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Logging and conservation: Economic impacts of the stocking rates and prices of commercial timber species

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ABSTRACT

Tropical forests vary greatly in their stocking rates of timber and the commercial value of the different tree species they contain. This significantly affects the economics of logging and, consequently, the viability of carbon payments to aid in the conservation or management of the world's forests. In this paper we first develop a conceptual model to investigate how theoretical opportunity costs and the conservation potential of carbon payments vary across forests with stocking rates and species composition. We focus the model on two possible conservation contexts: 1) strict protection of unlogged forests and 2) conservation of selectively logged forests. Results suggest that the type of forest, with regard to both timber volume and species composition, greatly affects the potential of a carbon payment to mitigate forest degradation. Additionally, two complementary insights emerge. First, in forests where timbers of high commercial value represent only a small proportion of total wood volume (and therefore carbon), selective logging may make conservation of the wider landscape more feasible, and cost-effective. Second, in forests where selective logging of highly-prized species has already occurred, engaging in long-term conservation of forest (and hence thwarting conversion to agriculture) may make the conservation of biodiverse landscapes more feasible, and their management more cost-effective.

1. Introduction

Here are some related truths that are not new. 1) Tropical forests, which contain over half the world's terrestrial species (Myers et al., 2000), are disappearing at an alarming rate. In the 1990s the global deforestation and degradation rate of these forests was roughly 8.1 million ha/year (Achard et al., 2002). 2) A recent study has shown that tropical deforestation is responsible for ~12% of anthropogenic greenhouse gas emissions (Van der Werf et al., 2009). 3) The significant role of tropical deforestation in global GHG emissions has led to the development of the potential emissions-trading mechanism known as REDD+ (Reducing Emissions from Deforestation and Forest Degradation) — incentivizing conservation or more sustainable logging techniques in order to reduce emissions of greenhouse gases (Sasaki et al., 2011).

In light of these related truths there is a search for win–win scenarios for tropical biodiversity and climate change mitigation, where tropical forests are protected, conserving both the species and carbon within them, and leading to a reduction in carbon emissions (Miles and Kapos, 2008; Gardner et al., 2009). However, the prospect of a win–win depends, in part, on a cost–benefit calculation with a clear understanding of the costs and benefits and of who realizes them. A simple framing of this issue might be: Do the benefits of REDD+ exceed the foregone benefits of logging or forest conversion? This question is complicated for many reasons, not the least being that tropical forests vary greatly in tree species composition and commercial timber volume, significantly affecting the economics of logging. At one extreme, there are tropical forests with a relatively small number of highly-valued timber species, such as some South American forests where mahogany (*Swietenia macrophylla*) or ipe (*Tabebuia serratifolia* and *Tabebuia impetiginosa*) are the primary targets (Kometter et al., 2004; Schulze et al., 2008). At the other extreme, there are tropical forests with a large number of commercially valuable species, such as the dipterocarp-dominated lowland rainforests of Southeast Asia (Fisher et al., 2011b). Additionally, the drivers of deforestation and subsequent land uses vary across the globe such that the offsetting the full opportunity cost of conservation may be feasible in some forests where the economic returns to logging and agriculture are low (Fisher et al., 2011a), but not in other forests

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where returns are high (Butler et al., 2009; Venter et al., 2009; Fisher et al., 2011b).

In this paper we explore how the differences between forests in stocking rates and price values of commercially traded species are likely to affect the feasibility of REDD+ schemes. We use 'profit' as the metric for which we will judge the feasibility of conserving and managing forests under REDD+ as opposed to other uses. Profit is the net gain (benefits–costs) a landowner or concession holder can make off of a given parcel of forest. We chose this metric for three reasons: 1) it holds with the economic model that a risk-neutral, rational decision-maker will undertake an activity (here logging) until the costs outweigh the benefits, (e.g., proxy for minimum compensation see Olschewski et al., 2005); 2) it can be easy to calculate with adequate forestry data; and 3) it can serve as a proxy for the opportunity cost of conservation (i.e., the foregone benefits of exploitation given the decision to conserve; see Rival, 2010; Fisher et al., 2011b for examples).

We first develop a conceptual model to investigate the opportunity cost of completely protecting or actively managing forests and then explore how carbon payments affect this opportunity cost. We investigate two management possibilities: (1) complete protection and (2) selective logging. We look at these two possibilities in two forests with very different stocking densities and timber values of commercial species — one forest where only a few large and highly prized species exist per unit area (i.e., low volume and high commercial value) and one forest where many large, but cheaply priced species exist per unit area (i.e., economic return is more a function of volume than species composition).

We then use recent data from logging operations in dipterocarp-dominated tropical forests in Southeast Asia to understand the opportunity cost of conservation and to investigate how carbon payments might compare to the cost of conservation under scenarios of strict protection and selective logging. Given the paucity of actual data available at the present time, our goal is not to offer specific recommendations for specific types of forest, but rather to provide a framework for understanding the potential cost of conservation in tropical forests.

2.0. Methods

Our theoretical model is based on empirically derived marginal cost and marginal benefit curves from two example forests (Fig. 1). First, logging data from the mid-1990s in the Chimanes Forest, Bolivia (Howard et al., 1996) are used to derive the marginal-benefit curve (dashed line) of a forest where a few highly prized species are sought.

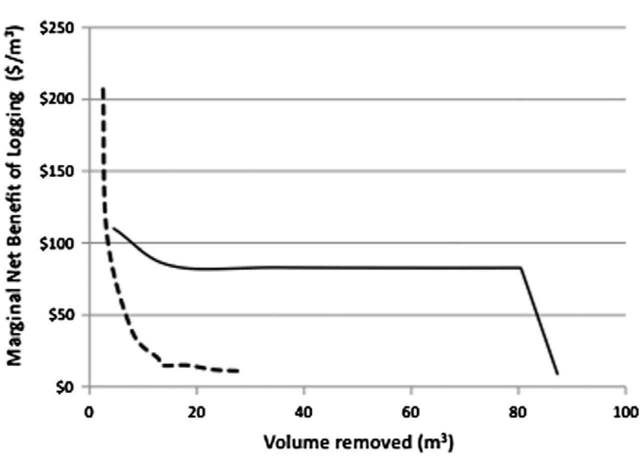

Fig. 1. Example marginal net benefit curves of logging in a) forests where there are a small number of highly prized timbers per unit area (dashed line) [data from mahogany logging Chimanes Forest, Bolivia, Howard et al., 1996], and b) forests where returns are driven mainly by volume not species type (solid line) [data from Sabah, Malaysian Borneo, Fisher et al., 2011a].

Hereafter, we call a forest with this type of marginal benefit curve a *prized-species forest*, signifying that the volume of sought after species is low, but of high commercial value. The data show that the top eight most commercially viable species yield roughly 28 m^3 ha^{-1}. However, it is the three higher-class species (*S. macrophylla*, *Cedrela* sp., *Astronium macrocarpon*), representing a yield of ~8 m^3 ha^{-1}, that return the greatest marginal benefit, with mahogany (*S. macrophylla*) dominating these returns. We can see that the marginal benefit curve flattens out abruptly and much of the logging yields very low net marginal gains (see Howard et al., 1996 for detailed species and economic data).

Second, data compiled across Southeast Asian dipterocarp forests serve as a model for our second example forest (solid line) (Fisher et al., 2011b). Herein, we call the type of forest that returns a marginal benefit curve of this shape as a *volume-based forest*. Across the eight species categories, only Selangan Batu (*Shorea* sp.) shows a differential marginal net benefit (marginal benefit–marginal cost) compared to the bulk of the data set (see Table 1). It is only once we reach a logging extraction pressure of about 85 m^3 ha^{-1} that the net returns fall steeply below ~\$80/m^3, due to market returns to the least desirable species. Using these two forest models we explore the interactions between logging costs, market returns and potential carbon payments.

2. The model

The economic benefit of harvesting timber from a given forest in its basic form is a function of the volume of timber removed, the price paid for the timber and the cost of extraction, such that:

$$\mathbf{R} = \sum \mathbf{V_i} * \mathbf{p_i} - \mathbf{c}$$

where **R** is the profit from logging; **v** is the volume removed of species **i**; **p** is the price of timber of species **i**; and **c** is the cost of extraction. This holds for the returns to logging a given forest and the profit on a given species within that forest.

We can think of two general functional forms for the cumulative gross returns of logging a forest (ignoring costs momentarily). The prized-species forest, has a cumulative profit function X(x) where $X'(x) > 0$ and $X''(x) < 0$ [where ′ and ″ are the first and second derivatives]. The volume-based forest, has a cumulative profit function Y(y) where $Y'(y) > 0$ and $Y''(y) = 0$ (Fig. 2a).

The shapes of the curves in Fig. 2a are a function of the volume removed and the price of the removed timber. The economic returns of the prize-species forest is driven by a few key species that are much more valuable than others (see Fig. 1). The constant slope of volume-based forest could net roughly the same value, or it could result from stocking rates (volume) and market prices being inversely related, thereby giving a uniform incremental gain in profit as volume increases. The dipterocarp-dominated forests of Southeast Asia resemble volume-based forests as do single species tree plantations (see Fig. 1).

Table 1
Species, cost and benefit data for logging lowland diptercarp forest in Southeast Asia to derive marginal net benefit of logging.
Derived from Fisher et al. (2011a), Edwards et al. (2011a), Ruslandi et al. (2011).

Species	Cumulative volume (m^3)	Gross returns (\$/m^3)	Total costs (\$/m^3)*	Marginal net benefit (\$/m^3)
Selangan Batu	4.49	179.95	61.06	118.89
Kapur	15.27	154.29	63.59	90.69
White Seraya (Urat mata)	35.42	153.11	68.34	84.77
Red Seraya (Seraya merah)	62.68	152.81	74.75	78.06
Yellow Seraya (Seraya kuning)	73.36	152.81	77.26	75.55
Keruing	80.28	152.81	78.89	73.92
Melapi	80.47	152.52	78.93	73.58
Other species	87.25	79.00	80.53	xxx

* Total cost as a function of volume removed.

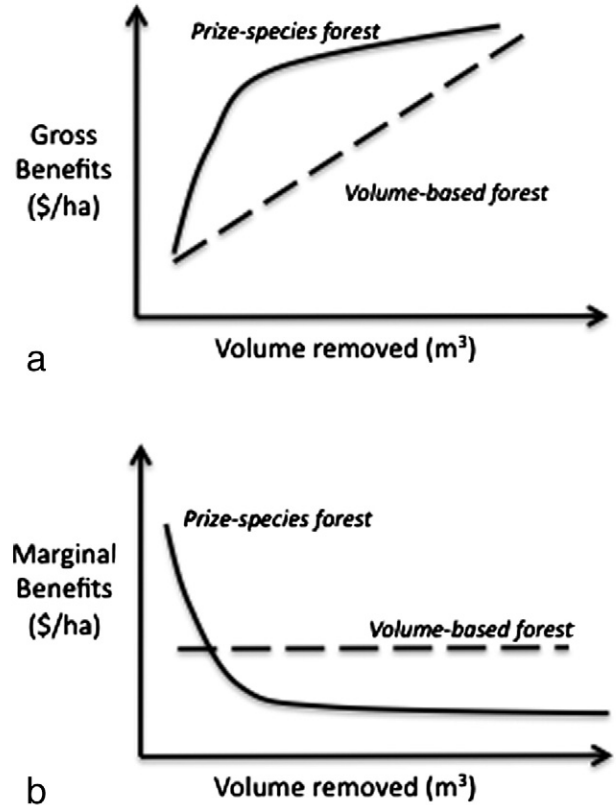

Fig. 2. a) Gross returns to logging ($/ha) as a function of volume of timber removed (m^3) for forests of two different species compositions. b) Marginal benefits of logging ($/ha) for forests of two different species compositions.

Economists are generally concerned with marginal costs and benefits, such that a rational, profit-driven landowner should stop logging when the marginal benefit equals the marginal cost. The marginal benefit curves for both types of forest are shown in Fig. 2b. Here again, it is easy to see that in the prized-species forest, the removal of the first units of wood returns the biggest gain. We also see that in the volume-based forest each additional cubic meter of timber removed returns the same benefit.

These marginal benefit curves are important because, when combined with marginal cost curves, they tell us where it is no longer profitable to log. In Fig. 3 we add a marginal cost curve to Fig. 2b. We illustrate a positive-sloping cost curve (dotted line), a typical case wherein it gets more expensive to remove each addition cubic meter of timber. This could be the case if additional roads are required or if logging operations move onto increasingly steeper slopes or difficult terrain. Now there are two points of interest in Fig. 3. V_x tells us at what point logging should cease in a prized-species forest, since this is the point where the cost of additional logging starts to exceed the benefit. V_y tells us where, under accelerating costs, logging should cease in a volume-based forest.

2.1. Protection of unlogged forests

We are now in a position to analyze how such cost–benefit relationships interact with both the decision context and species compositions of the forest. First we consider the opportunity cost of fully protecting an unlogged (primary) forest. From the viewpoint of a conservation organization, the opportunity cost of conservation is an indicative estimate of what it might have to pay a landowner to forego logging. Conversely, from the viewpoint of the landowner, this would be their lost profit by not logging. This means that the difference between the gross benefit and the cost would have to be offset. In Fig. 4a and b this financial offset is represented by the area between the marginal benefit curve (black line) and the marginal cost curve (dashed line).

The costs in this example are the standard logging costs: cutting, road building, skidding, royalties, concession fees, etc. What might a carbon market do to this situation? REDD+ would, in essence, move the marginal cost curve up. By logging a given forest, the actor gives up the benefit of a carbon payment. A foregone benefit is a cost, and therefore the cost of logging each cubic meter increases by the amount that could have been received through a carbon payment.

Fig. 4a and b shows that with a REDD-type program, the marginal cost curve shifts up such that the opportunity cost of conservation

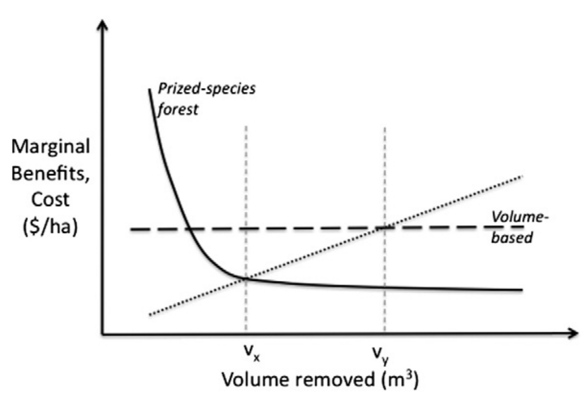

Fig. 3. Marginal benefit curves for prized-species forests (solid line) and volume-based (dashed line) and marginal cost curves cost (dotted line). Showing points where the marginal benefits equal the marginal costs (v_x and v_y).

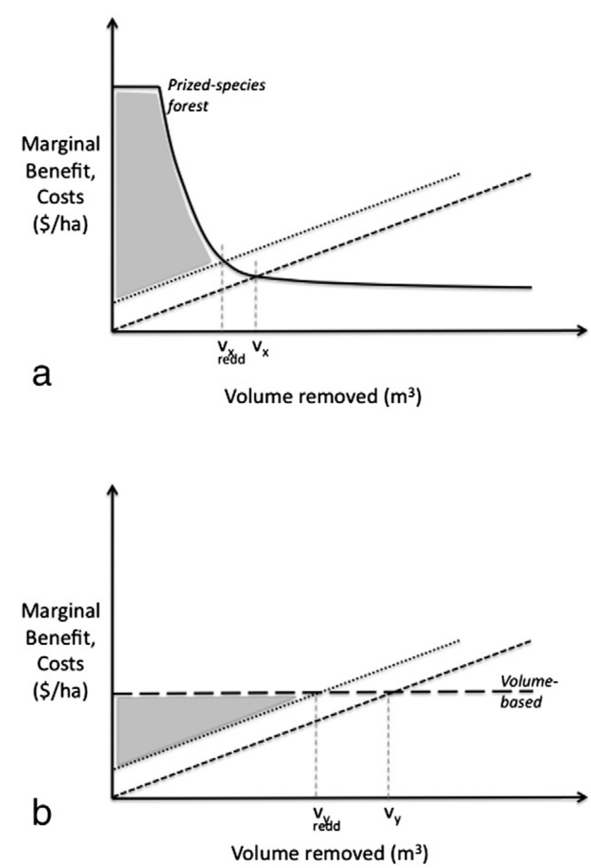

Fig. 4. a) Marginal benefit and cost curves showing the opportunity cost of full protection for prized-species forests with potential carbon payment (shaded area) and without (area between dashed line and solid line). b) Marginal benefit and cost curves showing the opportunity cost of full protection for volume-based forest with potential carbon payment (shaded area) and without (area between dashed line and long dashes).

becomes the shaded area (i.e., the area between the REDD+ cost curve [dotted line] and the marginal benefit curves). The key question is how far up do the cost curves shift? Knowing this allows us to predict at what point it becomes cost ineffective to continue logging. Similarly, if we know what the marginal cost and benefit curves look like, we can determine the carbon price that would make preservation competitive with logging.

2.2. Selective Logging

We now consider the theoretical opportunity cost of a conservation strategy that allows for selective logging. (We discuss the role of reduced-impact logging in the Discussion section). Fig. 5a shows how allowing selective logging affects the potential opportunity cost of conservation in our prized-species forest. Represented graphically, selective logging is allowed up to the vertical line at v* (arbitrarily drawn above the inflection point of the marginal benefit curve). Again we can see that the theoretical opportunity cost to conservation is the area between vertical line at v*, the marginal cost curve and the marginal benefit curve (gray + black area). Likewise, a carbon payment mechanism that allows selective logging increases the cost of logging (dotted line) and therefore reduces the opportunity cost in the model (black area).

In Fig. 5b, we assume that some minimum diameter-cutting limit is applied (V*) to a volume-based forest. Therefore, with much of the timber removed, the theoretical opportunity cost of conservation is represented by the area between the vertical v* line, the marginal benefit line and the marginal cost line (gray shaded area + black area). Again we see that a carbon payment increases the cost of logging, such that the marginal cost curve shifts up (dotted line) and the opportunity cost of conservation decreases (black area).

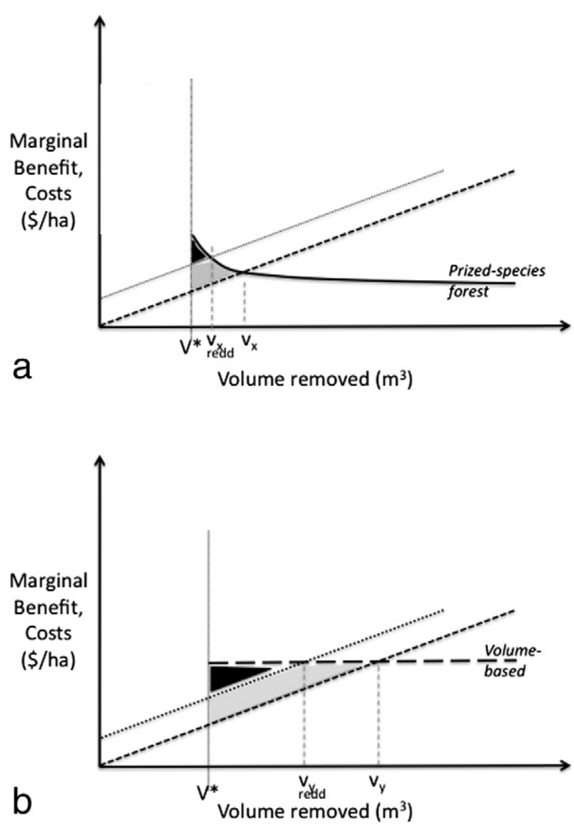

Fig. 5. a) Marginal benefit and cost curves showing the opportunity cost under selective logging regime for prized-species forests with potential carbon payment (black area) and without (black and shaded area). b) Marginal benefit and cost curves showing the opportunity cost of under selective logging regime for volume-based forest with potential carbon payment (black area) and without (black and shaded area).

2.3. Logging dipterocarp forests

In order to ground our conceptual understanding of the economics of logging rainforests, we flesh out the conceptual model with real data from logging in the lowland rainforests of Southeast Asia. We use published estimates of the costs and benefits of logging in diptercarp-dominated forests across Southeast Asia (Edwards et al., 2011a). These data were synthesized from 25 studies from across the region.

Yields are highly variable, ranging from 25 m^3 in Sarawak, Borneo to 205 m^3 in the Philippines. The mean across these studies is 87 ± 8.8 m^3 ha^{-1}. We then distributed this total volume across the seven most-extracted species plus a general category based on the ratios from an in-depth study of over 300,000 ha of logging concession data from Malaysian Borneo (Fisher et al., 2011b). (We are assuming that the relative volumes of the tree species in our study site in Malaysian Borneo hold true in other parts of Southeast Asia, but we currently lack the data to test this assumption). Data from the meta-study present yields from operations with 50–60 cm DBH cutting limits and ignore the reality that in many cases the cutting limits are lowered and there are often multiple entries (see Edwards et al., 2011b). The cost data come from two studies that investigate the net benefits of logging in these forests (Fisher et al., 2011b; Ruslandi et al., 2011). The costs are averaged here to even out the differences in the two studies.

To estimate the potential for REDD+ to close the gap between logging and conservation we used modeled emissions data for total carbon released during logging operations of various intensities (Pinard and Cropper, 2000). With these data we can estimate a carbon emission rate per cubic meter of timber removed.

3. Results

Exploration of the static model (Figs. 1–4) allows us to draw a few general conclusions. We see that if our goal is to fully protect an unlogged forest (Fig. 4a,b), the opportunity cost will be larger, regardless of the shape of the marginal benefit curve, relative to a decision to allow selective logging. The decision to allow selective logging reduces the opportunity cost. Here we can also see that both the full opportunity cost and the part that can be compensated by a carbon payment will depend on the economic profile of the forest (that profile being made up of both the total volume of each commercial species in the forest and the price of individual species) (Fig. 5a,b). The result is that if logging is allowed in a currently unlogged forest, the opportunity cost drops more precipitously for forests with a few highly prized species than for forests having many equally valued species, all other things being equal (e.g., operation costs, gross rent).

The model also demonstrates just how many data are needed to fully understand the economic tradeoffs involving conservation, logging, and management of forests. An accurate model requires a clear understanding of: (1) the returns to logging across the forest composition; (2) the marginal costs incurred in a logging operation; (3) the carbon emissions from the logging operation; and (4) an understanding of the carbon market itself (how carbon contracts and payments are operationalized). Moreover, the economic tradeoffs should be appreciated in light of the ecological tradeoffs, which require additional data on the impact of logging on biodiversity and ecosystem services, a topic we do not address in this paper but have addressed elsewhere (Fisher et al., 2011c).

Due to the amount of data needed to empirically explore the model, we are only able to do so for the volume-based forest. Here we can show two results. First, since we have marginal cost and benefit curves, we can estimate the theoretical opportunity cost of our first decision context: protecting an unlogged forest. In Fig. 6, the area between the marginal benefit curve (solid black line) and the marginal cost curve (long dashes) represents the opportunity cost which a conservation organization attempting to preserve an unlogged forest might face. Under the assumptions made here, this opportunity cost equates to ~\$7000/ha.

Second, since we have an understanding of the carbon emissions over a range of extraction rates in dipterocarp-dominated forests (Pinard and Cropper, 2000), we can investigate how a carbon payment might change this opportunity cost. We use a 5 year mean ($\pm$1 SD) European Trading Scheme (ETS) price point for carbon [ETS spot prices from Oct 2008–Jan 2013 − 5 year mean = \$15.60 $\pm$ 5.60/ton CO_2].

The 5 year mean carbon price cannot overcome the full opportunity cost of conservation in dipterocarp-dominated forests in Southeast Asia (at least up to ~85 m^3 removed per hectare, i.e., where the marginal cost curve crosses the marginal benefit curve) (Fig. 6). However, the variability in the ETS market (light gray-1 SD-error bars) suggests that when the carbon price is high, offsetting the opportunity cost is possible. While the current ETS spot price is at historic lows (~\$5.50/tCO_2 accessed April 2013), a functioning carbon market does move the cost curve closer to the marginal benefit curve and therefore goes some way towards mitigating an opportunity cost.

We can push this point further and calculate the carbon prices at which a certain level of opportunity cost might be compensated. Due to the fact that the marginal benefit curve is relatively flat (Fig. 6) there is little sensitivity to the carbon price. As such, it would take a payment of \$35/ton CO_2 (in 2009 US\$) to meet the opportunity cost of not logging 95% of the volume. For comparison, the April 2013 ETS price point for CO_2 was ~\$5.50/ton (Table 2.) While we do not have data to perform the same analysis for a prized-species forest, we can infer that covering the opportunity cost there is much more sensitive to a carbon payment, ceteris paribus.

4. Discussion

We set out to examine how different types of forests, with regard to both their stocking rates and differences in commercial timber species values, affect the opportunity costs of protection from logging under two conditions: (1) protection of unlogged forests and (2) conservation that allows selective logging. We find that it might be difficult for a carbon payment scheme to overcome the opportunity cost of conservation (at least as represented by logging profit) in both forest types modeled. However, if selective logging is allowed, the opportunity cost exhibits a steeper decline per unit of marketable timber removed in the prized-species forest types compared to the volume-based forestry enterprises. This suggests that conserving selectively-logged tracts might be a cost-effective approach for conserving tropical forests of the type where there are a few prized species, *provided* the logging does not destroy or diminish the elements of biodiversity that are the focus of conservation efforts (Edwards et al., 2011b).

Table 2
Potential role of carbon payments in meeting the opportunity cost of conserving unlogged forest.

Dipterocarp forest example				
Carbon price (\$/tCO_2)	\$35	\$30	\$25	\$20
% Opportunity cost met	>95%	~87%	~63%	~5%

Ignoring the carbon aspect of the result, this is essentially the insight contained in a 1997 article published in *Scientific American* by Richard Rice and colleagues Rice et al. (1997). At the time it was a somewhat controversial idea, where at the end of their paper on the sustainable forestry management options in tropical forests, they suggested that where selective logging targets an individual (or few) species naturally occurring at low densities, the best option for biodiversity and ecological conservation might be to accept the loss of these individual species via selective logging for the sake of preserving the rest. In effect, they suggested that we see the forest for the lack of a few trees. Since then, the advent of voluntary (and the prospect of involuntary) carbon markets have made Rice et al.'s idea potential more economically palatable and that is where our analyses contributes.

It is important to note, however, that our model represents a static analysis or snapshot of economic conditions. Conservationists and decision makers need to recognize the changing nature of the economics of logging, wherein forests that were once uneconomical to log (low-return, high-cost) can become economical if technologies or supply–demand dynamics change. Similarly, carbon markets have been erratic over the past five years. Any REDD+ project would have to both deal with price fluctuations and the structure of the contract (e.g., long term versus short term), both of which will affect the incentive to engage in REDD+-style of conservation (see Olschewski et al., 2005; Busch et al., 2012, for how contract structures change decisions). At the macro-scale, specific policies and revenue sharing might entail public budget deficits, while others might precipitate public budget surpluses (Busch et al., 2012). These sorts of considerations will certainly affect the degree to which a carbon payment is operationalized on the ground.

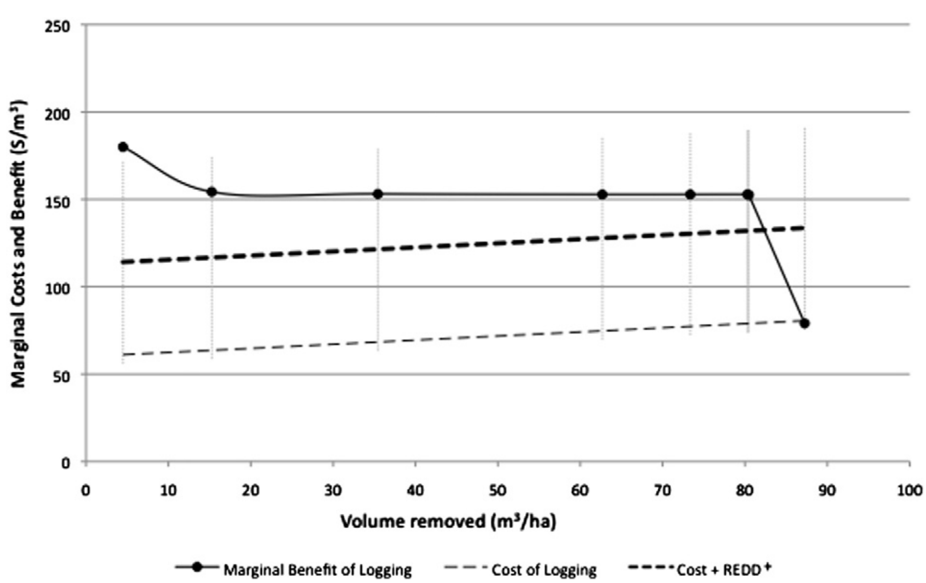

Fig. 6. Marginal benefit curve of logging in a diptercarp-dominated forest in Southeast Asia (solid line); associated marginal cost curve (thin dashes); and cost of logging plus REDD+ cost line representing a benefit foregone under logging activities (thick dashes – 5 year mean ETS price for CO_2 $\pm$ 1 SD – thin vertical dotted lines).

In addition to the changing economics of logging and incentive structures of a REDD+ mechanism, the way logging concessions are managed on the ground can affect potential opportunity costs. In the general model we discuss selective logging without clarifying what techniques are used. While such a discussion would not change the insights of the model, a further discussion of how a suite of reduced-impact logging (RIL) techniques might change the results is warranted.

RIL techniques can entail a near-term reduction in the profits from logging for a given volume extracted (Putz et al., 2008a). This is due to the interventions considered in RIL, such as avoiding logging on steep slopes and wet soils, restricting the number and size of logging roads and dumps, or leaving riparian zones forested, and also the cost of crew training and new equipment. In the long term, it may be the case that future offtake is increased by RIL (Holmes et al., 2002; Medjibe and Putz, 2012). However, given the high discount rates in potential REDD+ countries, these future yield benefits of RIL are unlikely to outweigh the immediate benefits of conventional logging practices (Pearce et al., 2003). RIL can also similarly be considered to increase the cost of logging a given volume due to increased management plan requirements, vine cutting and other such activities. In essence these activities effectively move the marginal benefit curve downwards.

RIL techniques have, however, been shown to reduce the carbon emitted from both the standing biomass and soil profiles (Pinard and Putz, 1996; Pinard et al., 2000; Putz et al., 2008b), potentially earning a credit for the reduction in carbon emitted (i.e., the difference in emissions between RIL and conventional logging). The degree to which RIL moves the marginal cost and benefit curves will dictate how the opportunity cost changes. This is an issue that requires a deeper understanding of both the opportunity and implementation costs of RIL, as well as the lifetime carbon emissions of logging under conventional techniques versus a suite of RIL options for the same forests.

We have discussed profit from commercial logging as an indicative metric to attempt to understand the potential of REDD+ to impact decisions in tropical forests. Profit as a metric is incomplete. For example, governments might see logging through a lens of job creation or, conversely, they might see it as negatively affecting some carbon reduction policy goal. Governments could also weigh lost taxes revenue against any reputational gains from carbon projects. Tax rates vary from country to country and may or may not be influenced by the underlying value of timber. Additionally, the stakeholders who have the rights to the carbon might be greatly influenced by the degree to which they can interact with carbon markets (e.g., high transaction costs for private landowners). The ETS price point for carbon was used here simply as a way to give a financial value to carbon. It is not representative of the cost of forest carbon projects, which might include costs incurred by local governments, consultants, transaction mediators, as well as carbon monitoring, reporting and verification costs. We have also not touched on the issue of corruption, which has been an issue in the forestry sector for decades. Finally, carbon payments might have to cover costs beyond the theoretical opportunity cost to the landowner, government, or carbon developer. For example, in an East African context, implementation costs can be close to twice that of calculated opportunity costs (Fisher et al., 2011a).

Conversely, profit as an indicator might overestimate the financial barriers to conservation via REDD+. For example, indigenous communities with secure land tenure may be willing to settle for much less from a REDD+ project than even they could earn from logging (or from selling rights to a logging company) because of the other values they place on their land (Rival, 2010). As such, profit is only one of many factors affecting the potential impact that REDD+-type intervention will have on the economics of commercial logging.

Finally, the impact that agricultural drivers have on forests throughout the tropics cannot be ignored. Across the tropics, 83% of new agricultural land created between 1980 and 2000 came at the expense of intact or disturbed forests (Gibbs et al., 2010). In Southeast Asia, converting forest for oil palm is not only a major driver of forest conversion (Koh and Wilcove, 2008), but is also so lucrative that it could greatly affect the feasibility of any carbon market (Butler et al., 2009; Venter et al., 2009; Fisher et al., 2011b). This leads us to question the economic feasibility of carbon payments in any place where forest conversion to high-return agricultural products is sanctioned. In recent years a number of studies have shown that logged forests retain a large proportion of the species found in primary forests, across several taxa (Meijaard et al., 2006; Berry et al., 2010; Edwards et al., 2011b; Woodcock et al., 2011; Gibson et al., 2011; Putz et al., 2012). Conversely, forest landscapes converted to agricultural plantation suffer a large reduction in biodiversity (Petit and Petit, 2003; Fitzherbert et al., 2008; Edwards et al., 2010; Gibson et al., 2011). Such a phenomenon is not only an issue with high-return agriculture, but also a result when low-return agriculture follows the arc of commercial logging. In light of this dynamic, ensuring that selectively logged forests are not converted to crops is likely to be one of the most cost-effective ways to expand protected areas, connect existing protected areas or create new reserves (Fisher et al., 2011c; Giam et al., 2011), thereby fostering a longer-term benefit for conservation, climate mitigation and biodiversity. Moreover, incorporating long-term conservation in selectively logged forests now might ensure that technological advances in logging or agriculture, or changing economic circumstances do not result in further degradation or destruction.

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