Research Article

The case for improved forest management (IFM) as a priority REDD+ strategy in the tropics.

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Abstract

We address the controversy over REDD+ financing for commercial loggers who reduce emissions by adopting improved forest management (IFM). We argue that REDD+ incentives should be available to commercial loggers who adopt IFM as long as carbon accounting is rigorous and safeguards are followed. Further, we argue that where full forest protection is not feasible, IFM should be advanced as a priority REDD+ strategy because it can (i) achieve robust emissions reductions without generating leakage or increasing the risk of non-permanence, (ii) generate a variety of local community benefits as a low-carbon development strategy, (iii) maintain native forest biodiversity, and (iv) reduce the likelihood of deforestation, particularly when forest management is community-based. We discuss solutions to some of the remaining challenges to creating incentives for IFM within a REDD+ mechanism. We encourage continued refinement of safeguards to ensure that verified climate benefits of IFM also generate social and biodiversity benefits. REDD+ financing is needed to catalyze the shift to IFM, but IFM should not be dependent (or at least not fully dependent) upon REDD+ financing for long-term financial viability. Measuring, monitoring, and validating emissions reductions from IFM have been a particular challenge, although new technologies and methods are promising. Technologies and methods used to account for avoided deforestation are usually not sensitive enough to detect changes in forest management practices. Funding is needed for research to develop and refine affordable methodologies for measuring, monitoring, and validating emissions reductions achieved through IFM.

Keywords: tropical forest carbon emissions, climate, reduced impact logging (RIL), community-based forest management, certification, safeguards, policy

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Introduction

To some, the buzz of a chainsaw deep inside a tropical forest is the sound of forest destruction. To others, it offers the potential for local stakeholders to make a sustainable living off of a forest that maintains its native diversity. Is sustainable forestry in the tropics a viable element of forest conservation strategies? This question has been controversial since the 1970s and remains so today [1-4]. Major financing for Reducing Emissions from Deforestation, forest Degradation, conservation, sustainable management of forests, and enhancement of forest carbon stocks (REDD+) brings new opportunities and fresh tinder to the controversy.

REDD+ raises a controversial, pragmatic question: Should commercial loggers[1] be eligible for incentives to reduce emissions through Improved Forest Management (IFM)? This question has important implications for prioritizing and/or restricting activities financed under emerging REDD+ frameworks. For example, currently U.S. overseas development funds for REDD+ are subject to greater restrictions when the commercial forest sector is involved [5]. While "sustainable management of forests" is included in the latest negotiated text for an international REDD+ framework [6], it remains to be seen how this term will be defined or what restrictions will be put on eligibility for incentives.

The implications of these emerging policy decisions for tropical forests are large. Over 20% of natural tropical moist forests (390 million hectares) are designated by national governments for logging [7-8]. This makes logging one of the dominant land uses in the tropics, surpassing agriculture in many areas [9, 10]. Likewise, logging plays an important role in the economic development strategies of many tropical forest countries [11]. Demand for timber is expected to significantly increase [12]. If the increasing demand for timber is not met, alternative materials such as steel and cement, with higher carbon footprints, would likely substitute for that demand, resulting in yet higher greenhouse gas emissions [13-14]. Demand for wood in the short-term can be expected to increase harvesting from natural forests, which occupy 93% of forested lands (7% being plantations) [15-17]. The expansion of industrial logging in the tropics presents a significant challenge to efforts to mitigate climate change by curbing deforestation and forest degradation. Currently, logging native forests represents about 20% or more of net forest emissions in many tropical forest systems [18-21]. While afforestation with timber plantations has a countervailing sequestration effect, this sequestration offsets less than 2% of deforestation emissions [22], even after accounting for recent expansion of plantation systems [15].

Here we make the case that commercial loggers should be eligible for incentives to reduce forest emissions through Improved Forest Management (IFM), as long as it is done properly. Further, we argue that IFM should be advanced as one of the more promising REDD+ strategies available in many tropical countries. Less than one percent of tropical forest area is certified under some form of IFM [17], and the remainder are generally subject to conventional logging that is unnecessarily destructive and a catalyst for deforestation [9, 23-24]. REDD+ incentives offer an opportunity to shift a large proportion of conventionally logged forest areas to IFM, with benefits of sustained natural forest cover and timber production, reduced emissions, ecosystem services for human communities, and biodiversity conservation.

[1] We use the term "commercial loggers" to refer to all types, ranging from local community-based operations to multinational logging companies. In the tropics, most commercial logging involves selective cutting of a few commercially recognized species, since most tropical tree species are not traded on the international market.

After describing what IFM is and how it is verified, we discuss these benefits of IFM for people and nature. We conclude by considering how REDD+ programs can help overcome the remaining barriers to advancing IFM.

Fig. 1. Improved Forest Management (IFM) includes better harvesting in areas where logging occurs, protection, or set-aside, of some areas from logging, and silvicultural practices to improve growth. Examples of specific practices in each category are given. Many of these practices provide measurable carbon benefits (Č). Many also invoke no leakage (Ł) to the extent that emissions reductions are achieved without reducing timber production.

What is Improved Forest Management (IFM) and how can it be verified?

Conventional timber harvest in tropical forests is typically performed by "selective logging," extracting a small number of commercial species from a large number of non-commercial species. From a strictly carbon emissions perspective, IFM might refer to any change from conventional logging that reduces net emissions. For the purposes of this paper we consider the more comprehensive concept of IFM as a suite of practices designed to reduce the negative environmental and social impacts of forestry activities while maintaining forest product supply (Fig. 1). In developed countries where relatively younger secondary forests are dominant, IFM is often considered a strategy for net sequestration at the landscape scale. In the case of tropical forests in developing countries, logging activities often occur in older-growth forests. In this case, IFM offers an opportunity to reduce net emissions associated with logging at the landscape scale. We can organize IFM practices into three categories [20]:

- **Better harvesting:** A variety of logging practices have been identified to reduce the impact of timber harvesting activities. Many, but not all, of these practices decrease emissions per unit volume of timber harvested. Examples of practices that reduce impacts (per area and/or per volume extracted), and associated forest carbon emissions, include the following:
  1. Improved design and construction of roads and skid trails to minimize the area impacted by the transportation network used to extract logs from the forest;
  2. Cutting trees so that they fall in a specific direction to minimize damage to other trees and maximize timber recovery (directional felling);
  3. Improved cutting of log sections to maximize the recovery of useful wood (better bucking). This begins with the felling cut to leave a lower stump;
  4. Cutting vines tangled in the tree tops so that a harvest tree does not bring several other non-commercial trees down with it.
  5. Using innovative, low-impact logging equipment – such as the monocable winch system – that slide logs along the forest floor with long cables, reducing the damage to forests by conventional skidding equipment (e.g. bulldozers);
  6. Reducing the felling of defective (e.g. hollow) trees which have little or no commercial value. Simple tests such as the “plunge cut” can be used to reduce unnecessary felling;
  7. Properly identifying commercial species before cutting so that non-commercial species are not cut down and abandoned [25]. A well-trained survey crew is needed to avoid mis-identification, and technologies are emerging to support tree identification.

- **Protection:** IFM practices include the identification and special management of conservation zones within forest management units such as logging concessions, in order to support ecosystem services such as biodiversity, old growth structure, flood control, water quality, and social values. Such conservation zones include:
  1. Riparian buffer zones - areas where land meets streams or rivers, which are sensitive to erosion and have high plant and animal species diversity;
  2. High Conservation Value Forests (HCVFs) - forests that contain concentrations of rare species, rare ecosystems, and/or areas of importance to local people;
  3. Steep slopes sensitive to erosion; and
  4. Corridors – forest areas that connect two or more larger blocks of forest.

- **Growth:** IFM also includes silvicultural practices to ensure the regeneration and growth of native timber tree species, which help maintain native tree diversity and provides a long-term source of timber production, income, and employment. Some such practices reduce net emissions (e.g. extended rotation times, reduced damage to crop trees) while others can increase emissions in the near term (e.g. larger canopy openings to regenerate shade intolerant timber species and/or liberate future crop trees); thus, careful planning of rotation lengths may be necessary to achieve both emissions reductions and sustainable supply of shade-intolerant tree species.

Independent third-party auditing systems exist to certify a variety of IFM practices. The most comprehensive and globally applied system for certifying a range of IFM practices is Forest Stewardship Council (FSC) certification. Of the three categories described above, FSC in tropical countries is more advanced in conservation zones and better harvest practices, and less advanced in silviculture. In addition to the three categories described above, FSC also includes critically important social principles and criteria to achieve socially responsible and equitable forest management.

Better harvesting practices in the tropics are built upon an established set of timber harvesting practices called Reduced-Impact Logging (RIL). These are described in academic studies [19, 26-27] and have been developed into a RIL Standard by the Tropical Forest Foundation (TFF) [28], and affiliates such as Instituto Floresta Tropical (IFT). Frequently tropical forest concessionaires employ such RIL standards as components of achieving FSC certification. These certifying and verifying bodies and existing standards (e.g. FSC, TFF) represent major institutional and information resources for achieving IFM; however, these systems were not designed explicitly to achieve or verify emissions reductions associated with IFM. As such, these existing standards do not always include a full suite of improved practices designed to reduce emissions, and the practices that are specified in these existing standards may not be explicit enough to be linked to quantitative emissions reductions. Nevertheless, these standards offer critical pre-existing systems for auditing forest management practices, and could be refined to more explicitly address emissions reductions.

More recently developed standards have been explicitly designed for forest carbon, such as the Verified Carbon Standard (VCS, http://v-c-s.org/). The VCS is the most widely used quality assurance system for accounting for greenhouse gas (GHG) emission reductions in the voluntary carbon market [29]. It includes fundamental principles, requirements, and methodologies for quantifying GHG emission reductions as well as a system for validation, verification, and registry. However, the VCS and other standards are not designed to address the complex and regionally specific social and environmental issues surrounding tropical forest management that FSC and TFF address. VCS and other standards can complement FSC and TFF by developing specific carbon methodologies for verifying the special case of emissions reductions achieved by shifting from conventional logging to IFM in a developing tropical country. Such a methodology appropriate for tropical forests has yet to be developed, although a draft methodology by The Nature Conservancy (TNC) and TFF is underway. Therefore, no existing auditing systems verify the full range of IFM practices described above and link practices with emissions reduction accounting. Adaptation, development and coordination of these systems are needed to do so.

Could REDD+ incentives for IFM result in more logging?

Critics of allowing REDD+ financing for IFM have raised a concern: If incentives are given to logging concession owners for IFM, could those incentives be used to expand logging in forests that should instead be fully protected? This concern arises from the perception[2] that REDD+ could subsidize logging on lands that were previously considered uneconomical to harvest. Such a scenario would not occur so long as credible and rigorous carbon accounting is implemented, in which case only measured emissions reductions from a business-as-usual logging scenario would be credited. Expansion of logging activities beyond the business-as-usual scenario would generate increased emissions, and would thus not benefit from REDD+ incentives. In the case of project-level activities in relatively limited accounting areas, there may be concern that a company with logging concessions distributed over large geographic areas could use some of the funds generated from adopting IFM in one concession to expand logging operations elsewhere. Project-level forest carbon standards should, and often do, address this concern by requiring tracking of funds beyond the carbon accounting area. Likewise, the potential for other unintended consequences of REDD+ incentives, such as negative social or biodiversity impacts, are addressed through safeguards such as tsssshe Climate, Community, and Biodiversity Alliance (CCBA, http://www.climate-standards.org/index.html). Efforts to further improve standards such as VCS and CCBA, as well as emerging governmental standards (e.g. The Climate Registry, http://www.theclimateregistry.org/) are a

[2] This perception is prevalent among NGOs which oppose REDD+ financing for IFM, with whom the authors have had numerous conversations on this topic at international venues (e.g. United Nations Framework Convention on Climate Change Conferences of Parties).

positive avenue for channeling concerns about unintended negative consequences of REDD+ incentives. With this in mind, not only should incentives for IFM not be seen as a threat to remote forests, IFM is a critical strategy for buffering remote areas against drivers of deforestation and forest degradation that are often linked to conventional logging activities [20].

The Benefits of Improved Forest Management

IFM can achieve substantial and measurable carbon benefits, generate local community benefits, sustain native biodiversity, and reduce deforestation. We review the basis for each of these potential benefits.

Emissions reductions

Under conventional selective logging practices, multiple non-commercial trees are damaged or destroyed for every commercial tree that is extracted. These "collateral damage" trees are left to rot or burn, emitting carbon dioxide as they do so. Better harvesting practices can significantly decrease this collateral damage, and increase timber recovered from harvest trees, through the practices described above. A variety of studies have looked at reduced impacts from implementing IFM practices, in particular reduced-impact logging (RIL) [30-35]. However, we have identified only three peer-reviewed studies (representing two sites) that have used field measurements to quantify those reduced impacts in terms of emissions reductions [8, 33, 35]. These studies found that reduced-impact logging methods can reduce emissions by about 30-50%. Additional set-asides of protection zones mentioned above would provide for greater carbon storage in those areas.

Unlike most REDD+ strategies, IFM avoids or minimizes two of the concerns about REDD+ emissions reductions accounting: leakage and permanence. IFM generates emissions reductions without leakage, with the exception of set-asides. To the extent that harvest levels are maintained, no leakage is generated. Leakage only occurs if supply to a market and/or labor is displaced, and neither of these would happen if IFM is able to maintain timber production and maintain or increase jobs (both of which are possible). Some improved logging practices can generate more timber while reducing emissions (e.g. improved bucking). On the other hand, conservation set asides, where logging intensity is reduced or eliminated, do invoke the issue of leakage, whether it be local (e.g. saw mills looking for roundwood supplies elsewhere) or international (i.e., global markets meeting demand elsewhere) because the logger may seek to compensate for the reductions in harvest levels by logging other areas. Set-asides are an essential part of achieving low impact, sustainable forest management. However, the extent of set-asides will need to be balanced by the need to maintain adequate production levels and minimize leakage. Sophisticated national and international leakage analysis on logging can be done [36], but given the reduced risk of leakage described above, would only be necessary in instances where leakage may be expected (e.g. logging is stopped altogether or substantial set-asides are needed).

Improved Forest Management practices also tend to reduce the likelihood of catastrophic disturbances caused by natural disasters like fire, both because fuel loads (i.e., dead biomass) are reduced, and because fire management practices are employed (as reviewed by [20]). Thus, we expect that the risk of non-permanence would be lower under IFM than under a business-as-usual scenario. This makes IFM potentially more attractive than other REDD+ strategies (such as the designation of protected areas or cancellation of logging concessions) which do not automatically include management practices to avoid natural disturbances. The ability of IFM to generate emissions reductions while maintaining the bulk of commercial production and reducing the risk of catastrophic damage to forests makes IFM an important low-carbon development strategy.

Community benefits

Conventional logging is a common source of conflict between external corporate interests driven by short-term profits and local communities who have traditional land rights and who are primary stakeholders of forest ecosystem services. On the other hand, conventional logging often provides welcome jobs to local and external communities. Similarly, many REDD+ strategies struggle with trade-offs at a local level between protection of forests and benefits to people from exploitation of natural resources. Arguably the most distinctive benefit of IFM as a REDD+ strategy comes in the form of maintaining and improving jobs, income, and ecosystem services for local communities that directly depend on sustaining standing native forests. Further, IFM can be leveraged to improve tenure for forest dependent communities. For example, equitable resolution of tenure disputes between commercial concessionaires and local communities are part of FSC certification. However, there are reasonable concerns that IFM will be used to green-wash the actions of external corporate interests that do not respect traditional community rights, particularly in countries where forest-based communities do not have strong legal tenure. It is essential that emerging national and international safeguards are designed to ensure REDD+ incentives are only provided for IFM that generates real net benefits for local forest-based communities.

Both more and better jobs can result from adoption of IFM, compared to conventional logging. Better forest management involves both hiring of additional technically trained staff (e.g. geospatial analysts, foresters) and better training for existing staff (e.g. chainsaw operators, bulldozer operators). Timber harvesting is the second highest risk occupation in the United States [37], and we assume it is at least as dangerous in developing countries. Many of the RIL practices, such as directional felling and cutting vines, reduce impacts on forests while also improving worker safety. Some standards specifically call for worker safety criteria. For example, FSC requires operators to meet or exceed applicable laws and regulations covering health and safety of workers and their families, ensuring adherence to these rules where they would often otherwise be ignored. In some cases, technology involving higher local employment can be used as part of IFM. Based on conversations with local managers, we find that IFM timber concessionaires in East Kalimantan, Indonesia employ eight times more local people when using low impact monocable winch systems that replace conventional bulldozer skidding systems. Expenses for the purchase, maintenance and operation of bulldozers are shifted to salaries for local employees, since monocable winch machinery costs a fraction of bulldozers yet require more people to operate. When impacts on forests are reduced, ecosystem services that communities rely on, such as potable water, flood control, fruit, fish, medicines, etc. are better maintained.

Biological diversity

Forests that are carefully managed for timber cannot replace protected areas as storehouses of biodiversity, but they can be an integral component of a conservation strategy that encompasses a much larger portion of the landscape than is feasible under strict protection alone [38]. In terms of biodiversity conservation, natural forest management for timber products is preferable to virtually all alternative land-use practices that generate global commodity products [39]. From a biodiversity maintenance perspective, tropical forests subjected to conventional selective logging sustain 80%-100% of native flora and fauna species [3]. Still better biodiversity conservation can be attained with improved forest management practices used in certified logging operations. We offer a few examples:

- FSC-certified forests typically maintain a greater number of conservation zones than conventionally logged forests. These include: special management buffer zones along rivers and streams, protected High Conservation Value Forests, and areas slated for forest restoration. A study of the impacts of FSC certification in 21 countries found that 63% of certified operations had improved riparian and aquatic management and 62% had improved treatment of sensitive sites and HCVFs [40]. On average, among the 118 operations analyzed, certified logging operations designated 22% of total area as HCVFs (totaling 2.5 million hectares, the size of Vermont) [41].

- A WWF Peru fauna monitoring project in the Espinoza Forest Concession identified FSC certified harvest areas with large-animal densities similar to those of protected areas [42].
- A study of forests in Malaysian Borneo concluded that forest certification had a positive effect on biodiversity. The certified forest sustained denser populations of endangered large animals, including orangutans and elephants, than elsewhere in the region. Tree species diversity under RIL was as rich as in old growth forests [39].

Reduced deforestation

Perhaps the greatest long-term carbon and biodiversity benefits from IFM come from reduced rates of deforestation in well-managed forests, especially when linked with community-based forest management. IFM involves long-term investments in the commercial productivity of forests which take decades to mature. IFM thus creates a stakeholder constituency with an economic incentive to avoid deforestation of the forests being managed. It also stands to reason that the incentive to avoid deforestation is greatest when local communities are the primary stakeholders in forest management, a concept now referred to as locally-controlled forestry (LCF) or community forest management (CFM). Profits from timber sales, job stability and ecosystem services offer incentives for local, forest-managing communities to avoid deforestation. Limited research is available to confirm the relationship between deforestation rates and IFM and/or LCF. However, results from four studies that have investigated these relationships are striking. A study by Hughell and Butterfield found that FSC-certified community-managed logging concessions in the Peten region of Guatemala have 20 times lower rates of deforestation than strictly protected areas [43]. A study by Duran-Medina et. al. compared the impact of protected areas and ejidos (community-based forest management areas) in Mexico. They found that both are valuable conservation approaches, but ejidos are more effective: forest cover is actually increasing within ejidos while net forest cover is declining within protected areas [44]. A recent meta-analysis comparing the conservation effectiveness of 40 protected areas and 33 community-managed forests (which were not necessarily sustainably managed for timber) reached the same basic conclusion: lower deforestation rates in community managed forests than in protected areas [45]. Another study from India finds that community-managed forests (compared with state-managed forests) achieve similar or better forest conservation outcomes at a much lower cost [46].

Advancing IFM as part of REDD+: Challenges and Solutions

The increasing demand for timber means that continued logging is inevitable. However, increased adoption of IFM practices is not guaranteed. A variety of challenges confront IFM, including:

- the development of policy and governance frameworks to resolve issues such as tenure conflicts, transparency, and corruption;
- the evolution of existing standards such as the Verified Carbon Standard, The Forest Stewardship Council, and the Tropical Forest Foundation to strengthen the implementation and verification of IFM linked with quantified emissions reductions;
- financing of up-front costs of adopting, measuring, and verifying IFM; and
- addressing scientific knowledge gaps where research is needed.

REDD+ has inspired efforts to address each of these challenges. We consider here in more depth the last two challenges (the more quantifiable issues within the scope of this paper): (1) up-front costs, where REDD+ incentives are needed, and (2) knowledge gaps where funding for research is needed.

Overcoming Short-term Barriers to Adoption

At the ground level, incentives from REDD+ are needed to overcome the initial investment and capacity barriers to adopting Improved Forest Management (IFM) practices (Fig. 2).

These initial costs of shifting to IFM include:

- a variety of technical training for staff that may only be available from foreign institutions,
- purchasing new equipment ranging from lower-impact machinery to computers and software,
- hiring and supervising additional employees, and
- planning, measurement, monitoring, and auditing processes.

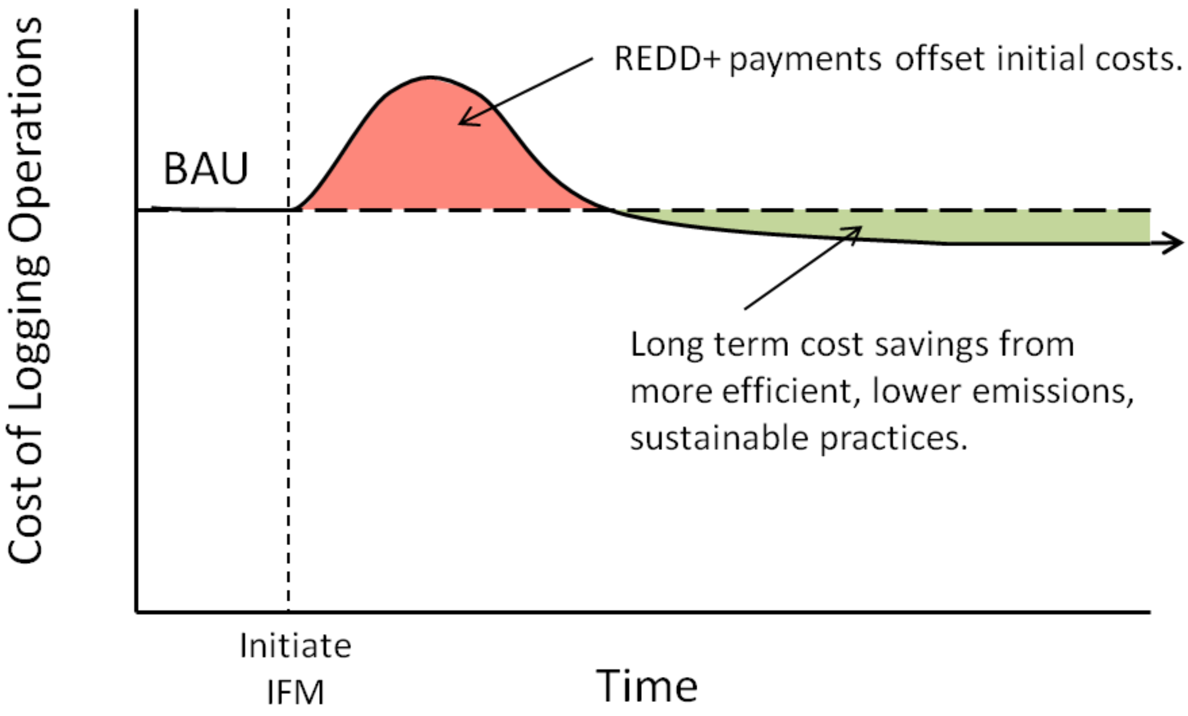

Fig. 2. REDD payments help overcome up-front costs associated with adopting IFM and certification. In some places REDD+ incentives could be phased out over the long-term to the extent that IFM practices provide long-term cost-savings (as indicated in this figure). However, IFM may not generate cost savings in landscapes where large areas should be protected from logging due to sensitivity and/or high conservation value. In such places where ongoing opportunity costs of adopting IFM are not offset by efficiencies of IFM, either regulatory intervention or long term incentives for REDD+ (or other ecosystem services) will be needed.

Even where initial capital investments can be made, forest managers often do not know how to access information on how to proceed with certification such as FSC, not to mention the elements of IFM that are not yet well integrated within FSC. While REDD+ incentives could overcome these initial cost barriers, logging concessions using IFM should become less dependent on REDD+ incentives over time. Once initial investments in IFM have matured, cost-savings become available due to efficiencies associated with IFM, including reduced fuel and repair costs for machinery, greater recovery of timber per tree felled, and more efficient use of labor hours by fellers, skidders, and haulers. Further, where IFM is formally recognized through certification systems (i.e. FSC), forest managers may benefit from price premiums and/or improved access to some markets.

Some academic studies have concluded that RIL ultimately generates cost savings [47-49] or is competitive with conventional logging [19]. Other studies have concluded that conventional logging is more profitable than sustainable forestry [2, 50-52]. An important site-specific factor is the amount of area taken out of production due to set-asides for steep slopes and riparian buffers. In general, inventory and planning costs are higher for RIL, while operating costs are usually lower, and it is difficult to generalize about the net outcome. In some cases REDD+ financing may only be needed to catalyze the adoption of IFM. In other cases, REDD+ financing (or a substitute) would be necessary on a long-term basis to make IFM competitive with conventional logging.

Formal certification (i.e. FSC) involves additional costs associated with social criteria, auditing, etc. Considering the limited adoption to date of improved practices [17], we suspect that costs outweigh savings in most locations. On the other hand, new legislation in Europe (FLEGT) and the United States (Lacey Act) designed to stop the import of illegally harvested wood may create a price margin for certified wood that could offset these higher operating costs over time.

Even when IFM is financially competitive in the long term, adopting and certifying IFM practices require significant up-front costs and capacity, which are barriers to adoption. REDD+ payments are needed to help small, medium, and large-scale logging operations adopt IFM and, where relevant, move toward certification (see Fig. 3).

At one end of the spectrum, small-scale, community-based forest management operations need the most support to build capacity, overcome up-front costs, and strengthen and document tenure rights. Considering the evidence that community-management of forests is a promising strategy for forest protection [43-45], community-managed forests should be considered for strong REDD+ investments in order to overcome these barriers to adopting IFM. The considerable evidence for a link between improved forest management and protection of forests when they are managed by local communities (as opposed to forests managed by large corporations or states) may be due to the longer-term and complex relationships between local communities and their forests, which provide both market-based income and non-market ecosystem services. This conclusion is consistent with a recent large study by Chhatre and Agrawal finding that community-owned forests are more likely to have deferred commercial exploitation, and higher carbon stocks, than state-owned forests [53].We therefore believe that community forest management is the most promising context for achieving forest conservation through sustainable, low-impact forest management.

On the other end of the spectrum, large-scale commercial operations can be expected to have the greatest access to capital, opportunities for economies of scale, and incentives to achieve certification (to the extent that they disproportionately supply international market demand for certified wood products). Large-scale operations should also be engaged as early adopters who can help tip the balance toward certified logging as an industry standard.

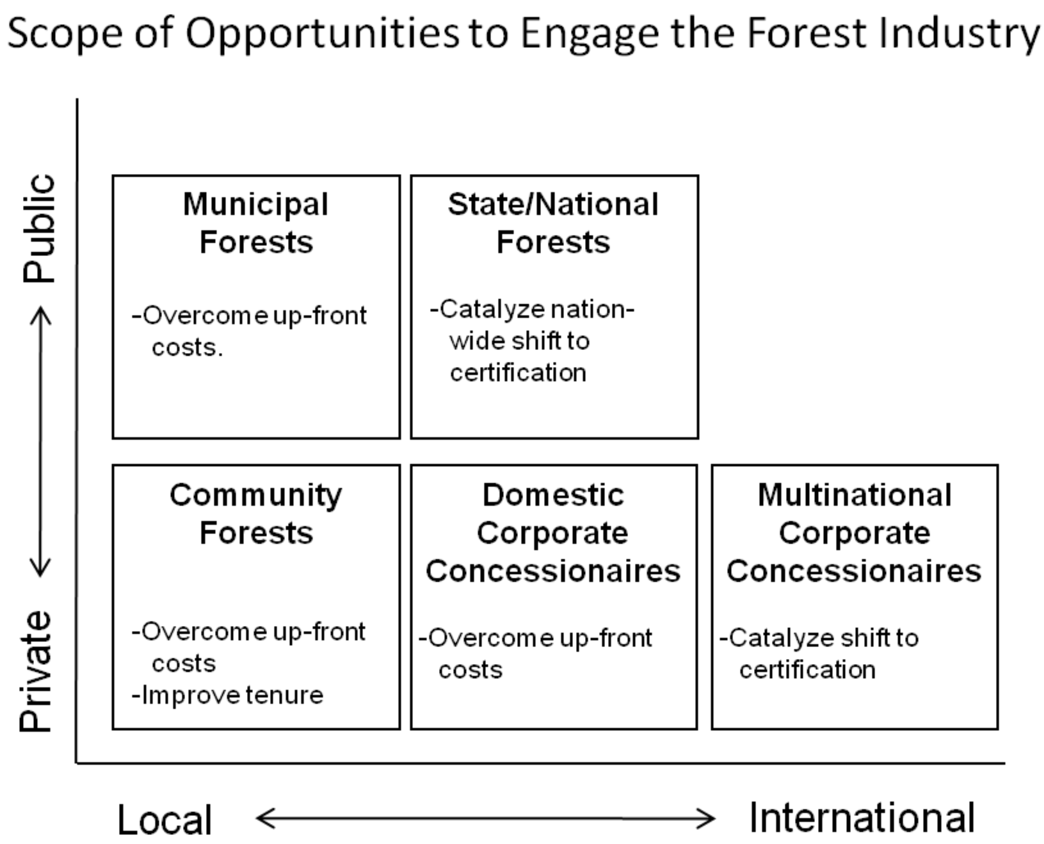

Fig. 3. The forest industry includes a wide range of agents, from community-based forest management to multinational corporate forest management. REDD incentives can help agents across this spectrum move towards IFM, as associated with both existing forest management standards (e.g. FSC, TFF) and emerging carbon standards (e.g. VCS, CAR, ACR). REDD incentives will be more critical to smaller agents in overcoming the up-front capital costs (indicated in Fig. 2). Community-managed forests are of particular interest given evidence of improved forest protection [27-28, 47]. It is also important to engage larger agents, such as government forest management agencies and multinational corporations, who are positioned to catalyze large-scale shifts towards IFM, certification, emissions reductions, and other co-benefits.

Research needs

In order for IFM to access REDD+ incentives, another barrier must be overcome: our current lack of inexpensive, reliable, and scalable methods and technology for measuring, reporting, and verifying emissions reductions resulting from IFM. As discussed above, while institutions exist for certifying components of IFM, no existing systems certify an additional set of practices designed explicitly to reduce emissions. Methodologies have yet to be approved within existing carbon standards (i.e. VCS) that verify emissions reductions achieved through IFM in tropical forests. Three research gaps will need to be addressed in tropical forest systems in order to develop and implement such methodologies within logging concessions: quantification of emissions reductions from IFM practices; development of monitoring methods; and quantification of the post-harvest carbon flux.

(1) Emissions reductions from IFM practices: Research is needed to identify individual IFM practices with emissions signals that can be feasibly monitored, and determine the additional emissions reductions (CO^2/ha logged and CO^2/ m^3 timber) achieved. This research will need to be conducted within different forest ecosystems across the range of landscape variables that can influence the impacts of logging practices (e.g. slope, soil, prior logging history). As discussed above, only a few studies have quantified emission reductions from improved logging techniques [35-36].

    Research on emissions from specific existing logging practices should be complemented by research to further refine alternative, low-emission logging practices. Examples include analysis of alternative skidding technologies, such as winch systems that avoid damage caused by larger machinery often used in skidding operations, minimizing width of haul roads, and avoiding the unnecessary felling of non-commercial trees due to poor species identification and/or poor identification of defective tree boles.

    Ecoregion-specific field-based forest inventory data are necessary for much of this work. In many regions, detailed tree measurements are needed to develop and/or test assumptions for allometry equations. Even Lidar remote sensing technology does not yet differentiate specific practices like avoiding the felling of defective or mis-identified trees and cutting vines. However, remote sensing technologies can dramatically improve the efficiency of field-based measurements [54].

(2) Remote sensing monitoring methods: Research is needed to identify affordable remote sensing technology for detecting and differentiating IFM from conventional logging at large. Advanced methods for analysis of Landsat imagery [18, 55] have revolutionized the detection of logging activity at large scales. However, they are sensitive to cloud cover, and the extent to which these methods can differentiate IFM from conventional logging is not yet clear. Once an affordable remote sensing technology is identified that can address these problems, scalable methods and software will be needed to consistently analyze large quantities of the remotely sensed data.

(3) Carbon flux after logging: Long-term research is needed to estimate net carbon flux after logging events, which involves tracking both decomposition and growth. Comparisons are needed both for different landscape variables (e.g. slope, soil, climate, forest type) and for different logging practices and silvicultural treatments. Published studies which provide estimates of growth and decomposition following logging are restricted to a limited number of research sites [56-60]. For a given forest type, alternate succession pathways can occur following disturbances such as logging. If logging creates conditions in which plants such as vines, bamboo, and herbs dominate, and/or a surge in tree herbivores (e.g. deer, elephants), the result may be little or no increase in carbon sequestration rates following logging [61-65]. On the other hand, silvicultural treatments can significantly increase rates of carbon sequestration following logging [61]. In either case, additional emissions may occur for over five years after logging due to elevated mortality of trees that are damaged or exposed by the logging [64]. These and other factors affecting estimates of carbon flux following logging are sensitive to multiple factors, including plant community composition, soil fertility, climate, and natural disturbance regimes [57]; it is therefore important to have regionally specific research available for credible estimates of carbon flux after logging.

To improve the effectiveness of IFM, and better understand the other potential benefits described above, further research is also needed on a broader set of research questions including (i) the financial implications of IFM, including both up-front costs and the longer-term financial picture, (ii) benefits of IFM for biodiversity and other ecosystem services; and (iii) benefits of IFM, and locally controlled forestry, on rates of deforestation. Some of the limited existing literature on these subjects has been discussed above, but these topics remain poorly understood. In particular, we have been unable to identify literature that links IFM in forests that are not community-managed with reduced deforestation rates – an important gap in our argument that IFM is an important strategy for avoiding forest conversion. Ideally, research on the range of IFM questions discussed above would be coordinated to develop a more comprehensive understanding of the benefits of IFM, the barriers and solutions to advancing and improving IFM, and how IFM promotes sbroader forest conservation goals.

Conclusions

- Improved Forest Management (IFM) integrates:
    i. better timber harvest practices that reduce impacts of logging,
    ii. conservation zones within forest management units to protect ecologically sensitive and high cultural value areas, and
    iii. silvicultural practices to increase carbon sequestration following timber harvests and sustain timber production.
- Improved Forest Management should be advanced as a priority REDD+ strategy because it can:
    i. achieve emissions reductions without leakage or elevated risk of non-permanence,
    ii. generate multiple local community benefits as part of a low-carbon development strategy,
    iii. maintain native forest biodiversity, and
    iv. reduce deforestation, particularly when forest management is community-based.
- Concerns that REDD+ incentives for IFM could result in expansion of logging in remote forests should be, and largely are, addressed by rigorous national carbon accounting along with safeguards. If credible carbon accounting methods are used, REDD+ incentives for IFM will only be generated when logging impacts are actually reduced. Further, IFM can be used as a strategy to buffer protected areas from drivers of forest degradation and conversion.
- The most promising opportunities from IFM are linked to community-based forest management ,which maximizes benefits to local stakeholders. Community-based IFM has been demonstrated to achieve dramatic reductions in deforestation rates.
- While IFM is a complex issue with many technical challenges, multiple institutions exist to support IFM in the tropics (e.g. FSC, TFF). Work remains to further the capacity and scope of these institutions and build links with emerging frameworks for verifying forest carbon emissions reductions (e.g. VCS).
- REDD+ incentives are needed to address the initial capital costs and capacity needs of adopting IFM. If REDD+ financing can catalyze adoption, IFM should not be dependent (or at least fully dependent) upon REDD+ financing for long-term financial viability. Management units that adopt IFM benefit in the long term from improved efficiency, sustainable production of timber, and advantages of timber certification such as price premiums and improved market access.
- Funding is needed for research on net emissions reductions achieved by implementing IFM practices. Critical research topics include (i) quantifying emissions reductions associated with specific improved practices at landscape scales, (ii) refining methods for analysis of remote sensing technology, and (iii) quantifying net carbon flux following logging activities. This research is necessary to develop and refine methodologies that can affordably measure, monitor, and verify emissions reductions achieved with IFM.

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References

[1] Chazdon, R. 1998. Tropical forests – log ‘em or leave ‘em? Science 281 (5381): 1295-1296.
[2] Pearce, D. Putz, F., Vanclay, J. 2003. Sustainable forestry in the tropics: panacea or folly? Forest Ecology and Management 172: 229-247
[3] Putz, F.E., P.A. Zuidema, T. Synnott, M. Peña-Claros+, M. A. Pinard+, Douglas Sheil, J. K. Vanclay, P. Sist, S. Gourlet-Fleury, B. Griscom, J. Palmer, and R. Zagt. 2012. Sustaining conservation values in selectively logged tropical forests: The attained and the attainable. Conservation Letters 5(4): 296-303
[4] Zimmerman, B., Kormos, C. 2012. Prospects for Sustainable Logging in Tropical Forests. BioScience 62: 479–487.
[5] Office, U.S. Government Printing. FY 2011 Public Law 111-117, p. 3398. Accessed: May 1, 2012. http://www.gpo.gov/fdsys/pkg/PLAW-111publ117/pdf/PLAW-111publ117.pdf.
[6] UNFCCC. December 2011. Accessed: May 1, 2012. http://unfccc.int/files/meetings/durban_nov_2011/decisions/application/pdf/cop17_lcaoutcome.pdf.
[7] Asner, G.P., Rudel, T.K., Aide, T.M., DeFries, R., Emerson, R. 2009. A contemporary assessment of change in humid tropical forests. Conservation Biology 23 (6): 1386-1395.
[8] Putz, F.E., Zuidema, P.A., Pinard,M.A., Boot, R.G.A., Sayer, J.A., Sheil, D., Sist, P., Elias, Vanclay, J. (2008). Improved tropical forest management for carbon retention. PLoS Biol 6 (7): e166. doi:10.1371/journal.pbio.0060166
[9] Nepstad, D., Verssimo, A., Alencar, A., Nobre, C., Lima, E., Lefebvre, P., Schlesinger, P., Potter, C., Moutinho, P., Mendoza, E., Cochrane, M., Brooks, V. 1999. Large-scale impoverishment of Amazonian forests by logging and fire. Nature 398: 505-508.
[10] Laporte N., Lin, T., Lemoigne, J., Devers, D., Honzák, M. 2004. Towards an Operational Forest Monitoring System for Central Africa. In: Remote Sensing and Digital Image Processing, Chapter Vol. 6: Land Change Science: Observing, Monitoring, and Understanding Trajectories of Change on the Earth’s Surface. Gutman, G. Janetos, A., Justice, C., Moran, E., Mustard, J., Rindfuss, R., Skole, D., Turner, B., Cochrane, M. (Eds.) Kluwer Academic Publishers, The Netherlands.
[11] FAO. 2009. State of the World’s Forests 2009. Rome.
[12] Kirilenko, A.P., Sedjo, R.A. 2007. Climate change impacts on forestry. Proceedings of the National Academy of Sciences. Proc Natl Acad Sci 104 (50): 19697-19702.
[13] Perez-Garcia, J., B. Lippke, J. Comnick, and C. Manriquez. 2005. An assessment of carbon pools, storage, and wood products market substitution using life-cycle analysis results. Wood and Fiber Science 37:140-148.

[14]Lippke, B., J. Wilson, J. Perez-Garcia, J. Bowyer, and J. Meil. 2004. CORRIM: Life-Cycle Environmental Performance of Renewable Building Materials. Forest Products Journal 54:8-19.

[15]FAO. 2010. Global Forest Resources Assessment 2010: Main Report. FAO Forestry Paper 163. Rome: Food and Agriculture Organization of the United Nations.

[16]Laporte, N., Stabach, J., Grosch, R., Lin, T., Goetz, S. 2007. Expansion of industrial logging in Central Africa. Science. 316:1451

[17]Siry, J., Cubbage, F., Ahmed, M., 2005. Sustainable forest management: global trends and opportunities. Forest Policy and Economics 7: 551—561.

[18]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.

[19]Putz, F. Pinard, M. 1993. Reduced-impact logging as a carbon-offset method. Conservation Biology, 7 (4): 755-757

[20]Griscom, B., D. Ganz, N. Virgilio, F. Price, J. Hayward, R. Cortez, G. Dodge, J. Hurd, F. L. Lowenstein, B. Stanley. 2009. The Hidden Frontier of Forest Degradation: A Review of the Science, Policy and Practice of Reducing Degradation Emissions. The Nature Conservancy, Arlington, VA. 76 pages. http://www.conservationgateway.org/file/hidden-frontier-forest-degradation-review-science-policy-and-practice-reducing-degradation-emis

[21]Huang, M., Asner, G. P. 2010. Long-term carbon loss and recovery following selective logging in Amazon Forests. Global Biogeochemical Cycles, 24, GB3028, doi:10.1029/2009GB003727.

[22]Montagnini, F., Porras, C. 1998. Evaluating the role of plantations as carbon sinks: an example of an integrative approach from the humid tropics. Environmental Management 22 (3): 459-470.

[23]Fearnside, P. 1997. Protection of mahogany: a catalytic species in the destruction of rain forests in the American tropics. Environmental Conservation 24 (4): 303-306.

[24]Barreto, P., Amarala, P., Vidala, E., Uhl, C. 1998. Costs and benefits of forest management for timber production in eastern Amazonia. Forest Ecology and Management 108 (1-2): 9-26.

[25]Daly, D. C. 2007. The local branch: Toward better management of production forests in Amazonia. Public Garden 22 (2): 12-15

[26]Holmes, T., Blate, G., Zweede, J., Pereira, R., Barreto, P., Boltz, F., Bauch, R. 2002. Financial and ecological indicators of reduced impact logging performance in the eastern Amazon. Forest Ecology and Management 163 (1-3): 93-110.

[27]Vidal, E., Johns, J., Gerwing, J., Barreto, P., Uhl, C. 1997. Vine management for reduced-impact logging in eastern Amazonia. Forest Ecology and Management. 98 (2): 105-114.

[28]Tropical Forest Foundation (TFF). 2009. Tropical Forest Foundation Standard for Reduced Impact Logging (TFF RIL Standard) TFF-STD-RIL-2006. Revised October 2, 2009. Alexandria, Virginia, USA. http://www.tropicalforestfoundation.org/get-verified/tff-ril-standard

[29]Peters-Stanley, M., Hamilton, K., Marcello, T., Sjardin, M. 2011. Back to the Future: State of the Voluntary Carbon Markets 2011. Report by Ecosystem Marketplace and Bloomberg New Energy Finance. 79 pages. http://www.forest-trends.org/documents/files/doc_2828.pdf

[30]Healey, J.R., C. Price, and J. Tay, 2000. The cost of carbon retention by reduced impact logging. Forest Ecology and Management 139: 237-255

[31]Bertrault, J.G. and P. Sist, 1997. An experimental comparision of different harvesting intensities with reduced-impact and conventional logging in East Kalimantan, Indonesia. Forest Ecology and Management 94: 209-218.

[32]Pereira, R., Jr., J. Zweede, G.P. Asner, and M. Keller, 2002. Forest canopy damage and recovery in reduced-impact and conventional selective logging in eastern Para, Brazil. Forest Ecology and Management 168: 77-89.

[33]Keller, M., M. Palace, G.P. Asner, R. Pereira Jr., and J.N.M. Silva, 2004. Coarse woody debris in undisturbed and logged forest in the eastern Brazilian Amazon. Global Change Biology 10: 784-795.

[34]Pinard, M. Putz, F. 1996. Retaining forest biomass by reducing logging damage. Biotropica 28(3): 278-295.

[35]Pinard, M. 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

[36]Sohngen, B. and Brown, S. 2004. Measuring leakage from carbon projects in open economies: a stop timber harvesting project in Bolivia as a case study. Canadian Journal of Forest Research 34: 829-839.

[37]US Bureau of Labor Statistics. http://stats.bls.gov/oshhome.htm.

[38]Putz, F., Redford, K., Robinson, J., Fimbel, R., Blate, G. 2000. Biodiversity conservation in the context of tropical forest management. The World Bank. Environment Department Papers: 75

[39]van Kuijk, M., F. Putz, and R. Zagt. 2009. Effects of Forest Certification on Biodiversity. Report commissioned by Netherlands Environmental Assessment Agency (PBL). Tropenbos International. Wageningen, the Netherlands.

[40]Newsom, D., Hewitt, D. 2005. The Global Impacts of SmartWood Certification. Rainforest Alliance. New York, NY.

[41]Newsom, D. 2009. Rainforest Alliance Global Indicators: First Results from the Forestry Program (June 2007 – August 2008). Rainforest Alliance. New York, NY. http://www.rainforest-alliance.org/resources/documents/forestry_global_indicators.pdf

[42]Rodriguez, A., Cubas. C. 2010. Forest certification in indigenous communities in Peru. In: ETFRN News 51: Biodiversity Conservation in Certified Forests. Wageningen, The Netherlands.

[43]Hughell, D. and R. Butterfield, 2008. Impact of FSC Certification on Deforestation and the Incidence of Wildfires in the Maya Biosphere Reserve. Rainforest Alliance. New York, NY.

[44]Duran-Medina, E., Mas, J., Velazquez, A. 2005. Land use/cover change in community-based forest management regions and protected areas in Mexico. In: The Community Forests of Mexico: Managing for Sustainable Landscapes. Bray, D. B., Merino-Pérez, L., Barry, D. (Eds.) University of Texas Press, Austin TX.

[45]Porter-Bolland, L. Ellis, E., Guariguata, M., Ruiz-Mallén, I., Negrete-Yankelevich, S., Reyes-García, V., 2012. Community managed forests and forest protected areas: An assessment of their conservation effectiveness across the tropics. Forest Ecology and Management. 268: 6-17.

[46]Somanathan, E., Prabhakar, R. , Mehta, B.S. 2009. Decentralization for cost-effective conservation. Proceedings of the National Academy of Sciences 106 (11): 4143-4147.

[47]Durst, P. B., Enters, T. 2001. Illegal logging and the adoption of reduced impact logging. Forest Law Enforcement and Governance: East Asia Regional Ministerial Conference. Denpasar, Indonesia.

[48]Holmes, T., Blate, G., Zweede, J., Pereira, R. Barreto, P. Boltz, F., Bauch, R. 2002. Financial and ecological indicators of reduced impact logging performance in the eastern Amazon. Forest Ecology and Management. 163: 93-110.

[49]Boltz, F., Carter, D.R., Holmes, T. P., Pereira Jr., R. 2001. Financial returns under uncertainty for conventional and reduced-impact logging in permanent production forests of the Brazilian Amazon. Ecological Economics 39 (3): 387-398.

[50]Rice, R., Gullison, R., Reid, J., 1997. Can sustainable management save tropical forests? Scientific American 276: 34-39.

[51]Bach, C. F. 1999. Economic incentives for sustainable management: a small optimal control model for tropical forestry. Ecological Economics 30 (2): 251-265.

[52]Boscolo, M., Vincent, J. 1998. Promoting better logging practices in tropical forests: A simulation analysis of alternative regulations. World Bank Policy Research Working Paper No. 1971 (1998). Available at: http://ssrn.com/abstract=604987.

[53]Chhatre, A., Agrawal, A. 2009. Trade-offs and synergies between carbon storage and livelihood benefits from forest commons. Proceedings of the National Academy of Sciences 106 (42): 17667-17670.

[54]Asner, G., Mascaro, J., Muller-Landau, H., Vieilledent, G., Vaudry, R., Rasamoelina, M., Hall, J., van Breugel, M. 2012. A universal airborne LiDAR approach for tropical forest carbon mapping." Oecologia 168: 1147–1160.

[55]Souza, C., Roberts, D., Cochrane, M. 2005. Combining spectral and spatial information to map canopy damage from selective logging and forest fires. Remote Sensing of Environment 98: 329-343.

[56]Fredericksen, T., Mostacedo, B. 2000. Regeneration of timber species following selection logging in a Bolivian tropical dry forest. Forest Ecology and Management. 131: 47-55.

[57]Baker, T., Swaine, M., Burslem, D. 2003. Variation in tropical forest growth rates: combined effects of functional group composition and resource availability. Perspectives in Plant Ecology, Evolution and Systematics. 6 (1,2): 21-36

[58]Huth, A., Drechsler, M., Kohler, P. 2004. Multicriteria evaluation of simulated logging scenarios in a tropical rain forest. Journal of Environmental Management. 71:321-333.

[59]Peña-Claros, M., Fredericksen, T., Alarcón, A., Blate, G., Choque, U., Leaño, C., Licona, J., Mostacedo, B., Pariona, W., Villegas, Z., Putz, F. 2008. Beyond reduced-impact logging: silvicultural treatments to increase growth rates of tropical trees. Forest Ecology and Management. 256:1458-1467.

[60]Blanc, L., Echard, M., Herault, B., Bonal, D., Marcon, E., Chave, J., Baraloto, C. 2009. Dynamics of aboveground carbon stocks in a selectively logged tropical forest. Ecological Applications 19 (6):1397-1404.

[61]Schnitzer, S., Dalling, J., Carson, W. 2000. The impact of lianas on tree regeneration in tropical forest canopy gaps: evidence for an alternative pathway of gap-phase regeneration. Journal of Ecology. 88: 655-666.

[62]Griscom, B., Ashton, M. 2006. A self-perpetuating bamboo disturbance cycle in lowland forests of Madre de Dios, Peru. Journal of Tropical Ecology. 22: 587-597.

[63]Griscom, B. 2003. Successional dynamics of bamboo-dominated forests in southeastern Peru. Ph.D. Dissertation. Yale University. New Haven, Connecticut.

[64]Pinard, M., Cropper, W. 2000. Simulated effects of logging on carbon storage in dipterocarp forest. Journal of Applied Ecology. 37: 267-283.

[65]Lawes, M., Chapman, C. 2006. Does the herb Acanthus pubescens and/or elephants suppress tree regeneration in disturbed Afrotropical forest? Forest Ecology and Management 221(1-3): 278-284.