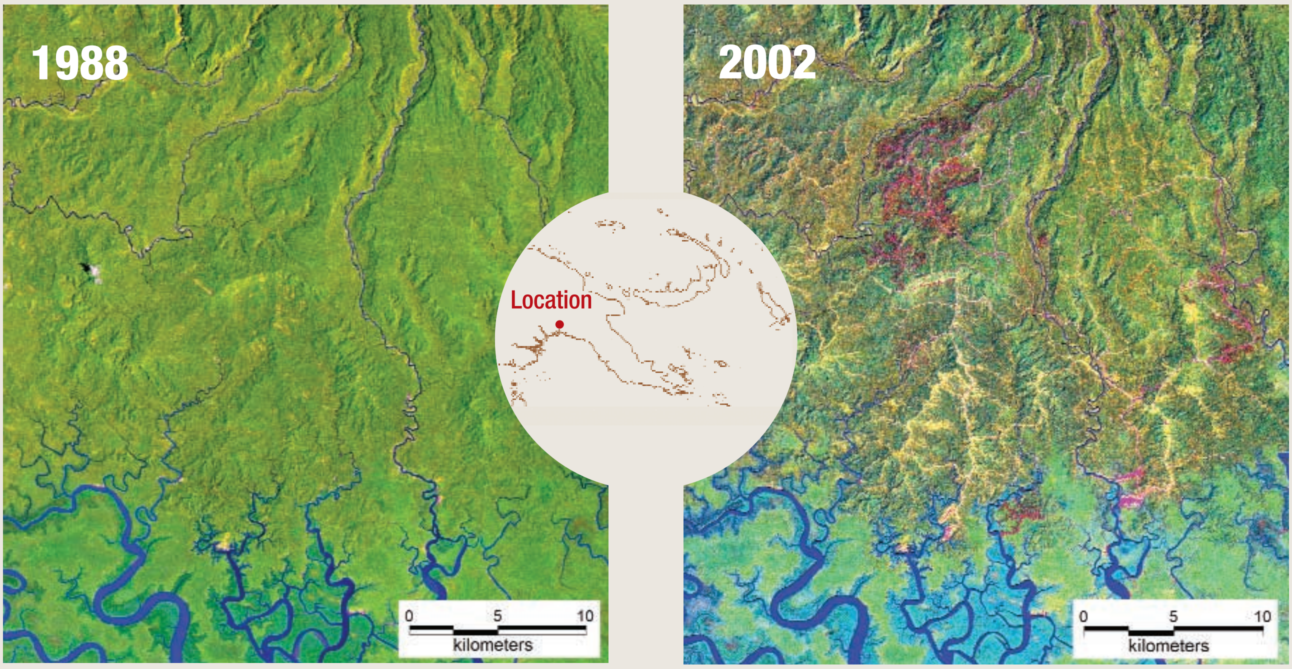
Despite the name, "selective logging" results in a substantial amount of indiscriminate damage to the forest. The first pass of logging tends to remove many of the largest trees and with them a significant amount of the biomass of the forest. This has implications for both the climate and the long-term economic viability of logging operations. A study in Bolivia found that a second cut would yield only 21% of the volume of the first.[35] In the process of selectively felling and extracting timber, many non-target trees are damaged or killed. This collateral damage is either burned or left to decompose and is not reflected in the reported harvested volumes. The disturbance of fragile tropical soils and vegetation by heavy machinery during road building, harvesting, and skidding, results in further carbon losses.

A recent, comprehensive report on the forests of Papua New Guinea (PNG) noted that nearly half of the trees in a typical "selective" logging operation are killed. Only 5-6% of the total wood volume is removed as timber – most of the rest ends up as greenhouse gases in the atmosphere.[36] An estimated 20.5-23.2 million tonnes of carbon were released in 2007 as a result of logging-related deforestation and forest degradation. By comparison, the largest coal-fired power plant in the United States released 7.4 million tonnes of carbon in the same year.[37] The authors estimate that if carbon were assigned a nominal value of US$10 per tonne of CO_2, the annual emissions from logging operations in PNG would be worth more than the total value of forestry exports, which averaged $156 million annually in recent years.[38]



Detecting degradation: selective logging in Borneo detected using new analytical technology. *Left*, Landsat satellite image of a logged area. *Right*, the same image after analysis using the Carnegie Landsat Analysis System (CLAS).[39]

Selective logging, carbon and forest loss in Papua New Guinea



It will take more than improved logging techniques to save the forests of Papua New Guinea. Satellite images show the same area of forest before (1988) and after (2002) 'selective' logging operations.[49]

Papua New Guinea (PNG) contains the third largest contiguous block of tropical forest in the world, behind the rainforests of the Amazon and Congo basins, but its forests are rapidly being degraded or cleared as a result of industrial logging, described as "selective" but bordering on clear-cut.

A comprehensive survey of the condition of PNG's forests using detailed remote sensing imagery was completed in 2008. The results showed for the first time the true extent of the damage caused by industrial logging.[41] Between 1972 and 2002, about 36% of the accessible, commercially-valuable forests were logged, most within the past two decades. An estimated 24% of logged areas were subsequently deforested. Nearly all of the commercially accessible forests of PNG – around 13.5 million hectares – are either under logging concession or earmarked for future logging. The study predicts that at the current rate of logging, 83% of PNG's forests will be commercially depleted by 2021.[42]

"[T]he current practice in harvesting natural forests is that of selective logging... In many concession areas it presents an almost clear felling of the scene after the operation."
PNG's Draft National Reforestation Policy, 2005[40]

The repercussions are severe for rural populations, biodiversity and the climate. Most of PNG's five million rural inhabitants depend on these forests, where 5-7% of all the world's plant and animal species are found. PNG's forests contain as much as eight billion tonnes of carbon,[43] which the logging industry is rapidly depleting.[44] The 2008 survey found:

- Logging-related deforestation and forest degradation led to a projected release of 20.5 - 23.2 million tonnes of carbon in 2007.
- Extensive collateral damage means that nearly half of the trees in a typical "selective" logging operation are killed.
- In 2007, the volume of wood wasted was 16 times greater than the volume exported.

PNG is at the forefront of the political momentum behind REDD. But its international political agenda contrasts sharply with its domestic reality. The extent of illegal logging, arguably the highest in the world, is estimated to range from up to 70% (World Bank) to over 90% of all logging in the country (Greenpeace).[45] Corruption and mismanagement have been documented time and again.[46] Logging in PNG has been characterized as "extremely careless".[47] An independent review commissioned by the government in 2004 and supported by the World Bank, and a 2007 assessment by the ITTO, found that virtually all industrial logging in PNG was unsustainable.[48] Given the extent of illegal logging and corruption characterising the industry, it is not credible that the industry could reduce its emissions anytime soon.

Reduced impact logging

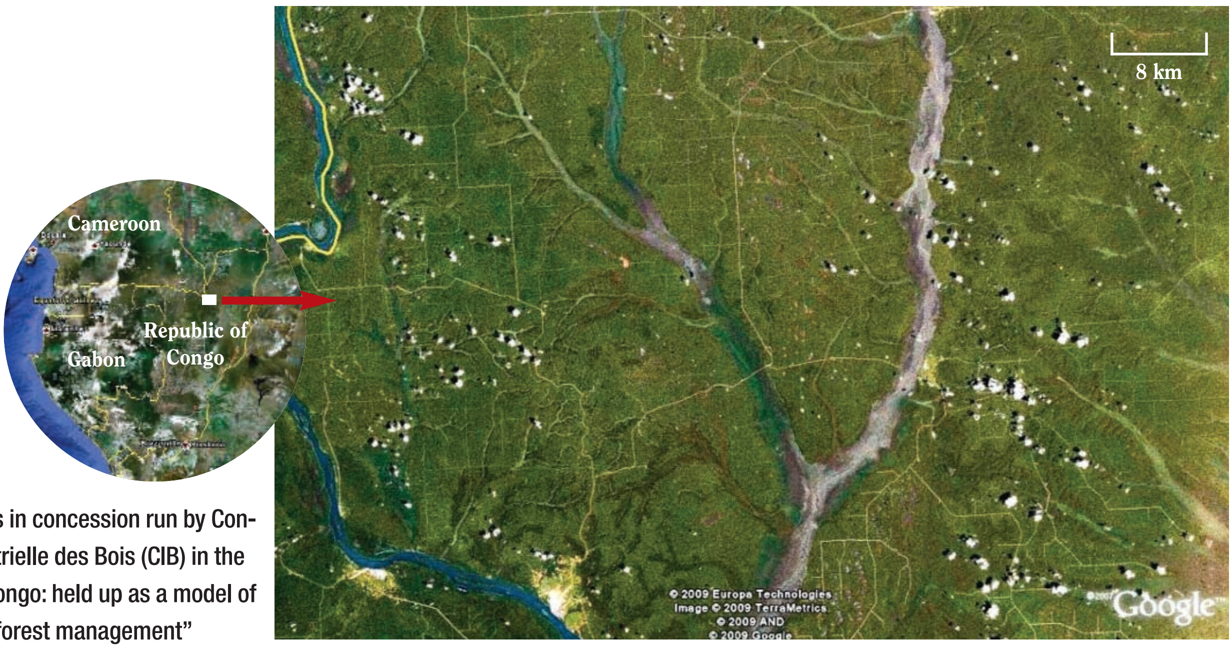
"Reduced impact" logging (RIL) attempts to decrease the collateral damage inflicted during selective logging through a number of measures, including better planning of roads and skid trails, improved felling techniques, and the removal of vines that would otherwise drag non-target trees down. A study in Sabah, Malaysia, found that RIL destroyed 15% of large non-target trees compared to 41% in conventional logging operations; one year after logging, RIL sites were found to retain 67% of the original biomass, compared to 44% for the conventionally logged sites.[50] According to an analysis published in 2008, over a 30-year period RIL techniques can reduce the total carbon emissions of logging by 30% relative to conventional selective logging.[51]

However, comparisons of emissions from RIL with a business as usual scenario of conventional selective logging are misleading. These comparisons hide the substantial damage that RIL causes to forests *relative to their undisturbed state*. Damage caused by RIL varies depending on the abundance of commercially valuable trees – the greater the abundance, the greater the logging intensity, therefore the more damage inflicted. Logging intensities are typically higher in South East Asian forests than in Latin America and Africa. The 2008 analysis referred to above showed that RIL can reduce the carbon content of a natural forest in Malaysia by nearly 40% during a 30-year logging rotation.[51] This is due to the removal of large trees and collateral damage to additional trees, vegetation and soil. Although the application of RIL techniques was predicted to decrease total carbon loss by 30 tonnes per hectare relative to conventional logging, it still resulted in the loss of 78 tonnes of carbon per hectare (see Figure 1). Most of this carbon ends up in the atmosphere, and it may take centuries for the forest to fully recover again, and then only if the logging ceases. A study of the sustainability of RIL in the eastern Amazon found that at the rate the forest is being logged RIL is "clearly insufficient" to ensure sustainability, and that only 50% of the commercial stand could recover within 30 years.[53]

"Selective" logging, even in its "reduced impact" form, causes an immediate and significant release of carbon from direct and collateral damage and associated infrastructure.

An assessment of a logging operation certified by the Forest Stewardship Council (FSC) in the southern Amazon employing RIL found that collateral damage released twice as much carbon as the harvest of target trees.[54] While on average only one or two trees were harvested per hectare, ten trees were severely damaged in the felling of each target tree, and six trees per hectare were destroyed in the construction of log decks and roads within the same area. Overall, logging damage produced 4.9-8.8 tonnes of carbon per hectare, contained in coarse woody debris. This is over twice the amount removed as logs (2.1-3.7 tonnes of carbon per hectare).

A concession run by Congolaise Industrielle des Bois (CIB) in the north of the Republic of the Congo is sometimes



Logging roads in concession run by Congolaise Industrielle des Bois (CIB) in the Republic of Congo: held up as a model of "sustainable forest management"

alluded to as a model of "sustainable forest management". But even here, in the course of harvesting 120 trees, another 727 trees were severely damaged (stems snapped or uprooted) and left to decompose, resulting in half a tonne of carbon in collateral damage created per cubic metre of commercial timber extracted.[55] The carbon loss from skid trails in this operation was determined to be 6.8 kg per metre of trail, or 0.09 tonnes per hectare, while roads generated 2.6 tonnes per hectare. Overall, the study found that the total carbon loss resulting from this "reduced impact" logging was 10.2 tonnes per hectare (including extracted biomass carbon and damaged biomass carbon in logging gaps, skid trails, and logging roads).

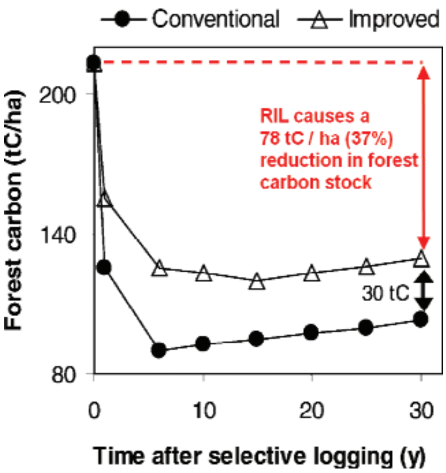


Figure 1: Comparison of the effect of conventional and improved ("reduced impact") logging on forest carbon stocks. (Taken from Putz *et al*, 2008; with annotations added in red)[52]

Regeneration: A century or more

Forests that have been subject to selective logging may regenerate depending on the intensity of logging (i.e. number of trees removed or killed through collateral damage per hectare) and the number of times a site is logged. If a site has been only "lightly" logged and is not subject to further disturbance then it can regenerate (depending also on the condition of the forest in the surrounding landscape). However, estimates show that it can take centuries for a logged forest's total carbon stock to return to pre-logged levels.[56]

For example, a model of post-logging carbon dynamics in primary *dipterocarp* forests in Asia estimated that it would take 120 years for the forest to recover the carbon lost as a result of selective logging.[57] In addition, the ability of the particular species being logged to regenerate over time is unknown (even in the case where replanting is attempted). A study of net carbon fluxes from forest clearance and regrowth in the Amazon estimated that the carbon uptake of secondary forests offsets only one-fifth of the carbon emissions from deforestation.[58]

Logged in a day, centuries to grow back. *Global Witness*

The Myth of Harvested Wood Products

Under the Kyoto Protocol, losses of forest carbon attributable to removal of harvested wood products (HWP) are assumed to be losses to the atmosphere at the time of harvesting. Some countries, and notably the timber industry, claim that harvested wood products act as a carbon pool, and are trying to have these recognised as such in the post-2012 climate agreement (due to be concluded at UNFCCC COP 15 in December 2009) by allowing estimated losses of carbon from logged forests to be discounted by estimates of retention in products derived from such harvesting. If this notion is accepted in the absence of full carbon accounting and reporting, it would provide a perverse incentive to log natural forests and almost certainly open up methodological loopholes that would under-estimate emissions.

When the full carbon impact of the life cycle of wood-derived products is taken into consideration, it is clear that the "HWP" argument does not hold up, particularly when these products are sourced from primary forests (see Figure 2). When considering the net climate impact of a forest product, it is necessary to include the carbon emissions resulting from:

- **Initial clearing** of road access and skid trails
- **Harvesting**, including fossil fuels used by heavy machinery and chainsaws
- **Collateral damage** to living woody biomass and soil carbon (both immediate and delayed)
- **Transportation** of logs, pulpwood and woodchips
- **Manufacture, importation and maintenance** of logging vehicles and equipment
- **Primary processing**: sawing into lumber; manufacture of plywood, etc
- **Secondary processing**: turning primary products into end products and constructing buildings
- **Transportation** of wood products from processing site to retail locations
- **Disposal**: discarded products burned or sent to landfills.

All of these emissions must be subtracted from the estimated carbon stored in wood-based products[59] – calculated over the lifetime of the products involved.

Collateral damage alone can be more than twice the amount of carbon contained in the volume that leaves the forest, let alone the volume of the product leaving the processing facility.

Large amounts of forest products end up in landfills, where anaerobic conditions lead to the production of methane. This gas has a global warming potential 25 times greater than CO_2, and it is estimated that over half the carbon released from decomposing wood in landfills is in the form of methane.[60]

Fossil fuel use is also associated with each stage in the production and disposal of wood products. Transportation alone (of forest products from sawmill to retail store), can cause carbon emissions amounting to as much as 70% of the carbon stored in the lumber.[61] Significant fossil fuel use is also associated with road building and harvesting operations and primary and secondary manufacturing.

Finally, in order to prove true additionality, it needs to be demonstrated that carbon in wood-based products will be locked up for longer than it would have been had it remained in an unlogged natural forest. It would also have to be proved that new forest products do not just replace existing forest products, which once discarded will release carbon into the atmosphere through decomposition.

The combination of all these considerations makes it highly unlikely that including harvested wood products, particularly those sourced from natural forests, in forest inventories would ever identify a net carbon sink. Further, accounting for HWP would be complicated and costly, constituting a methodological nightmare that would merely serve to further underestimate emissions attributable to forest degradation. Furthermore, it would do little to drive the reduction in consumption of wood products that must be made, in developed countries in particular, in order to address climate change by decreasing energy use and forest degradation attributable to this sector.

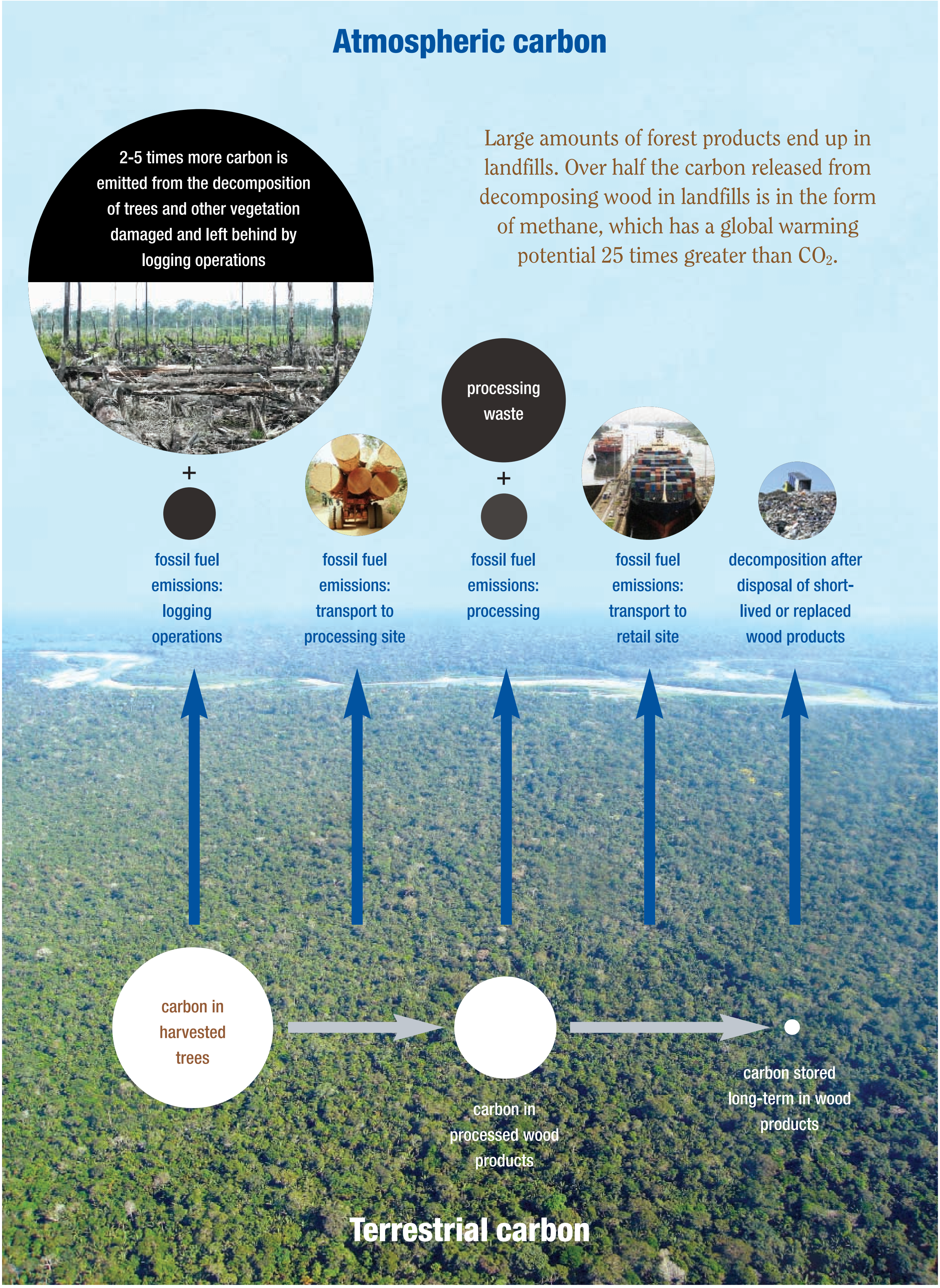


Figure 2: Carbon emissions from harvested wood products. *Main photo: Global Witness. Inset photos (left to right): Wetlands International; Global Witness; thinkpanama.com; Mattias Olsson*

Logging roads: the beginning of the end

Carbon losses incurred at the time of logging are just the beginning. Once a forest has been degraded and perforated by roads, it becomes vulnerable to destruction by secondary, human-induced processes such as clearing for agriculture.

A unique feature of industrial logging is the creation of dense networks of logging roads in areas of previously intact forest. A recent study used remote imaging to identify 51,916 km of logging roads in the forests of the Congo Basin in Central Africa.[62] Most of these roads are concentrated in countries where intensive industrial logging has been underway for a number of years. Gabon, for example, already has a network of 13,400 km of logging roads – more than the length of the German autobahn network – carved out of areas of largely uninhabited forest.

Logging roads open up forests to encroachment by a range of new actors that would not otherwise have had access including industrial agriculturalists, illegal loggers, subsistence farmers and hunters. A decade ago, FAO drew attention to the destruction that logging roads bring, finding that the deforestation rate due to conversion to agricultural land was eight times higher in forests that have previously been logged than in undisturbed forests.[63]

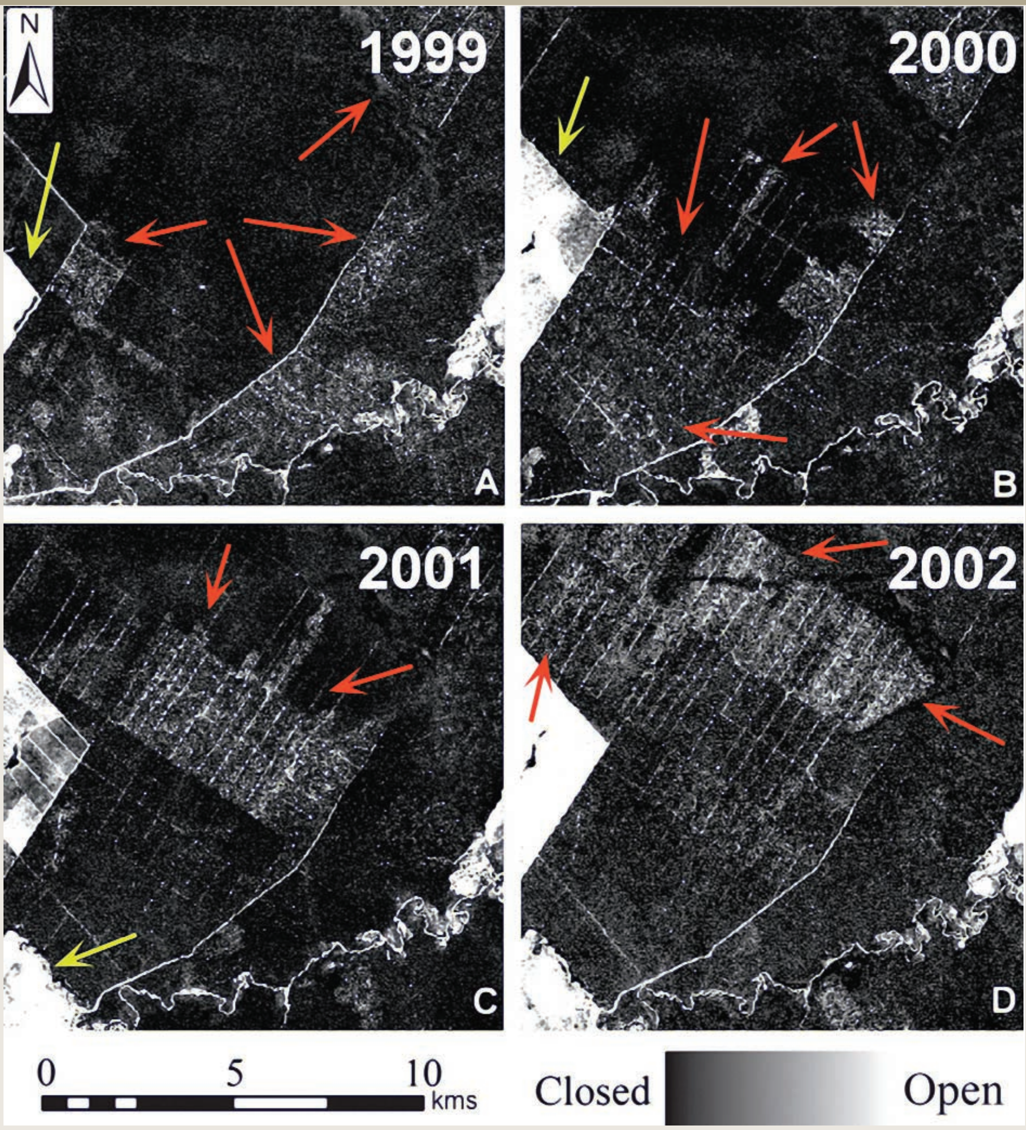
In areas with high population pressures, such as the eastern fringes of the tropical forests of the Amazon, logging exposes the forests to the risk of permanent conversion to agriculture and associated settlements.[64] The negative impacts on forests caused by subsistence agriculturalists[65] and illegal loggers[66] using the access provided by logging roads have been well-documented in Indonesia.

In regions with lower population density, such as parts of the Congo Basin, new roads provide greater access leading to unregulated logging and poaching activity in remote areas that are difficult to control. As a result wildlife becomes more vulnerable to exploitation for the commercial trade in bushmeat.[67] The loss of these forest-associated species leads to "empty forest syndrome", whereby the absence of animal vectors results in the failure of a surprisingly large number of plant seed dispersal and germination processes, further impoverishing the forest and its ecological resilience.[68]

Gabon has 13,400 km of logging roads – more than the length of the German autobahn network

Logging roads open up remote areas of forest to agricultural conversion, illegal logging and hunting. *Global Witness*

Selective Logging in the Brazilian Amazon: the road to deforestation



The march of logging and deforestation in the Brazilian Amazon, 1999-2002. Yellow arrows show deforestation; red arrows show selective logging (from Broadbent et al, Biological Conservation 2008[74]).

About a quarter of the world's deforestation occurs in Brazil. The widely acknowledged direct causes of deforestation are conversion to pasture or industrial agriculture. New scientific studies, however, show that industrial logging should be added to the list.

Recent research led by scientists at the Carnegie Institution for Science involved the first large-scale assessment of logging in the Brazilian Amazon[69] based on high-resolution satellite imagery and new analytical techniques capable of detecting small forest canopy openings. A number of striking observations were made:

• The area of forest being degraded by selective logging was roughly equal to the area deforested over the same period.[70]

• The level of degradation was high – 76% of the canopy damage was severe enough to leave the forest susceptible to drought and fire.[70]

• On average, one-third of the forest area that was selectively logged in the year 2000 was completely deforested by 2004.[71]

• Logging allowed deforestation to move deep into intact forest. Within 25 km from major roads, logged forest was up to four times more likely to be deforested than undisturbed forest.[71]

Between 1999 and 2001, degradation from selective logging in the Brazilian Amazon released up to 80 million tonnes of carbon annually[70] – more carbon than is released each year by the fourteen highest emitting coal-fired power plants in the United States combined.[72] Despite these massive emissions, industrial logging is continuing to expand rapidly. The FAO expects 13 million hectares of forest to be under private concession in the next decade, eventually reaching 50 million hectares.[73]

Forests on fire: industrial logging increases vulnerability

The degradation caused by industrial logging in primary and modified natural tropical forests leaves them more vulnerable to natural disturbances and climate-related stresses such as drought, storms, disease, pestilence and, perhaps most importantly, to natural and human-caused fires.

Intact tropical rainforests are virtually immune to fire,[75] but as these forests are degraded by human activities the frequency and extent of fires increase.[76] In particular, degradation due to industrial logging is one of the major causes of increased fire susceptibility in tropical forests.[77] The canopy gaps caused by logging disrupt the cool, moist micro-climate underneath the canopy. Exposure to sun and wind dries out vegetation and increases the likelihood of fire.[78] In addition, collateral damage from logging leaves behind dead and dying debris that once dried can serve as fuel for fires. The combined effect is an increase in the flammability of the forest. Openings in selectively logged forests in the eastern Amazon were found to burn after 5-6 rainless days and in secondary growth forests after 8-10 days.[79] It can take years to decades for logged forests to recover their natural resistance to fire.[80]

The terrible fires that swept through tropical forests during the El Niño droughts of 1997-98 show how much more vulnerable logged forests are to fire than undisturbed forest. During this period, fires in Brazil and Indonesia alone released an estimated 0.833 - 2.593 billion tonnes of carbon into the atmosphere, the equivalent of up to 40% of total global fossil fuel emissions during this period.[82] In Indonesian Borneo, an area the size of Costa Rica burned, half of which was forested. An analysis of satellite images before and after the fires found that 60% of previously logged forest had burned while only 6% of primary forest was affected.[83] Selective logging in the Brazilian Amazon was also found to increase the susceptibility of forests to fire.[84] An increase in the severity and frequency of forest fires is a significant negative outcome of industrial logging in tropical forests, one that can have more devastating effects and release far more carbon than the logging operations themselves.[85]

An increase in the severity and frequency of forest fires is a significant negative outcome of industrial logging in tropical forests, one that can have more devastating effects and release far more carbon than the logging operations themselves.[81]

Wetlands International

Each year, fires in Indonesia's degraded peat forests cause a haze of smoke that extends as far as Singapore and Malaysia. *Wetlands International*

Conclusions

Industrial logging in primary and modified natural forests poses a clear threat to forests and to the global climate system. Claims by the industry and its supporters that industrial logging can be "sustainable" and benefit the climate, and should not be equated with degradation, do not stand up against the accumulating scientific evidence. A growing body of scientific literature indicates that even when logging practices follow "selective" or "reduced impact" guidelines, there are immediate and substantial carbon emissions caused by direct and collateral damage. This damage is extensive even with "reduced impact" logging and puts the remaining forest on a path towards further degradation. At the same time, new research continues to reveal that old-growth, intact forests retain a vigorous carbon sequestering capacity for centuries and are much greater carbon stores than had previously been thought.

Roads and fire are among the greatest "climate hazards" associated with industrial logging. It is well known that dense networks of logging roads in tropical forests open them up to encroachment by illegal loggers, subsistence farmers and poachers. It is perhaps less well known that, compared with undisturbed forests, studies have shown that logged forests are: up to eight times more likely to be deforested and converted to agricultural land; up to four times more likely to be deforested within 25 km of major roads; and ten times more likely to burn.

"Reduced impact" logging is often equated with "sustainable forest management". But there is nothing "sustainable" about a practice which, in the best case scenarios, kills or damages 6 - 10 trees in addition to the one harvested and produces in the range of about 10 - 80 tonnes of carbon per hectare depending on logging intensity. Studies which compare emissions from RIL with a business as usual scenario are not only misleading, they play to industry interests rather than help to solve climate change. The carbon implications of RIL, indeed all forms of logging, should always be assessed against the carbon dynamics of the intact forest in the absence of human disturbance, not by comparing it with more destructive logging operations.

The argument that harvested wood products should be recognised as a carbon pool under the UNFCCC is the latest industry ploy to down play its emissions. The amount of carbon remaining "locked up" in long-lived solid wood products is negligible compared with emissions over their life cycle. Moreover, introducing HWP into accounting and reporting procedures under the UNFCCC constitutes a methodological nightmare that is best avoided.

Attempts to include "sustainable logging" within the scope of activities eligible for REDD benefits are disingenuous and driven by vested interests. Industrial logging in natural tropical forests is fundamentally incompatible with the goals of REDD. If REDD is to deliver meaningful and lasting reductions in emissions and provide a tool for adaptation to climate change, ending industrial logging in primary and natural tropical forests, including under the guise of sustainable forest management, must be part of the solution. Apart from the climate impact of *all forms* of industrial logging in tropical forests, the extent of illegality and unsustainable practices rife in the industry will turn any efforts to "green" logging into little more than a pipe dream.

References

1 FAO, 2005, *Forest Resources Assessment*. Accessed 11 May 2009 at: http://www.fao.org/docrep/008/a0400e/a0400e00.htm

2 IPCC, *Climate Change 2007: Synthesis Report*

3 UNFCCC Decision 1/CP.13, para. 1(b)(iii), Bali, 3-14 Dec 2007. REDD is now being referred to as "REDD-plus", i.e. it will be an expanded mechanism incorporating forest management activities including "sustainable forest management".

4 In particular, the Montreal Process Criteria and Indicators; http://www.rinya.maff.go.jp/mpci/

5 Butler, R.A. and Laurence, W.F. 2008. *New strategies for conserving tropical forests*. Trends in Ecology and Evolution, 23, 469–472.

6 Lewis S. (and 32 other authors), 2009. *Increasing carbon storage in intact African tropical forests*. Nature, 457, 1003–1007.

7 Asner, G.P., Rudel, T.K., Aide, T.M., DeFries, R., Emerson, R. 2009. *A Contemporary Assessment of Global Humid Tropical Forest Change.* Conservation Biology, in press.

8 Studies cited in Mackey, B.G., Keith, H., Berry, S.L. and Lindenmayer, D.B. 2008. *Green Carbon: the role of natural forests in carbon storage*. *Part 1, A green carbon account of Australia's south–eastern Eucalypt forest, and policy implications.* Australian National University E–press.

9 See section titled *Reduced impact logging* in this report for examples.

10 See for example: Putz, F.E., Zuidema P.A., Pinard M.A., Boot R.G.A., Sayer J.A., *et al*. 2008. *Improved Tropical Forest Management for Carbon Retention*. PLoS Biol 6(7): e166. doi:10.1371/journal.pbio.0060166

11 Siegert, F., Ruecker, G., Hinrichs, A. and Hoffmann, A. 2001. *Increased damage from fires in logged forests during droughts caused by El Niño*. Nature, 414, 437–440.

12 Page, S.E., Siegert, F. Rieley, J.O., Boehm, H.V., Jaya, A. and Limin, S. 2002. *The amount of carbon released from peat and forest fires in Indonesia during 1997*. Nature, 420, 61–65.

13 FAO/ATIBT, 1999. *Road infrastructures in tropical forests. Road to development or road to destruction?* Report co-edited by the Food and Agriculture Organization of the United Nations (FAO) and the Association Technique Internationale des Bois Tropicaux (ATIBT). Accessed 26 March 2009 at: http://www.fao.org/docrep/x1361E/x1361e00.HTM

14 Laporte, N.T., Stabach, J.A., Grosch, R., Lin, T.S., Goetz, S.J. 2007. *Expansion of Industrial Logging in Central Africa*. Science, 316, 1451.

15 Asner, G.P., Broadbent, E.N., Oliveira, P.J.C., Keller, M., Knapp, D.E. and Silva, J.N.M. 2006. *Condition and fate of logged forests in the Brazilian Amazon.* Proceedings of the National Academic Society of the USA, 103, 12947–12950.

16 Shearman, P.L., Ash, J., Mackey, B., Bryan, J.E., and Lokes, B. 2008. *State of the forests of Papua New Guinea*. University of Papua New Guinea.

17 World Bank, 2006. *Sustaining Economic Growth, Rural Livelihoods, and Environmental Benefits: Strategic Options for Forest Assistance in Indonesia*.

If the climate change regime and REDD are to deliver lasting reductions in emissions, ending industrial logging in natural forests must be part of the solution. *Steve Jackson*

18 Ingerson, A. 2009. *Wood Products and Carbon Storage: Can Increased Production Help Solve the Climate Crisis?* Washington, D.C., The Wilderness Society.

19 FAO, 2005. *Forest Resources Assessment*. Accessed 11 May 2009 at: http://www.fao.org/docrep/008/a0400e/a0400e00.htm

20 IPCC, *Climate Change 2007: The Physical Science Basis*.

21 IPCC, 2001. Climate Change 2001: Working Group I: The Scientific Basis, Chapter 3, Table 3.2.

22 Malhi, Y., Luiz E., Aragao, D, Huntingford, C., Fisher, R., Zelazowski, P., Sitch, S., McSweeney, C., and Meir, P. 2008. *Exploring the likelihood and mechanism of a climate change induced dieback of the Amazon Rainforest*. Proceedings of the National Academy of Sciences, December 15, 2008.

23 Mackey, B.G. *et al.* 2008. *Green Carbon: the role of natural forests in carbon storage. Part 1, A green carbon account of Australia's south–eastern Eucalypt forest, and policy implications*. Australian National University E–press.

24 Uhl, C. and Kauffman, J. B., 1990. *Deforestation, Fire Susceptibility, and Potential Tree Responses to Fire in the Eastern Amazon*. Ecology, Vol. 71, No. 2, April 1990.

25 Mackey, B.G. *et al.* 2008. *Green Carbon: the role of natural forests in carbon storage. Part 1, A green carbon account of Australia's south–eastern Eucalypt forest, and policy implications*. Australian National University E–press.

26 Secretariat of the Convention on Biological Diversity, 2003. *Interlinkages between biological diversity and climate change. Advice on the integration of biodiversity considerations into the implementation of the United Nations Framework Convention on Climate Change and its Kyoto protocol.* CBD Technical Series no.10.

27 *Ibid.*

28 Luyssaert, S., Schulze, E.–D., Borner, A., Knohl, A., Hessenmoller, D., Law, B.E., Ciais, P. and Grace, J. 2008. *Old–growth forests as global carbon sinks*. Nature 455: 213–215.

29 *Ibid.*

30 Baker, T.R. and 17 other authors. 2004. *Increasing biomass in Amazonian forest plots. Philosophical Transactions of the Royal Society London*. B 359, 353–365.

31 Lewis, S. *et al.* 2009. *Increasing carbon storage in intact African tropical forests*. Nature Vol 457, 19 February 2009.

32 FAO, 2005. *Forest Resource Assessment*.

33 Studies cited in Mackey, B.G. *et al.* 2008. *Green Carbon: the role of natural forests in carbon storage. Part 1, A green carbon account of Australia's south–eastern Eucalypt forest, and policy implications*. Australian National University E–press.

34 Asner, G.P. *et al.* 2009. *A Contemporary Assessment of Global Humid Tropical Forest Change. Conservation Biology*, in press.

35 Dauber, E., Fredericksen, T.S., Peña, M., 2005. *Sustainability of timber harvesting in Bolivian tropical forests*. Forest Ecology and Management 214, 294–304.

36 Shearman, P.L. *et al.* 2008. *State of the Forests of Papua New Guinea*. University of Papua New Guinea.

37 Environmental News Service, 18 March, 2008. Accessed on 19 May 2009 at: http://www.ens–newswire.com/ens/mar2008/2008–03–18–04.asp

38 Report to the ITTO (prepared by the Government of Papua New Guinea). *Forest Law and governance in Papua New Guinea in the context of sustainable forest management: Proceedings of the regional multi-stakeholder workshop on forest law enforcement and governance.* Port Moresby, Papua New Guinea, 10 and 11 October 2006. Report at: http://219.127.136.74/preview/Staging_Server/3227/E-C42-6.doc.

39 Images provided by G. Asner. For a description of CLAS see: Asner, G.P., Knapp, D.E., Broadbent, E.N., Oliveira, P.J.C., Keller, M. & Silva, J.N. 2005. *Selective logging in the Brazilian Amazon*. Science, 310, 480–482.

40 Government of PNG, 2005. *Draft National Reforestation Policy* (referenced in Greenpeace, 2008. *Preserving Paradise: The value of protecting Papua New Guinea's forests for climate*).

41 Shearman, P.L. *et al.* 2008. *State of the forests of Papua New Guinea*, University of Papua New Guinea.

42 *Ibid.*

43 Greenpeace, 2008. *Preserving Paradise: The value of protecting Papua New Guinea's forests for climate*.

44 Shearman, P.L. *et al.* 2008. *State of the Forests of Papua New Guinea.* University of Papua New Guinea.

45 Greenpeace, 2008. *Preserving Paradise: The value of protecting Papua New Guinea's forests for climate*.

46 Barnett, T., 1987. *Commission of Inquiry into Aspects of the Timber Industry in Papua New Guinea*; Overseas Development Institute (ODI), 2007. *What can be learnt from the past? A history of the forestry sector in Papua New Guinea*, Papua New Guinea Forest Studies 1 at www.odi.org.uk/fecc/resources/reports/png_paperone_history.pdf; Report to the International Tropical Timber Council, ITTC(XLII)/7, 4 April 2007. *Achieving the ITTO Objective 2000 and sustainable forest management in Papua New Guinea: Report of the Diagnostic Mission*.

47 Greenpeace, 2008. *Preserving Paradise: The value of protecting Papua New Guinea's forests for climate.*

48 For a summary of the independent review, see: Forest Trends, 2006. *Logging, legality, and livelihoods in Papua New Guinea: Synthesis of Official Assessments of the Large–Scale Logging Industry*, Volume I; Report to the International Tropical Timber Council, ITTC(XLII)/7, 4 April 2007. *Achieving the ITTO Objective 2000 and sustainable forest management in Papua New Guinea: Report of the Diagnostic Mission.*

49 Images taken from Shearman, P.L. *et al.* 2008. *State of the forests of Papua New Guinea*. University of Papua New Guinea (annotated for the purpose of the illustration).

50 Pinard, M. and Putz, F., 1997. *Monitoring carbon sequestration benefits associated with a reduced–impact logging project in Malaysia. Mitigation and Adaptation Strategies for Global Change*, 2: 203–215.

51 Putz, F. *et al.* 2008. *Improved Tropical Forest Management for Carbon Retention*. PLoS Bio 6(7): e166. doi:10.1371/journal.pbio.0060166

52 *Ibid.*

53 Sist, P., and Fevreira, F.N., 2007. *Sustainability of reduced–impact logging in the Eastern Amazon*. Forest Ecology and Management, 243, 199–209.

54 Feldpausch, T.R., Jirka S., Passos C.A.M., Jasper F., Riha S.J. 2005. *When big trees fall: Damage and carbon export by reduced impact logging in southern Amazonia*. Forest ecology and management, Vol. 219, 199–215; Scientific Certification Systems (SCS), 2003. *Natural forest management certification evaluation of Rohden Indústria Lígnea Ltd. Fazenda Rohsamar in Juruena Mato Grosso State – Brazil*, Conducted under the auspices of the Forest Stewardship Council (FSC) and SCS Forest Conservation Program. Accessed on 6 May 2009 at: http://www.scscertified.com/PDFS/forest_rohden_eng.pdf

55 Brown, S., Pearson, T., Moore, N., Parveen, A., Ambagis, S. and Shoch, D. 2006. *Impact of selective logging on the carbon stocks of tropical forests: Republic of Congo as a case study. Report submitted to the United States Agency for International Development.*

56 Harmon, M. E., Ferrell, W. K. and Franklin, J. F. 1990. *Effects on carbon storage of conversion of old–growth forests to young forests*. Science, 247, 699–702.

57 Pinard, M.A. and Cropper, W.P. 2000. *Simulated effects of logging on carbon storage in dipterocarp forest*. Journal of Applied Ecology, 37: 267–283.

58 Steininger, M.K. 2004. *Net Carbon Fluxes from Forest Clearance and Regrowth in the Amazon*. Ecological Applications, Vol. 14, No. 4, Supplement: The Large–scale Biosphere–Atmosphere Experiment in the Amazon, S313–S322.

59 Mackey, B.G. *et al.* 2008. *Green Carbon: the role of natural forests in carbon storage. Part 1, A green carbon account of Australia's south–eastern Eucalypt forest, and policy implications*. Australian National University E–press.

60 Ingerson, A. 2009. *Wood Products and Carbon Storage: Can Increased Production Help Solve the Climate Crisis?* Washington, D.C., The Wilderness Society.

61 Adapted from Gower, S.T. (and 12 other authors). 2006. *Following The Paper Trail: The Impact of Magazine And Dimensional Lumber Production On Greenhouse Gas Emissions: A Case Study.* The Heinz Center.

62 Laporte *et al.* 2007. *Expansion of Industrial Logging in Central Africa*. Science, 316, 1451.

63 FAO/ATIBT, 1999. *Road infrastructures in tropical forests. Road to development or road to destruction?* Report co-edited by the Food and Agriculture Organization of the United Nations (FAO) and the Association Technique Internationale des Bois Tropicaux (ATIBT). Accessed on 26 March 2009 at: http://www.fao.org/docrep/x1361E/x1361e00.htm.

64 Asner, G.P. *et al.* 2006. *Condition and fate of logged forests in the Brazilian Amazon*. Proceedings of the National Academic Society of the USA, 103, 12947–12950.

65 Uryu, Y. (and 15 other authors). 2008. *Deforestation, Forest Degradation, Biodiversity Loss and CO2 Emissions in Riau, Sumatra, Indonesia: One Indonesian Province's Forest and Peat Soil Carbon Loss over a Quarter Century and its Plans for the Future*. WWF Indonesia Technical Report, Jakarta, Indonesia.

66 Jepson, P., Jarvie, J.K., MacKinnon, K., Monk, K.A. 2001. *The End for Indonesia's Lowland Forests?* Science, 292, 5518–5519.

67 Bennett, E., Eves, H., Robinson, J., Wilkie, D. 2002. *Why is eating bushmeat a biodiversity crisis?* Conservation in Practice Vol. 3, No. 2, pp. 28–29.

68 Redford, K.H. 1992. *The empty forest*. BioScience, 42, 1–12.

69 The study area included the five states responsible for 90% of deforestation within the Brazilian Amazon: Acre, Pará, Rondônia, Roraima, and Mato Grosso.

70 Asner, G.P. *et al.* 2005. *Selective logging in the Brazilian Amazon*. Science, 310, 480–482.

71 Asner, G.P. et al. 2006. *Condition and fate of logged forests in the Brazilian Amazon.* Proceedings of the National Academic Society of the USA, 103, 12947–12950.

72 Carbon emissions from U.S. power plants are based on 2006 levels. Obtained from website, accessed on 17 May 2009 at: http://www.dirtykilowatts.org/index.cfm

73 FAO, 2009. *State of the World's Forests.*

74 Broadbent, E. N., Asner, G.P., Keller, M., Knapp, D.E., Oliveira, P.J.C., Silva, J.N., 2008. *Forest fragmentation and edge effects from deforestation and selective logging in the Brazilian Amazon.* Biological Conservation 141, 1745-1757.

75 Uhl, C. and Kauffman, J.B., 1990. *Deforestation, Fire Susceptibility, and Potential Tree Responses to Fire in the Easter Amazon*. Ecology, Vol. 71, No. 2, 437–449.

76 Cochrane, M. 2003. *Fire science for rainforests*. Nature, 421, 913–919.

77 Siegert, F. *et al.* 2001. *Increased damage from fires in logged forests during droughts caused by El Niño*. Nature, 414, 437–440.

78 Holdsworth, A., and Uhl, C., 1997. *Fire in Amazonian selectively logged rain forest and the potential for fire reduction*. Ecological Applications 7 (2), 713–725; Nepstad, D.C., Verissimo, A., Alencar, A., Nobre, C., Lima, E., Lefebvre, P., Schlesinger, P., Potter, C., Moutinho, P., Mendoza, E., Cochrane, M. and Brooks, V. 1999. *Large–scale impoverishment of Amazonian forests by logging and fire*. Nature, 398, 505–508.

79 Uhl, C. and Kauffman, J. B., 1990. *Deforestation, Fire Susceptibility, and Potential Tree Responses to Fire in the Eastern Amazon*. Ecology, Vol. 71, No. 2, April 1990.

80 Holdsworth, A and Uhl, C. 1997. *Fire in Amazonian selectively logged rain forest and the potential for fire reduction*. Ecological Applications 7 (2), 713–725; Cochrane, M., 2003. *Fire science for rainforests.* Nature, 421, 913–919.

81 Nepstad *et al.* 1999. *Large–scale impoverishment of Amazonian forests by logging and fire*. Nature, 398, 505–508.

82 Cochrane, M., 2003. *Fire science for rainforests*. Nature, 421, 913–919.

83 Siegert, F. *et al.* 2001. *Increased damage from fires in logged forests during droughts caused by El Niño.* Nature, 414, 437–440.

84 Holdsworth, A. and Uhl, C., 1997. *Fire in Amazonian selectively logged rain forest and the potential for fire reduction*. Ecological Applications 7 (2), 713–725.

85 Nepstad *et al.* 1999. *Large–scale impoverishment of Amazonian forests by logging and fire*. Nature, 398, 505–508.

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