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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.

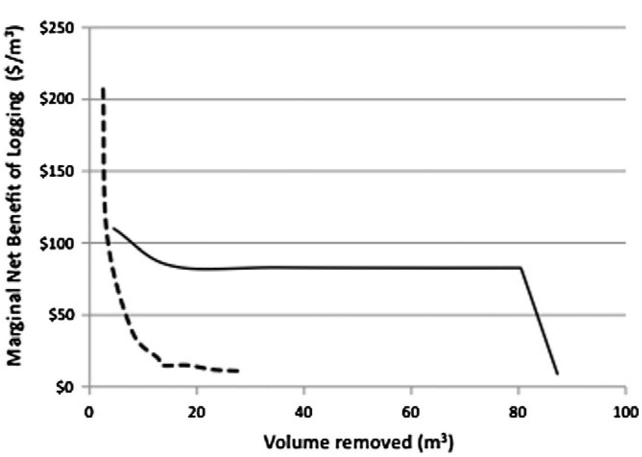

Fig. 1. Example marginal net benefit curves of logging in a) forests where there are a small number of highly prized timbers per unit area (dashed line) [data from mahogany logging Chimanes Forest, Bolivia, Howard et al., 1996], and b) forests where returns are driven mainly by volume not species type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