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26 Trading forest carbon to promote the adoption of reduced impact logging[1]

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INTRODUCTION

The Clean Development Mechanism (CDM) of the Kyoto Protocol (UNFCCC, 1997) created the possibility of trading forest carbon by allowing industrialized countries with emission reduction commitments to meet a part of their commitments by financing specified forestry activities in developing countries. Under the agreement reached in July 2001 at Bonn (COP6.bis), although improved forest management in developing countries will not be eligible for carbon credits at least for the first commitment period of 2008-2010, it will however be considered for future commitment periods (Pronk, 2001). Financing for improved forest management may also be made available from a Special Climate Change Fund, which will include activities that help countries adapt to climate change, including forestry activities (Pronk, 2001). At COP6.bis, industrialized countries pledged to provide over US$ 450 million to an adaptation fund by 2005 (IISD, 2001). The fund will also be financed from a share of the proceeds from CDM project activities (Pronk, 2001).

The United States, which rejected the Kyoto Protocol, is preparing alternatives to it. Whether any forestry activities in developing countries will be included is still unknown. However, it seems likely that some form of trade in forest carbon will be included, given that the high cost of meeting emission reduction commitments at home was one of the key reasons for the United States' rejection of the Protocol (IISD, 2001). Therefore, although at this stage there is a great deal of uncertainty, the prospects for increased international financial flows to support improved management of tropical forests in the future are a real possibility.

The benefits from trading forest carbon have been supported strongly by those who believe that improved tropical forest management will be difficult unless forest owners and managers are compensated for the environmental services of their forests (Pearce *et al.*, in press). On the other hand, some have argued that instead of striving for improved management, the best option for tropical forests would be outright protection or one low-intensity harvest followed by protection (Rice *et al.*, 1997; Cannon *et al.*, 1998). Still others have pointed out that the potential for supporting improved management with carbon payments is likely to be applicable only to niches, unless policies and institutions that impede better practices are also reformed (Smith *et al.*, 2000). An analysis of the potential role of carbon trading in supporting improved management could therefore make an opportune contribution to the clarity of the debate.

This paper focuses on the potential for using carbon trading to stimulate adoption of reduced impact logging (RIL)-based sustainable forest management. While the incremental carbon benefits of improving harvesting alone may be rather limited, significant carbon benefits could result if carbon

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[1] This analysis is based on the following paper, currently under review by Forest Policy and Economics "Could trade in forest carbon contribute to improved tropical forest management?"

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required for regeneration. It is not uncommon for many areas to be logged repeatedly at short time intervals (i.e. 10 to 15 years) and because these forests often lack effective management, the areas are subject to rapid degradation and eventual loss of forest cover. In many parts of the world, these forests could expect no more than three to four logging operations before the forest becomes nonviable for commercial logging. With each successive harvest of timber, there is a reduction in the living biomass, which is a carbon sink, and an increase in the amount of dead organic material, which contributes to an increase in carbon dioxide emissions through decay and sometimes fire (Applegate, 1982). As the forest systems degrade through repeated logging at short cutting cycles, fire, and cyclones/hurricanes, they move closer and closer to shrubland or a grassland community. In these plant communities the capacity for sequestering carbon and maintaining sinks is limited due to smaller biomass for accumulation both above and below ground. The potential for grasslands, particularly those dominated by *Imperata cylindrica,* to burn with high levels of frequency exacerbates the situation further, resulting in additional carbon emissions.

Practices similar to the above CLR scenario have been noted in countries such as Brazil, Indonesia, the Philippines, Thailand and West and Central Africa (Uhl *et al.*, 1997; Kartawinata *et al.*, in press; Lasco *et al.*, in press; Sist, 2000), with the process often taking as little as 30 years. Lasco *et al.* (in press) show that data on land cover changes in the Philippines appear to be consistent with extensive repeated logging at short intervals. While the increase in the area under logged-over forest in the Philippines corresponded closely to the decline in primary forest for the first few years after timber harvesting commenced, after a couple of decades, the increase in logged-over forest was markedly lower than the decline in primary forest, while the area under shrublands and grasslands increased markedly.

A number of hypotheses exist for the prevalence of premature re-entry logging. Boscolo and Vincent (1998) show that re-entry logging is likely after 10 years if logging costs in logged-over forests are lower than in virgin forests due to existing infrastructure. This makes the extraction of previously uneconomic species and tree sizes viable. Uhl *et al.* (1997) point out that in Pará, Brazil, local log scarcity led to increases in the price of logs and logging rights and in the number of species commercialized, thus making re-entry logging viable. The difficulty of preventing encroachment and illegal logging by outsiders is another hypothesis put forward by Kartawinata *et al.* (in press) for Indonesia, while Sist (2000) claims that the failure to carry out forest inventories leads to commercial species being discovered at a later stage.

The above studies and observations in many tropical countries indicate that CLR may be a more representative baseline scenario for many tropical forests than CL (i.e. conventional logging with cutting cycles of 30 to 60 years). This has significant implications for carbon sequestration benefits, for the opportunity cost of adopting RIL and for policy measures to support SFM.

There is a dearth of information on monitoring changes in the standing biomass of tropical forests and therefore carbon accumulation over long periods under different management regimes (i.e. RIL versus CLR). However, there is information based on limited measurements of forest stands of periods up to 60 years along with anecdotal evidence that provides us with a relatively good understanding of the likely scenario, given the prevailing conditions in many tropical forest environments (Pinard, 1995; Lee *et al.*, 1996). In swamp forests in Sumatra, Indonesia, 28 tC/ha were saved by introducing manual methods of timber harvesting compared to mechanical methods (Ken MacDicken, pers. comm).

The below-ground biomass accumulation is also affected by the harvesting technique. The biomass of tropical rainforests in Southeast Asia is between 400 and 500 t/ha (oven-dry weight) with the roots and other below-ground biomass comprising about 100 t/ha or 20 percent (Rodin and Bazilevich, 1967; Applegate, 1982; Pinard and Putz, 1997). In other tropical forests in West Africa or in tropical America (Ghana and Jamaica) the total biomass is 300 t/ha (oven-dry weight) (Greenland and Kowal, 1960; Tanner, 1980). Any destruction of the above-ground biomass will lead to an increase in the amount of dead material below ground and a likely increase in carbon emissions. Details on the exact process involved in the cycling of carbon below ground and the quantity of carbon dioxide released in tropical forests are not well understood and estimates are unknown.

In Figure 1, we present in broad terms the pattern of change in forest biomass under RIL-based SFM on a 40-year cutting cycle compared to CLR where the area is managed poorly and characterized by premature re-entry logging at approximately 10-year intervals.

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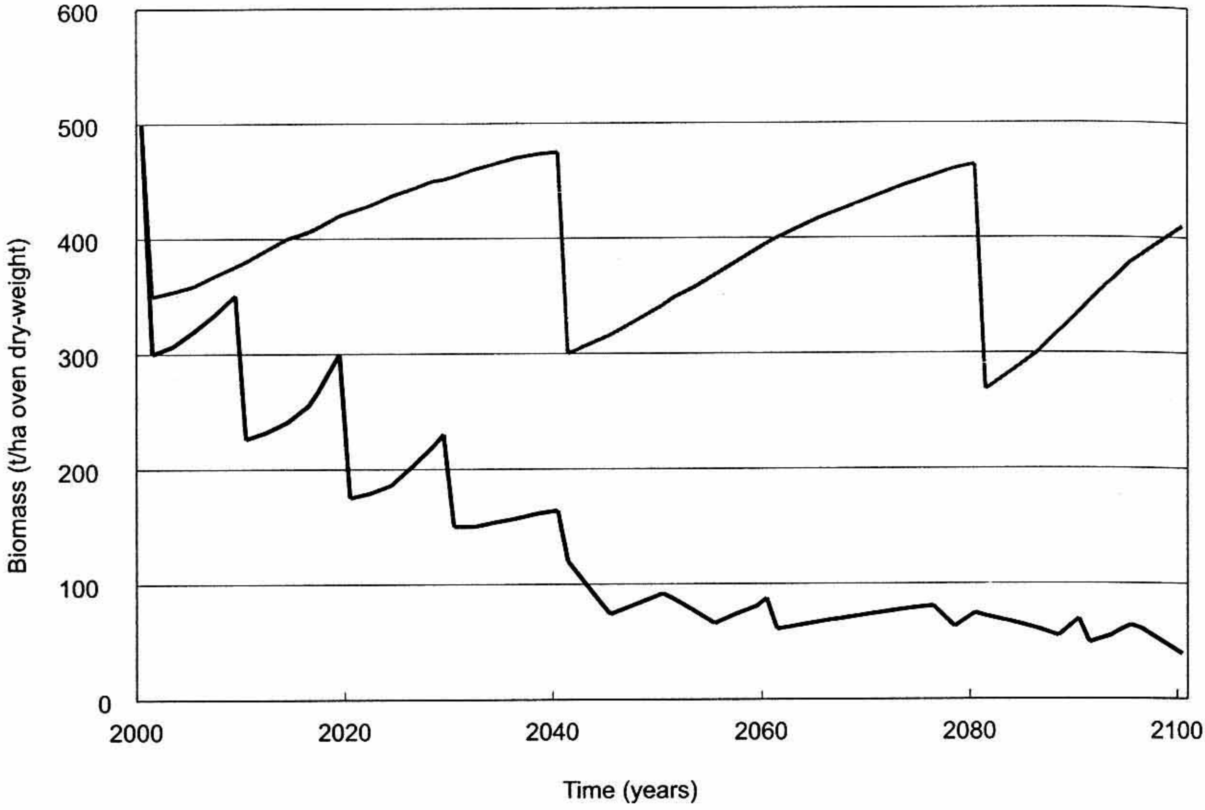

Figure 1. Biomass accumulation of a forest managed under RIL vs CLR

If the model is developed over a 100-year period, the first harvesting operation in a tropical forest, where the total biomass is in the order of 500 t/ha (Brady, 1997; Rodin and Bazilevich, 1967; Applegate, 1982; Pinard and Putz, 1996) is undertaken at time zero, shown as the year 2000 in Figure 1. The resultant difference in total living biomass between the RIL and CLR operations is likely to be in the order of 20 to 25 percent of the total biomass, with the RIL operations resulting in a biomass reduction of 30 percent (Sist and Bertault, 1998; Pinard, 1995; Don Nicholson, pers comm) and CLR 50 percent. These estimates are based on changes in tree numbers, severity of damage to trees (small and large) and estimates of changes in basal area (Elias 1998; Yosep *et al.*, 2000; Jonkers, 1987; Verissimo *et al.*, 1992; van der Hout, 1999; Pinard *et al.*, 1995). Under RIL, less volume is removed per gross unit area of forest than under CLR if exclusion areas (stream buffers, steep areas, cultural and religious sites) where timber harvesting is not permitted occupy a significant proportion of the forest management unit.

Following the initial harvesting, the forest is likely to show little change in the carbon stored below ground, in litter and vegetation, compared with the amount removed as logs and decay as a result of trees smashed during the operation. In the RIL area, the forest is likely to begin to accumulate biomass (sequester carbon) more quickly than on the CLR site. This is due to the smaller amount of dead organic matter produced and a larger number of healthy trees and shrubs in the residual stand, and smaller gaps in the forest (reduces shock on shade-tolerant trees and less exposed soil). The CLR area is likely to experience a small delay in biomass accumulation and then, as the light-demanding and fast-growing species take advantage of the 'open' forest conditions, the rate of biomass accumulation will rise sharply, followed by a reduction as the fast-growing pioneer species' growth rates slow and they reach maturity. The rate of biomass accumulation at age 20 years may then approximate that of RIL. However, some studies indicate that if the damage or loss is around 50-60 percent, it is unlikely that the likely rate of accumulation will approximate that of RIL forests (Pinard *et al.*, 1995). The biomass storage or carbon accumulation depends on a number of factors including timber volume removed, distribution of the tree sizes (growth class) removed or destroyed, damage to the residual stand and response to the canopy openings (Pinard *et al.*, 1995).

At age 10 to 15 years, the CLR forest is likely to be logged for a second time (Figure 1). This results in less commercial biomass removed, smaller trees removed compared to the initial harvest, additional damage to the residual stems, loss or removal of many individuals in the lower canopy and further opening of the upper canopy with additional soil exposure. Following logging, there are less advanced individual stems and fewer understorey species on which to accumulate biomass. During the first 6-9 months after the second harvest, a large number of light-demanding, fast-growing, short-lived small-sized species, such as *Macaranga* spp., *Mallotus* spp., *Trema* spp. and *Alphitonia* spp. invade the open sites and dominate these areas for at least 20-30 years (Applegate, 1992; Lasco *et al.*, in press).

By age 40 years, the RIL area is likely to be harvested along with the CLR area. External factors influencing the cutting cycle for both types of logging include ease and cost of access to the forest, species and tree size demanded by markets and timber-processing technology.

The second logging in the RIL area is likely to result in a reduced commercial volume and a reduction in the average size of the trees harvested compared to the first harvest. Most large, mature trees of commercial value would have been harvested in the first cutting cycle, leaving those that are more uniform in size for the second and subsequent cutting cycles. The large over-mature trees with limited commercial log value at the time of first harvest are still non-commercial and if still standing, would be allowed to remain. At this time, the CLR forest would have been harvested three or four times with a likely reduction in log volume, greater damage to remaining stems and a reduced rate of recovery or biomass accumulation in the residual forest. Uhl *et al.* (1997) report that after 30 years, CLR results in a badly impoverished forest prone to fire and vine invasion and more closely resembling brushland. Hence in many locations, in the tropics, the forest will have been reduced to shrubland in 40 years. During each 10-15 year cutting cycle associated with the CLR operation, the forests can be characterized as having a reduction in forest biomass, more damage to the residual stand, a reduced seedling pool and stems in the advanced growth stage, a greater incidence of fire and the chance that the ecosystem will be reduced to shrubland and eventual grasslands with a biomass of 80 t/ha and 5-7 t/ha, respectively (Burrows, 1976). In places such as Southeast Asia, these grassland areas become dominated by *Imperata cylindrica*. The incidence of fire, which facilitates this process in places such as Indonesia, increases in times of severe drought associated with the El Niño event that occurs approximately every 4-5 years (Applegate *et al.*, in press). During the 1997/98 fires in Indonesia, where large areas of heavily logged forest were harvested and burned, conventional logging techniques were used. Many of the burned logged-over areas had an understorey cover of fast-growing, short-lived tree and shrub species dominating the site. The situation in many areas has worsened with further degradation of the sites towards grassland with fewer large live trees remaining for regeneration. In some situations, the whole process may be interrupted by conversion to another land use. This becomes more and more likely as the value of the residual forest decreases with each perturbation. Increased incidence of fire in logged-over forests has also been demonstrated in the Amazon by Uhl and Kauffman (1990); this has facilitated the degradation process.

Overall these results indicate that the incremental carbon benefits of RIL-based SFM may be significantly larger than previously assumed, particularly in the long run. It could be argued however that allowing these extra carbon benefits to qualify for credits may impede efforts to improve logging practices, given that more carbon could be sold under poor logging practices. One way to overcome the problem of perverse incentives would be to replace project-specific baselines with standardized baselines incorporating minimum standards. Furthermore, minimum standards could be improved over time, thus gradually reducing the prospect of selling extra carbon by following poor logging practices.

Additionality

Additionality means that projects have to demonstrate that improved management would not have occurred without the project. This could be done by showing that the project activity (i.e. RIL-based SFM) is financially less profitable than the business-as-usual scenario (i.e. CLR). Even if CLR is more profitable, additionality could be established if other barriers to the adoption of RIL-based SFM existed.

Available data on the financial profitability of RIL relative to CLR are inconclusive because:

- assumptions about CLR practices in most studies may not be representative of actual conditions in tropical forests;
- available studies differ as to the components included as RIL; and
- the relative profitability of RIL and CLR is sensitive to site-specific biophysical and socio-economic factors.

Given these caveats, we evaluate results from a few recent and fairly comprehensive studies. Two studies from Pará State in the Eastern Amazon in Brazil, indicate that RIL need not increase timber-harvesting costs and can even result in cost savings (see also Holmes *et al.* in this volume). Barreto *et al.* (1998) estimate that net receipts using RIL are 35 percent higher than CL. The increase in net receipts falls to 13 percent, however, when increased salaries of workers trained in RIL practices are taken into account. The net present value (NPV) of SFM (i.e. RIL plus silvicultural treatments) is 38 to 45 percent higher for SFM than for CL, for discount rates ranging from 6 to 20 percent. The NPV estimates do not, however, take higher salaries of trained RIL workers into account. Most significantly, when a CLR scenario is assumed with re-entry logging after 10 years, as is common in the Amazon (Uhl *et al.*, 1997), the NPV of RIL-based SFM is no different from that under CLR (Barreto *et al.*, 1998). Although re-entry logging would reduce timber volumes for the second cut, the discounted effect of the second cut on NPV tends to be much lower than that of the first cut (Boscolo *et al.*, 1998).

Another estimate (Holmes *et al.*, 1999), from the same area, shows that net receipts from RIL are 19 percent higher than for CL. This study may have underestimated the volume of timber commercialized under CL, because although it shows that trees felled under CL are larger than those felled under RIL, the profitability estimates assume a standard potential volume for CL and RIL, adjusted for wastage. Higher salaries for trained RIL workers and premature re-entry logging under CL are also not taken into account.

In contrast to the above studies that are relatively optimistic about RIL, a recent study from a dipterocarp forest in Sabah, Malaysia is consistent with the more widely held perception that the financial profitability of RIL-based SFM is lower than that of CL. Healey *et al.* (in press, see also Tay *et al.* in this volume) estimate that the NPVs of RIL-based SFM for a time horizon of 120 years, are lower than those for CL by about US$ 1 000 per logged hectare and by about US$ 2 000 per representative hectare (i.e. taking into account both logged areas as well as areas excluded from harvesting under RIL because of environmental considerations). In areas characterized by steep topography (as in Sabah, Malaysia), the net loggable area under RIL is drastically lower (44 percent lower than under CL in the study area). Logging intensity is also lower under RIL, giving a 22 percent reduction in yield per logged hectare. Resulting timber revenues are 132 percent higher under CL than under RIL (Healey *et al.*, in press), with the difference being due more to the areas excluded from logging under RIL, than from lower logging intensity. The lower commercial volume in the first harvest, together with the higher costs of implementing RIL, overwhelms the higher timber volume harvested under RIL in the second harvest, even when the second harvest volume is 31 percent higher than under CL. Healey *et al.* (in press) do not assume a CLR scenario (i.e. timber from re-entry logging is not taken into account). Arguably, for dipterocarp forests where premature re-entry logging is widespread, the financial benefits of CLR relative to RIL would be even higher, at realistic discount rates, although, as shown in Figure 1, timber-harvesting activities under CLR are likely to cease by the third or fourth harvest due to the total depletion of the commercial forest resource.

Overall, the above studies indicate that the profitability of conventional logging may be significantly higher than most previous estimates indicate when re-entry logging is taken into consideration.

Another notable conclusion that emerges from the above studies is the significance of the volume of timber commercialized, particularly in the first decade, as a determinant of financial profitability. Table 1 shows that in Pará, Brazil, where the NPV favoured RIL, timber volumes for the first harvest under RIL were 130 percent higher than under CL (Barreto *et al.*, 1998). In the dipterocarp forests of Indonesia and Malaysia, where the NPV favours CL, timber volumes were 43 to 65 percent lower (Pinard and Putz, 1996; Sist and Bertault, 1998). Waste reduction under RIL is clearly significant. Barreto *et al.* (1998) show, for example, that 7 percent of felled timber is wasted under CL due to bole splitting, bucking errors and lost logs. In their study area as much as 20 percent of volume felled under CL was not found. However, when exclusion zones (areas steeper than the legal limit specified in the regulations) under RIL are as high as in Sabah, Malaysia, the effect of foregone timber from exclusion zones overwhelms the effect of waste reduction.

Table 1. Timber volumes available for commercialization under RIL and CL

	CL	RIL	RIL as % of CL
Eastern Amazon Brazil (m^3/ha)[1/]	30	39	130
Asian dipterocarp forests			
Sabah, Malaysia (m^3/ha)[2/]	154	100	65
Sabah, Malaysia[3/] (timber revenues: $/ha)	6 761	2 913	43
East Kalimantan, Indonesia (m^3/ha)[4/]	56	28	59

[1/] Barreto *et al.*, 1998; [2/] Pinard and Putz, 1996; [3/] Healey *et al.*, in press; [4/] Sist and Bertault, 1998

The volume of timber is significant also because maximizing timber volumes is a key consideration for the timber industry. In many parts of Asia and Latin America, timber-processing capacity has expanded aggressively, while timber supplies have become increasingly scarce. In Indonesia for example, Scotland *et al.* (in press) estimate that a roundwood supply-demand imbalance of around 33 million m^3 exists, which is marginally higher than official roundwood production. Sizer and Plouvier (2000) attribute the increasing presence of Asian timber companies in Africa to the increasing log shortages faced by the timber industry in Asia. In Pará, Brazil, Holmes *et al.* (1999) report that log scarcity has increased delivered log prices to the timber shed by 10-30 percent and doubled the cost of harvesting rights between 1990 and 1995. The rapid expansion in the processing industry is attributed to bans on log exports and subsidies for forest conversion to agriculture and estate crops, which indirectly subsidized the timber-processing industry by providing cheap logs from conversion areas (Barr, 2000; Uhl *et al.*, 1997). Where enforcement is poor, illegal logs also provide artificially cheap supplies to processing industries (Scotland *et al.*, in press).

One more feature worth pointing out is that in vertically integrated companies (as is common in both Asia and Brazil), 78 percent of net receipts come from processing, while logging accounts for only 22 percent (Verissimo *et al.*, 1992). This implies that increases in the efficiency of logging under RIL or even small increases in the profitability of logging are likely to be overwhelmed by the need to ensure adequate log supplies to the processing industry to avoid foregoing processing profits. This is likely to exacerbate the opportunity cost of adopting RIL significantly, particularly in areas where RIL volumes are considerably lower.

Even in regions where volumes during the first harvest are higher under RIL, a number of barriers to adoption of RIL are likely to exist. Among them are delays due to planning or suspension of operations under wet weather, the need to invest in equipment required by RIL, lack of training and technical knowledge about RIL and tenure insecurity (Putz *et al.*, 2000; Barreto *et al.*, 1998).

Thus, in spite of data inadequacies, the above studies indicate that it should be possible to establish the additionality of RIL-based SFM carbon projects.

Leakage

Leakage implies that if improved management within the project area results in an increase in emissions outside project boundaries, these new increased emissions are deducted from the credits earned by the project. Leakage is likely when project activities reduce log output, with no alternative activity taking its place. People are then likely to shift the activity to a location outside project boundaries. Negative leakage can also take place, if the RIL carbon project leads to the spontaneous adoption of RIL outside project boundaries. Emission reductions resulting from this should then be credited to the carbon project.

Leakage resulting from SFM projects supported by carbon revenues is likely to be highest in areas where timber volumes in the first couple of decades are lower than under CLR and processing capacity exceeds sustainable log supplies. In these areas, depletion of timber supplies often creates pressures for illegal logging and increasing exploitation of timber resources abroad. SFM projects that reduce timber harvests could add to these pressures and thus result in leakage. Enterprises, for instance, are unlikely to allow earnings to fall by reducing the volumes processed. Instead they are likely to attempt to maintain earnings by using up processing and logging capacity by carrying out compensatory logging in areas outside project boundaries or even in other countries, as has occurred in the case of Asian firms operating in Central Africa (Sizer and Plouvier, 2000). Where enforcement capacity is weak, SFM projects could exacerbate illegal logging. Informal logging teams could be financed, for example, to log in national parks, which is a common practice in Indonesia today (Scotland *et al.*, in press). Faced with reduced log supplies, the timber industry could also lobby for increases in the area allocated for conversion to agriculture, which usually includes automatically the right to log the area before conversion. Barr (2000), for example, argues that this has occurred in Indonesia.

Exclusion zones under RIL would also reduce employment opportunities. Verissimo *et al.* (1992) estimate, for example, that every 5 ha of forest logged in Pará, Brazil, provide employment for one person. Leakage could result if labourers are compensated for reductions in employment earnings by activities that degraded forests, such as forest conversion to agriculture.

If the reduction in timber volumes under RIL-based SFM is sufficiently large to drive up prices (which arguably could occur if a large number of carbon RIL projects were implemented) it could stimulate logging in areas that were previously not economically viable. The potential magnitude of leakage from this effect would depend on the extent to which timber prices are responsive to declines in timber volumes as well as the extent to which expansion in logging is driven by timber price increases, as opposed to other factors, such as road construction. Leakage would be reduced in the longer run, if higher timber prices resulted in replacement of timber by substitutes for certain uses.

The above examples highlight situations where policy makers, CDM rule-makers, project developers and certifiers need to be alert to the potential for leakage and take measures to control it. Policy changes, such as removing subsidies for the processing sector, could reduce the potential for leakage. RIL projects in areas where commercialized volume is likely to be significantly lower under RIL, could include a component for plantations supported by carbon revenues, to make up for shortfalls in log supplies (Smith, in press). Technologies for further improving waste reduction and increasing log utilization under RIL could help to reduce leakage. Alternative income opportunities could also be developed for communities, to compensate them for employment losses resulting from exclusion areas.

While leakage could be significant where RIL reduces harvested timber volumes, negative leakage is a possibility where RIL results in increased timber volumes. Given the importance of timber volumes in determining the profitability of vertically integrated industries, companies outside the project area may voluntarily adopt RIL even without carbon revenues from a CDM project. This would increase the carbon credits earned by the project. Adoption of RIL alone need not, however, preclude other unsustainable practices like premature re-entry logging. Thus, the scope for negative leakage is likely to be limited unless projects are focused in regions with policies and institutions supportive of SFM.

Project duration and the risk of project failure

Project duration is relevant for carbon accounting in forestry projects because carbon is sequestered or stored only while the forest or its harvested products exist. In contrast, substituting clean energy for fossil fuels prevents emissions from entering the atmosphere in perpetuity. Since forestry projects will be used as a substitute for emission reduction, carbon accounting methods are required to make credits from forestry projects equivalent to credits from clean energy projects. There is as yet no agreement on methodologies to take account of project duration, but it is highly likely that short duration projects will earn carbon credits at a significantly lower rate relative to longer duration projects. Estimates indicate that taking account of project duration could increase the cost of many medium duration projects of around 20-30 years by 50 percent or even several fold (IPCC, 2000).

While RIL-based SFM is by its very nature a long-term concept, investors may not be willing to commit to long duration projects, particularly where the risk of project failure is high. Even though carbon projects would compensate forest managers for the opportunity cost of adopting RIL-based SFM, in many cases the reasons SFM does not occur are not always financial. Project failure is likely in cases where CDM projects are unable to address the underlying causes of unsustainable logging (Smith *et al.*, 2000). Examples are situations where forest ownership and use rights are subject to frequent disputes as occurs in Brazil (Barreto *et al.*, 1998) and Indonesia (Scotland *et al.*, in press), or where the opportunity cost of forested land is increasing due to agricultural subsidies or the construction of development or logging roads into forested areas. The risk of project failure from human-induced fires is likely to be particularly high where incentives for conversion of forests to estate crops are high and fire is seen as an economical means of land clearing. This phenomenon was partly responsible for the fires in Indonesia in 1997 (Applegate *et al.*, in press). Thus, longer duration, and therefore more cost-effective projects, are more likely to be possible in areas where policies and institutions are conducive to SFM.

Cost-effectiveness

The price of carbon in a fully-fledged market is still highly uncertain, because CDM rules have yet to be fully determined. Grubb *et al.* (2001) review a range of models that estimate the price of carbon without participation of the United States. These models probably also represent the closest available approximation to recent developments on issues such as the role of carbon sinks in industrialized countries and EU emission levels. Their review concludes that indicative prices could range from US$ 25/tC to US$ 75/tC. Prices are probably likely to be closer to the lower end of this range for several reasons. First, the higher end of this range assumes that emission reductions resulting from economic decline (as has occurred in the former Soviet Union) would have to be reinvested in emission reduction projects, thus increasing demand for carbon projects. This has not yet been agreed. Secondly, they assume that non-carbon gases are as costly to reduce as carbon dioxide, although they are in general much cheaper to control (Grubb *et al.*, 2001). Thirdly, these estimates ignore land-use change projects in developing countries, although it is now known that reforestation and afforestation projects will be included in the CDM (IISD, 2001), thus making the supply larger than assumed in the models.

In an unrestricted market with numerous buyers and sellers, all projects that can supply carbon at a cost lower than the market price should be cost-effective. However, the surplus accruing to project partners will be low for projects whose costs are close to the market price.

Healey *et al.* (in press) provide the most comprehensive estimates of cost-effectiveness, although they too ignore premature re-entry logging in the baseline. While this implies that carbon sequestration benefits may have been underestimated, it also implies that the opportunity cost of adopting RIL-based SFM may have been underestimated, particularly under realistic discount rates.

Given these caveats, Healey *et al.* (in press) estimate that at discount rates of 4 to 10 percent, the opportunity cost to the timber industry of adopting RIL in Sabah, Malaysia, would range from US$ 33/tC to US$ 42/tC. If, as we argue, the lower end of the range reported by Grubb *et al.* (2001) is more realistic, the cost-effectiveness of these projects remains doubtful.

The estimates by Healey *et al.* (in press) also exclude a number of cost categories which carbon projects will have to incur. These include the transaction costs of doing business in carbon markets, such as project development, marketing and certification costs, the costs of negotiating with project partners and host-country governments and the cost of monitoring and verifying carbon emissions. These costs could be substantial. The Noel Kempff forest protection carbon project in Bolivia, for instance, is estimated to have spent around US$ 750 000 on project development and institutional support to the Bolivian government and has allocated US$ 1.7 million for monitoring and verification of carbon emissions over 30 years (Nigel Asquith, unpublished data). Monitoring costs are likely to be higher for forest management projects than for forest protection projects, given that the incremental carbon benefits are likely to be lower and therefore a higher level of precision would be required.

In cases similar to Sabah, Malaysia, where commercial volumes are substantially lower under RIL, carbon credits are also likely to be lost due to leakage, thus further eroding cost-effectiveness.

Healey *et al.* (in press) also assume a project time horizon of 120 years. As pointed out earlier it may not be realistic to expect investors to commit for such long periods, particularly in areas where political and economic risks increase the possibility of project failure. In such cases, carbon credits would be earned at a lower rate, thus also reducing cost-effectiveness.

Healy *et al.*'s results from Sabah, Malaysia, are in contrast to those of Boscolo *et al.* (1998), who estimate a cost of under US$ 5/tC for the same study site. It should be pointed out, however, that the results of Boscolo *et al.* (1998) are based on a range of *ad hoc* cost estimates of RIL practices. More significantly, their results do not take into account lower timber volumes under RIL due to exclusion areas and lower logging intensities. Their results are useful, however, because they imply that RIL projects may be cost-effective, where timber volumes in the first cut (or arguably in the first decade) are comparable under RIL and CLR. This could occur, as the results of Barreto *et al.* (1998) show, in forests where few areas need to be excluded from logging under RIL and where levels of wood waste under CLR are high. As indicated earlier, leakage is also likely to be lower under these circumstances. The likelihood of real long-term improvements in management could be increased in these areas by embedding projects in an integrated program to create a supportive environment for SFM, including measures such as tenure security, control of illegal logging and increased information and training (Smith, in press).

ENVIRONMENTAL AND SOCIAL CO-BENEFITS

According to the Kyoto Protocol (UNFCCC, 1997) CDM projects should help host countries "achieve sustainable development". Although sustainable development is not defined, it is usually loosely interpreted to imply that CDM projects should have beneficial environmental, social and economic impacts and be consistent with priorities of countries hosting CDM projects and with commitments under other international environmental agreements (IPCC, 2000). Whether or not CDM projects adequately contribute to sustainable development will be determined by host countries (Pronk, 2001). Criteria may therefore vary considerably from country to country.

Biodiversity

Putz *et al.* (2000) argue that biodiversity conservation in the tropics can be enhanced by using well-managed timber production forests as a supplement to forest reserves, given that national parks are insufficient on their own to conserve the diversity of the world's tropical forests.

One way to reduce the environmental impact of timber harvesting is to focus on stand- and structure-based indicators, including structural complexity, species composition, connectivity and heterogeneity (Lindenmayer *et al.*, 2000). This is possible if the emphasis is placed on four areas: 1) establishment of biodiversity priority areas, 2) application of improved conservation measures within production forests, 3) multiple-use goals and scales to spread risk in production forests, 4) adaptive management to test the validity of structure-based indices of biological conservation by using management practices as experiments.

The last three are encapsulated in the principles involved in improved harvesting practices developed in many tropical countries as codes of practice and RIL guidelines and principles as outlined by Dykstra (1996), APFC (1999) and Applegate and Andrewartha (2000). Thus, RIL-based SFM projects have the potential to provide environmental co-benefits.

Social co-benefits

Some RIL guidelines also reduce the negative impact of CLR on local communities. Shanley *et al.* (2000) show, for example, in Pará, Brazil, that 15 of the species which provide the non-timber forests products (NTFP) most highly valued by local communities, are also species targeted by loggers. RIL should help to safeguard these species at least in exclusion areas. The importance of exclusion areas in safeguarding NTFPs is consistent with the findings of Healey *et al.* (in press). While the value of the rattan harvest was very similar for RIL and CL in logged areas in Sabah (Malaysia) it was US$ 257/ha higher for RIL when both logged and unlogged areas were taken into consideration.

Shanley *et al.*'s findings (2000) indicate that premature re-entry logging also affects the availability of NTFPs. After about a decade of repeated logging episodes and fire, they found a drastic drop in average volumes of NTFPs, such as game, fruit, and fibre, which were important for the nutrition and health of the rural and urban poor. NTFP harvests declined not only because of the removal of trees providing NTFPs, but also due to collateral damage to other trees, as well as seedling destruction and soil compaction. CL also impeded access to NTFPs and agricultural fields because felled trees, flooding and thick secondary growth obstructed passage through the forest. Thus, a number of RIL guidelines that reduce the area disturbed, reduce damage to non-target species and reduce post-logging environmental damage also provide social benefits. While the greatest social benefits will probably result from exclusion areas, a number of other RIL guidelines could also help to safeguard local livelihoods.

CONCLUSIONS

The Clean Development Mechanism (CDM) of the Kyoto Protocol raised the hopes of many, that payment for carbon sequestration services would provide a significant incentive for sustainable management practices in industrial forestry in tropical countries. Data to assess how realistic these hopes are, remain scant. Also a high degree of uncertainty about CDM rules makes any assessment hazardous. Subject to these caveats, our analysis shows that:

- Expectations about the contribution carbon projects could make towards inducing sustainable timber harvesting should be scaled down. This is partly because even if tropical forest management qualifies for credits after 2010, CDM implementation rules are likely to place limitations on the use of forest management projects for meeting emission reduction commitments. It is also because the cost of RIL-based SFM projects may be higher than previous estimates indicate. This is because while most studies assumed a permanent forest estate is maintained under conventional logging we argue that a more realistic conventional logging scenario is repeated timber harvesting at short intervals, leading to degradation of logged areas into shrubland and grassland. While this scenario increases the potential carbon and other environmental benefits from RIL projects in the long run, it also increases the opportunity cost of adopting RIL-based SFM, particularly in the short term. Previous estimates also ignored the transaction costs of operating in carbon markets and the risk of project failure.

- The cost-effectiveness of RIL-based SFM projects is likely to be highly site-specific. RIL projects are unlikely to be cost-effective where steep topography and high biodiversity values result in logging being excluded in a high proportion of the forest management unit. This reduces the commercial volume of timber harvested in RIL relative to conventional logging and raises the compensation required by the timber industry to adopt RIL, because ensuring adequate log supplies for timber processing mills is a key determinant of the profitability of vertically integrated timber companies.

- RIL projects should be targeted to areas where timber volumes under RIL are similar to volumes under conventional logging with repeated harvesting at short intervals. This is particularly important during the first two decades after logging. In these areas, if projects are part of an integrated package of measures to support sustainable management, there could be a possibility of real long-term improvements in logging practices. Measures could include for example, ensuring tenure security, resolving land conflicts, reducing illegal logging, supporting certification and addressing market failures, such as the lack of information about the benefits of RIL and training in RIL practices.

- Pro-active measures could also be taken to expand the niche for RIL projects and reduce the risk of leakage and project failure. Demarcation of timber-harvesting exclusion zones, as indicated in many codes of practice for improved timber harvesting in the tropics, draws on the guidelines of the Biodiversity Convention's ecosystem approach. This could provide leverage for supporting funds from multilateral agencies, such as the Global Environment Facility, or from conservation agencies, to compensate for the reduction in timber volumes resulting from exclusion zones. CDM RIL projects could include a CDM-supported component for plantations to compensate for log supply shortfalls. Technologies for further reducing waste and increasing log utilization under RIL could increase timber volumes under RIL. Reduction of subsidies to the processing sector would help to reduce processing demand. Subsidies include not only direct subsidies, such as soft loans, but also hidden subsidies, such as cheap log supplies resulting from log-export bans, illegal logging and deforestation.

- CDM RIL projects should not be perceived as a "silver bullet" for inducing sustainable management and preventing forest degradation. If targeted carefully and embedded in an integrated program of policy reforms they could, however, considerably enhance the effectiveness of more conventional approaches, while also contributing to climate change mitigation and biodiversity conservation. Pro-active measures could also be used to expand the niche for CDM RIL projects.

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