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Article

Sustainable Forest Management and Carbon in Tropical Latin America: The Case for REDD+

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Abstract: In this review paper, we assess the economical, governance, and technical conditions that shape forest management in tropical Latin America with particular regard to efforts to reduce forest-based carbon emissions. We provide a framework for discussions about ways to improve forest management that achieve environmental objectives while promoting local and national development and contributing to local livelihoods. We argue that many management practices that lead towards sustainability are only likely to be adopted where there is good governance backed by financial incentives for effective enforcement of management regulations. We propose some policy interventions designed to lower net greenhouse gas emissions by decreasing rates of forest degradation and increasing carbon stock recovery in logged-over or otherwise degraded forests. Implementation of REDD+ could provide critical compensation to forest users for improved management practices in the absence of, or in combination with other economic incentives.

Keywords: sustainable forest management; forest policies; REDD+; Latin America

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1. Introduction

Tropical forests are threatened by the distinctly different processes of deforestation and forest degradation. While deforestation involves the conversion of forests to another land use type, degradation results in forests that have lost some of their ability to provide environmental goods and services. In economic terms, deforestation tends to be associated with investments in other land uses, mainly agriculture [1], whereas degradation tends to be linked to short-term extraction of forest rents or wildfires. Forest degradation translates into losses of biodiversity, reduced capacity of forests to provide the full spectrum of goods and services, enhanced likelihoods of subsequent deforestation, and reduced resilience and adaptation potential to climate change [2].

International discussions about Reduction of Emissions from Deforestation and Forest Degradation Plus Enhanced Carbon Stocks (REDD+) to date have focused on deforestation, with less regard for the processes of forest degradation or for issues related to forest resources use. This oversight is noteworthy because substantial emissions result from degradation due to unsustainable forestry activities and wildfires [3-5]. There is clearly a need for greater attention to the dynamics, impacts, and consequences of forest degradation, particularly in those parts of tropical Latin America where forest degradation often precedes or promotes subsequent deforestation [6].

While tropical forest management practices are basically similar across regions, some aspects are unique to Latin America. For example, in this region there is still a large amount of forest (mainly in the Amazon Basin) with relatively low rural population densities, which contrasts with some parts of tropical Africa and most of tropical Asia. In addition, in contrast with some other tropical regions, formalization of land tenure rights and promotion of sustainable forest management (SFM) have progressed rapidly of late in Latin America. Furthermore, a much stronger civil society constitutes an important actor in negotiating changes in forests and environmental policies. Nonetheless, in spite of the progress made, many unresolved issues remain that make it difficult to advance rapidly towards wider adoption of responsible forestry practices.

2. Why is There still so much Tropical Forest Degradation and So Little Good Management?

While some progress has been made in improving management, a large portion of the remaining tropical forest is still not well managed. The area of tropical forests managed sustainably in the International Tropical Timber Organization (ITTO) producer countries was estimated as 36 million ha in 2005, representing a mere 5% of tropical forests [7]. Why, despite the obvious long-term economic and environmental benefits from good forest management, do forest users continue to employ unnecessarily destructive practices, and why do forest institutions struggle to implement standards, guidelines, and regulations that would ensure responsible management? There have been many attempts to answer these enduring questions [8-10] and there is certainly no shortage of explanations for why good forest management is not more widely embraced, including:

- *Economic*: high opportunity costs of maintaining forests as compared to other land uses; substantial up-front investments needed for improved forest management; lack of financial benefits from adopting improved forest management *versus* the use of conventional practices; and, consumers are mostly unwilling to pay premium prices for timber from well-managed or certified operations.

- *Governance*: government policies are biased against improved forest management (e.g., lack of credit and high transaction costs to process permits); lack of serious governmental commitment to enforce forestry regulations; lack of tenure security or unclear tenure and resource rights; and, weak institutional capacity to enforce the adoption of forestry regulations and avoid encroachment.
- *Knowledge and technical guidance*: inadequate understanding of the benefits of adopting improved forest management practices; technical prescriptions perceived by forest users as too complicated or not practical; perceptions of forest abundance by the private sector (timber industries and local communities); lack of trained staff; and, inefficiency and waste in the forest and along the market chain.

Several of these factors work in concert to constrain adoption of improved forest management, thus making it difficult to isolate their effects. We will not discuss the abovementioned factors in general terms but rather explore in greater detail the principal factors that shape forest management in the Latin American tropics.

3. Factors Shaping Tropical Forest Management

3.1. Lack of Serious Intent by Major Stakeholders to Improve Forest Management

In most instances of predatory use of natural resources, the question of "willingness to manage" is asked both in the political and extractive industry arenas, but also by society in general. Basically, do government policies and actor behaviors reflect the extent to which society values forests? The value of forests to the public sector and to politicians generally derives overwhelmingly from socio-economic considerations (e.g., timber supply, state revenues, and employment) whereas environmental issues are sidelined. For example, in the Brazilian Amazon, a region of about 20 million inhabitants, total GDP in 2002 was US$ 28 billion of which US$ 2.3 billion corresponded to the timber industry, which generated about 380,000 jobs in 2004 [11]. As noted by Keller *et al.* [12] "*given this situation, it is curious that current government policies and the commercial situation in Brazil make it impossible to obtain bank loans for timber operations. This contrasts with the situation for farmers and ranchers in the Brazilian Amazon region, who receive abundant credit*." The latter is related to diverging policy priorities and reflects the disproportionate influence of agribusiness in shaping governmental policies.

With rising environmental concerns, including increasingly gloomy climate change scenarios, it would seem reasonable to expect societies to have greater concerns about ecosystem services, such as carbon storage, watershed protection, and the maintenance of biodiversity. The willingness of the industrial timber sector to adhere to higher environmental standards, which can be roughly assessed by the progress made in forest certification, should reflect societal pressure for improved forest management. A quick analysis of the Forest Stewardship Council (FSC) certificates by June 2009 reveals that 10 M ha of forest was certified in the Latin American tropics, with Brazil (5.5 M ha) and Bolivia (1.8 M ha) leading [13]. This is certainly positive, but it still shows that business-as-usual (predatory conventional logging) remains the norm.

3.2. High Opportunity Costs of Maintaining Forests

Societal pressure for improved forest management may be dampened because forest resources are perceived as being abundant. Thus, forest operations moving from one predatory extraction site to the next may seem more rational than careful management of forest resources with the intention of coming back for a second harvest after 20–30 years. This perception of abundance is particularly relevant in Amazonia where rural population densities are low and a 'move on' economic strategy can be easily justified and even sustained at least for the time being.

Predatory forest exploitation and conversion are often financially more attractive than careful management [14,15]. The opportunity costs of maintaining standing forests increase further with improved access, as the industrial forestry rent frontier is approached, and the economic value of other land uses increases [16]. The consistent underestimation of these opportunity costs is one reason why so many forest-unfriendly land-use decisions are being portrayed as financially rational [17]. In turn, low timber prices can also further raise the opportunity costs of maintaining forest [18]. Where forested land becomes suitable for agricultural crops, pastures, or plantations due to increased access, standing trees are viewed as impediments to profit maximization. Furthermore, where access is difficult, the terrain is rugged, the soils are unsuitable for intensive use, governance is weak, and tenure insecure, predatory logging is often the financially most remunerative land-use option [15,19].

Most of the expansion of the agricultural frontier in tropical Latin America was at the expense of forest. During the 1980s, 74% of South American and 90% of Central American lands used for agricultural expansion came from forests; for the 1990s the figures were similar (76% and 89%, respectively) [1]. About seven out of eight South American hectares converted in the 1980s and 1990s eventually became pastures; in Central America it was about three out of four—a feature that is fundamentally different from Asia where conversion is triggered by permanent agriculture and perennial crops (including fast-growing trees) not pastures [1].

High rates of forest conversion are in large part associated with the higher profits obtained from agricultural compared to forest uses, especially if the profits from the final timber felling are added to subsidies and rents from land grabbing: deforestation can be one way to establish more secure land property rights. In the past, due to the poor development of infrastructure and limited markets, agricultural expansion into the Amazon forest was to a substantial extent driven by state incentives (e.g., tax holidays, cheap credit, and government-sponsored land colonization schemes), but currently cattle ranching and agricultural cropping are often profitable in their own right [20]. Cattle ranching encompass a wide range of privately profitable operations [21] that become even more lucrative with road improvements and construction of meatpacking plants in production zones, thus reducing transportation costs [22]. At the same time, infrastructure development led to the expansion of soybean cultivation into the drier areas of the Amazon Basin, such as Mato Grosso and western Pará. Soybean cultivation typically replaces pastures rather than forests [23], but forests are nonetheless affected due to the displacement of cattle herds into forested regions [24].

Logging frontiers in the Brazilian Amazon typically precede the expansion of agricultural frontiers. Over the past three decades, logging frontiers gradually moved from the margins of the Amazon Basin (e.g., southern Mato Grosso and eastern Pará) to the center of the Basin (e.g., central Pará, southern Amazonas and northern Mato Grosso) [11]. In more remote areas, informal predatory logging violating

forestry regulations tends to be the norm. Some of the large-scale illegal logging is driven by timber companies working in public forestlands; in other cases timber comes from private landholdings, community lands, and extractive reserves [25].

3.3. Costs and Benefits from Improved Management versus *Business-as-Usual*

One often cited reason why loggers have not adopted improved management practices is that, contrary to the results of one prominent study in Eastern Brazil [26], reduced impact logging (RIL) or other best practices are less profitable than conventional logging. In lightly selectively logged lowland forest on the relatively level terrain in the Eastern Amazon, both loggers and society [26] seem to benefit from investments in planning and training for enhanced harvesting efficiency. In contrast, on more difficult terrain, such as in Malaysian Borneo, loggers complained that yields from RIL sites were substantially lower because harvesting was disallowed on steep slopes and in riparian buffer zones [27]. Regardless of the conditions, substantial financial outlays are needed for preparing detailed harvesting plans and training workers in directional felling and low-impact yarding techniques, but whether these costs are recouped apparently varies and adopting the full package of RIL practices may or may not be profitable. At this stage, it is not yet clear which of the RIL practices have the highest associated costs and benefits to different stakeholders and under different forest conditions [9,28].

Achieving and maintaining forest management certification has associated financial costs, even if all governance and regulatory conditions are 'ideal,' which is often not the case. Industrial loggers are more often able to pay these costs than communities and smallholders. A review of certification in Latin America shows that in the absence of donor support, the costs of certification are prohibitive for many community-based operations, which have often failed to maintain FSC certification once donor funding ceased [29]. In Mexico and Guatemala, many community-based operations are certified, but due to substantial and long-term assistance from governments and donors, community forestry in these two countries is particularly well developed [30-32].

Despite the progress achieved with community forestry and forest certification in Mexico, some smallholders in forested *ejidos* still choose not to undertake legal forestry operations, and some even clear their forests for agricultural purposes. Overall, the number of timber certified operations in Mexico is no longer growing, presumably due to high costs and failure to secure many financial benefits [33]. Notably in the state of Quintana Roo, six once-certified community forestry operations (108,000 ha) allowed their certificates to lapse for a variety of reasons including hurricane damage, low harvest volumes, and the lack of financial benefits from selling certified wood in national markets [34]. Similarly, the economic viability of certification in Acre, Brazil, is jeopardized because markets are flooded with cheap timber from predatory and/or illegal operations [35]; this situation is also familiar elsewhere in the Amazon region. Most fundamentally, forest certification efforts are being undermined by the failure of most markets to pay sufficient premiums for certified timber [36].

3.4. Insecure or Unclear Tenure and Forest-Use Rights

While generally better defined than in Africa and some parts of Asia, insecure or unclear tenure is still widespread in forested landscapes in Latin America. Lack of long-term, legally binding forest concessions and other forms of resource tenure agreements, particularly for public forestlands,

constitutes a major impediment to improved forest management [37]. Unclear tenure not only affects industrial logging, but also timber management undertaken by individual landholders and communities. Insecure tenure precludes solid contracts and raises financial discount rates [38].

Many governments in Latin America are in the process of delimiting public forests and granting forest rights to private landholders and communities [39,40]; in Brazil, public production forests are starting to be granted through a concession system [25]. These efforts are important but it is one thing to grant rights to individual landholders or communities, and another to assure that these actors have the capacity to enforce such rights when there are persistent competing tenure claims. The mere fact that many forest areas today have weakly enforced tenure may simply indicate that what they produce is not sufficiently valuable to justify the investment in firmly enforced property rights. Hence, granting rights and enforcing tenure security is not just a "policy issue" of either well-meaning or evil governments. It is just as much an economic question insofar as insecure conditions are to a large extent endogenously determined by the low value of the resources at stake, triggering (arguably rational) under-investments in full enforcement of property rights. REDD+ could provide big incentives to clarify tenure, alleviating the existing low interest of establishing clear rights because of the widespread inability to recognize fully forest values. A concern, however, might be that as tenure has not previously been established, it becomes possible for powerful actors to claim tenure under future REDD+ mechanisms potentially dispossessing the 'real' forest users.

The basic question about forest tenure rights thus becomes to what extent is it justified to invest public resources in their enforcement? Tenure rights are more likely to be enforced when these rights are linked to some specific actor's demands (e.g., private sector or communities). This is the case of the public forests granted to forest concessions, which cover 5 M ha in Bolivia [41] and 7 M ha in Peru [42]; an even larger area in Brazil currently being allocated [43]. Tenure rights also appear more likely to be enforced by communities that are able to formalize their tenure and usage claims. For example, about 197 M ha in the Amazon Basin have been or are being formally granted to indigenous people under a variety of arrangements; overall this corresponds to 25.3% of the territory [44]. A novel approach to granting forest use rights is the social forest concession idea being applied in Bolivia and Guatemala: to date, 0.7 and 0.5 M ha, respectively, of formal forest access rights have been allocated to what were only recently "informal" but often traditional local users [39]. Forestlands being granted to small- and large-scale private landholders could become an important supply of timber, e.g., along the Trans-Amazon highway in Brazil [45].

Ongoing efforts to improve forest land tenure are not entirely free of problems. For example, Bolivian forest concessions are threatened by encroachment by smallholders; neither private concessionaires nor the State are investing much to halt them. Similarly, many communities do not have the capacity to control informal logging inside their territories [41,46]. Another problem that is common in Mexico is that although land and forestry rights of *ejidos* are clearly defined by law, boundary disputes persist due to inaccurate delimitation during the agrarian reform processes. A first phase of a federal program aimed at land regularization (PROCEDE) has been finalized, but about 8% of agrarian zones (*nucleos agrarios*) were left out due to persistent and conflictive tenure issues or internal social problems. A recent study revealed that out of a sample of 120 forestry *ejidos*, 38% had unresolved boundary conflicts with another *ejido*, and about half considered that such conflicts negatively affected their forestry operations [47].

3.5. Inappropriate Policy and Regulatory Frameworks

Over the past two decades most Latin American countries reformed their forestry regulations, some repeatedly so (e.g., Bolivia, Ecuador and Peru). All forest policy reforms endeavored to promote SFM by clarifying rights to forest resources and by promoting the adoption of reduced-impact logging practices. They typically strengthened long-term concessionary rights, shifted from volume- to area-based stumpage fees that are easier to collect, and based the allocation of exploitation rights on public forestlands on public bidding. Unfortunately, the new rules were complex, sometimes to an unrealistic extent, and many did not acknowledge the diversity of forest ecosystems. They also typically imposed a relatively homogenous management model based on large-scale commercial logging even when actors and contexts were highly diverse. Often timber companies and local forest users (including indigenous people and smallholders) face the same rules, thus greatly increasing the transaction costs for the smaller operations.

Loggers and landowners justifiably complain that forest regulations are unduly complicated, were created by authorities that do not understand their socio-ecological contexts, and lack the financial resources needed to support adoption of the required practices. The requirement to comply with complex forest regulations to undertake commercial logging operations has created, in some cases, institutional barriers against local actors [39].

Community-based forest enterprises find it exceedingly difficult to manoeuvre through the complex of well-intended forest regulations [48]. One widespread reaction to this situation in Peru is that the new rules are generally being disregarded [42]. In Brazil, laws and regulations are also becoming highly complex, so that many loggers, including communities, are driven towards illegality [49]. Cumbersome procedures are also a problem in Mexico where the state lacks the capacity to process forest management permits in a timely fashion or to verify compliance on the ground [50]. Similarly, the suite of regulations in Mexico governing non-timber forest products are difficult to implement for species such as chicle (*Manilkara chicle*), camedor palm leaves (*Chamaedorea elegans*), and some wild mushrooms [51]. Generally, excessively complex and costly regulations discourage landholders from formally managing their non-timber forest products.

Some institutional issues add to the difficulties forest users face when trying to implement forest regulations. Public forest agencies generally have limited capacities to monitor compliance with forest management plans and to verify the legality of logs transported from production areas to processing centers. For example, in a high-profile operation in 2005, the Brazilian federal police arrested more than 100 industry and government personnel, including several from FSC-certified operations. Of the 12 FSC-certified operations in the Brazilian Amazon in that year, some suspended their operations because logging permits were almost impossible to obtain [12]. Although the Brazilian government has invested substantially in forest monitoring systems, the judiciary system is seldom as effective in sanctioning law breakers [52].

3.6. Lack of Trained Forestry Staff

The shortage of qualified forestry professionals, which is the norm across the tropics [53], serves to slow the adoption of improved management practices [8,54,55]. The largest forestry training program

in the Brazilian Amazon, the Instituto Floresta Tropical (IFT), currently trains only about 600 people per year [12]. Since 1995 this training initiative has played a key role in generating interest and capacity in RIL [56]; virtually every FSC-certified operation in the Brazilian Amazon can be linked to it. While IFT's contributions are substantial, over the past 15 years fewer than 5000 Brazilians received hands-on training in forest management [57]. If Brazil's vast network of public production forests is to contribute substantially to national REDD targets, then 27,000 to 33,000 trained forestry professionals will be needed [58,59].

With regard to community forestry operations in Mexico, the tradition of changing technical staff every three years in concert with the broader changes in community leadership results in regular losses in expertise which retard improvements in forestry operations. The community assembly designates forestry management functions through collective decision-making, but high turnover results in institutional memory loss and substantial costs for repeated training, costs with negative impacts on forestry operations [30].

3.7. Inefficiency and Waste in the Forest and Along the Market Chain

In selectively logged tropical forests globally, an estimated 20% of the volume of harvestable timber is either lost or purposely abandoned in the forest due to poor harvest planning, inappropriate felling and inefficient and wasteful bucking practices [60]. For the trees that are harvested, typically less than 50% of the total volume of usable bole wood reaches the mill. In most tropical sawmills, the yield of sawn timber from logs is often only 35%. The drying of sawn wood results in an additional 10% volume loss. Finally, when the dried lumber is processed into furniture or other products, the yield is generally less than 70%. Yields in the plywood sector are marginally better because mills are more efficient, but also because they only process high grade logs. Data on harvesting and processing efficiency in Latin America are scarce but generally correspond with this pattern [61]. Timber wasted in the forest (not including branch wood) reaches 30% in conventional logging operations [26], typical sawmill efficiency is below 50% and only about 50% of the sawn timber of high-value species makes it to the markets [61].

4. Proposed Ways to Improve Forest Management, Reduce Emissions, and Enhance Carbon Stocks in Production Forests

The following section presents some recommended policy changes that might improve forest management following the three realms introduced in Section 2. Some are related to the incentive structures needed to foster adoption of more sustainable practices, others are linked to the institutional conditions and systems required to improve land and forest resource governance, and another group relates to specific management practices. We also explore the complementary role of REDD+ for supporting SFM practices, since financial compensation to forest users may soon become available.

4.1. Stop Illegal and Tolerated Forest Frontier Expansion

There is a need to address some of the root economic factors that act as disincentives to SFM, mainly those related to the continued availability of substantial quantities of illegal and non-certified

timber together with timber that is a by-product of deforestation. As long as such supplies are abundantly available, it is hard to imagine much of a future for SFM in market-based economies. Measures needed to control illegal logging and deforestation include: (a) improve command-and-control systems to enhance legality; (b) stop illegal takeovers of public lands, including protected areas and other sources of illegal timber extraction; (c) increase public institutional presence in frontier regions; (d) promote efforts at forest product legality assurance and full forest management certification; and, (e) use internationally generated REDD+ transfers to pay for these efforts, once their carbon mitigation impacts have been assessed. It is important to note that proponents of SFM cannot expect automatic allocation of REDD+ funds; rather, the case will have to be made that substantial additional carbon can be maintained by switching from conventional logging to improved forestry practices. Securing REDD+ support will also require careful analyses of the often country-specific bottlenecks to adoption of RIL and other SFM-favouring modifications of current practices and how REDD+ resources should be most efficiently allocated to alleviate these constraints.

4.2. Develop Incentives to Improve Management

To promote improved forest management, taxes, subsidies, and market-based instruments (MBI) can help internalize the social costs and thereby match societal benefits with private returns, while otherwise stimulating changes in entrepreneurial behavior [38]. Forest certification is a familiar MBI established to promote the adoption of sound forest management practices, but performance bonds can also serve the same purpose. These refundable bonds are deposited in a governmental account at the beginning of the concession period and gradually returned to the concessionaire if harvesting is executed in accordance with RIL and other standards; fines for noncompliance are deducted, as appropriate, thus increasing environmental leverage. Performance bonds can also compensate, at least in part, for the discounting challenge to long-term management; by ensuring that concessionaires receive income gradually, especially towards the end of the rotation period, bonds can help induce less myopic behavior [62]. In developing such a bonds system, it is essential to design mechanisms to avoid exclusion of small-scale actors who might like the resources to invest upfront and to avoid tentative plans by corrupt operators or governments to default payment.

4.3. Foster more Third-Party Certification

Voluntary, third-party certification represents a fairly recent approach in the long history of attempts to improve tropical forest management. Certification has its detractors, and the mechanism is not flawless, but at least the FSC takes into account social, ecological, and economic considerations, and so avoids some of the shortfalls of previous approaches and policies that tended to consider only part of the picture. The key question concerning this market-based incentive is what limits its wider adoption and effectiveness?

Ultimately, financial constraints explain why many forests, particularly community-managed ones, are not yet certified [53,63,64]. There is an overall consensus (but few supporting data) that certification is causally linked to improvements in regard to biodiversity , future yields of timber and non-timber forest products, carbon retention, and various other ecosystem services [65,66]. In some cases certification even works where governments have little willingness to enforce forestry

regulations. That said, in addition to needing favorable market conditions, certification works best where, forestry laws are enforced, financial incentives for certified forestry are available, and land tenure is reasonably secure [63].

Given that certified forests incur less damage and store more carbon within residual stands, supporting forest certification could be another way to use REDD+ funds [66]. The FSC is working to reduce certification costs for small and low intensity managed forests, but further incentives or subsidies are needed [63]. Such incentives are critical for small firms, including communities that harvest only small volumes of timber for local markets in which there are no "green premiums. Where the carbon benefits of improved forest management relative to a baseline of conventional practices can be documented, a REDD+ fund for certification could help assure the social, economic, and environmental soundness of forestry operations. Of course special attention will need to be paid to the structure of these payments to avoid possible perverse incentives from REDD+ subsidies such as reducing harvesting intensities to retain carbon but then harvesting larger areas.

4.4. Develop Incentives to Enhance Carbon Stocks in Logged, Burned, and Otherwise Degraded Forests

A wide range of methods are available for restoring degraded forests ranging from letting forests regenerate on their own to actively managing degraded areas to accelerate regeneration and growth. Both methods are appropriate for most of the 60% of tropical forests that were degraded in the latter half of the 20th Century—about 1,084 million ha [66]. For example, a REDD+ restoration intervention to encourage natural recovery might use a combination of actions to control illegal logging, promote reduced-impact logging, lower logging intensities, reduce damage from grazing animals, and control wildfires. This approach has been successful in Costa Rica and Puerto Rico where deforested areas recovered their old-growth biomass and species richness after only 30–40 years [68]. A more active restoration approach is to accelerate recovery by controlling species that compete with natural regeneration, or by augmenting regeneration with planted seeds, seedlings, or cuttings. There are many successful examples of these more active restoration treatments across the tropics [69,70].

4.5. Increase Security of Tenure and Resource Access for Forest Owners and Concessionaires

Transferring rights to communities, especially those that depend on forest resources, often helps promote forest conservation while also improving local livelihoods [71]. One study of 80 forest commons in 10 tropical countries reported that carbon stocks increased with the size of the forest, the authority to make decisions locally, and community ownership [72]. Nevertheless, as necessary as clear rights over forest resources can be, they do not constitute a sufficient condition to promote SFM. The actual efficiency of tenure security in promoting forest management and conservation depends on many market and institutional conditions that determine the ability of communities to realize their property rights and benefit from the management of their resources [40,41].

Securing long-term access for concessionaires to public forests may promote good management, but rigorous auditing mechanisms are needed to ensure good practices. Particularly in areas with extensive forests and limited public infrastructure, well-run forest concessions can help maintain forests while providing social benefits [73,74]. Similarly, community ownership or secure private tenure or usage rights seem to be prerequisites for good management, but are not sufficient to prevent owners from

acting in ways that impose social costs on others, for example by converting forests to other uses. For one thing, illegal logging does not stop when forests are held in common [75,76]. Therefore, in addition to secure tenure, other more conservation-targeted incentives are required to improve forest management, which REDD+ could co-finance.

4.6. Increase Efficiency of the Forest Sector Through Appropriate Taxation

Wood wastage along the market chain from the forest to the final product results partially from the design of tax and royalty systems. When levies on harvested timber are collected far from felling sites, timber that does not make it to the assessment point is not accounted for, and can be wasted without penalty. To maximize recovery of felled timber, royalties should be assessed as close to the stump as possible. Ideally, taxes should be calculated on the basis of gross standing volumes (clear bole volumes of standing trees). This approach would encourage concession holders to minimize wastage due to poor felling, poor bucking, and otherwise inefficient log utilization. A somewhat less favorable alternative would be to calculate royalties in the forest according to the volume felled. To make any of these approaches work, large numbers of corruption-resistant governmental field staff are needed, along with the funds needed to incentivize good behavior (e.g., ensuring proper salaries, benefits, rewards, making sure that trespassers are punished…) and to allow them operating independently in harvesting areas. Advances in remote sensing technology now make it possible to monitor whether logging is occurring where authorized, but assurances of good harvesting practices can only be provided by trained staff working in the forest. REDD+ could help co-finance some of these incremental costs.

4.7. Simplification of Management Rules and Regulations

One major lesson learned from decades of efforts at improving tropical forest management is that forestry regulations need to be simplified and adapted to the local realities of the diverse range of forest users. In particular, the procedures for developing and approving forest management plans and mechanisms for verification of compliance need to be made more feasible for the full range of logging operations, especially smallholders and small-scale sawyers. The minimum set of rules to be applied should vary with forest type, size of logging operation, and intensity of management, so as to allow for the flexibility in management practices that reflects differential forest user goals.

4.8. Promote Enhanced Use of Reduced-Impact Logging (RIL) Techniques

Substituting conventional logging by RIL through the effective implementation of regulation and/or incentive mechanisms would be a major step towards SFM, and would substantially reduce carbon emissions from logged forests. Putz *et al.* [5] estimated that a switch to RIL in forests legally managed for timber harvesting would reduce global carbon dioxide emissions by 0.58 Gt per year. Post-logging silvicultural treatments would double this benefit (see below). Longer-term benefits of RIL practices accrue to forest owners, long-term concession holders, and climate-conscious citizens around the world, because RIL-logged stands regenerate more quickly than those logged conventionally. Recent

studies of post-RIL forest recovery suggest that the long-term carbon benefits of RIL are being substantially underestimated [57].

4.9. Where Necessary to Sustain Timber Yields, Promote Post-Logging Silvicultural Treatments

Substantial evidence is now available that in some cases even dutiful application of RIL techniques will not guarantee that timber yields will be sustained [5]. Shortfalls in future timber yields after RIL can be avoided by reducing harvesting intensities [77], but a complementary option is to apply post-logging silvicultural treatments to enhance regeneration and growth rates of commercial species. For example, in Bolivia, industrial-scale silvicultural research revealed that in addition to application of basic RIL guidelines, collateral damage to future crop trees (FCTs) was substantially reduced if they were clearly marked prior to logging [78,79], and releasing FCTs from local competition including their liana loads after logging [69,70]. These treatments also promoted post-RIL regeneration of commercial timber species [80]. Even populations of over-exploited species such as mahogany can recover with application of appropriate silvicultural treatments [81].

4.10. Train Forest Workers and Reward Them Appropriately

Given how little it costs to train an experienced forest worker in RIL techniques ($ 500–1,000 per worker in Brazil and Guyana; [58]), the continuing degradation of forests because of lack of skilled personnel is not justifiable. Irrespective of the ancillary benefits of training, such as worker safety, biodiversity retention, and riparian zone protection, REDD+ investors will still need estimates of the carbon benefits derived from training forest workers in RIL. Remuneration systems for forest workers need to reward those who effectively apply these best harvesting practices. Payment systems that include a fixed monthly salary, a piece rate bonus, and a reward dependent on work quality would motivate workers at little additional cost. Such incentives are needed even where RIL practices benefit logging contractors and forest owners so as to assure that the benefits are shared by forest workers [9].

5. Conclusions

Several economic, governance, and technical issues impede rapid advance towards SFM in Latin America. In the economic realm, the key factors are often the high opportunity costs of maintaining forests and the limited economic benefits, if any, from improved *versus* conventional logging practices when there are few other incentives for promoting sound forest management. In the governance realm, while forest governance has improved through forest tenure reform and changes in forestry regulations, land tenure problems persist in forested landscapes, and failure to enforce forestry regulations still limits a wider adoption of SFM. Finally, the lack of trained staff and inappropriate wage systems, together with inefficiencies and waste along the production and market chain, constitute the main technical impediments for adopting improved management practices.

We outlined various ways how obstacles in the way of SFM could be surmounted, some linked to the development of incentives for adoption of better management practices and others to simplification and enhancement of regulatory frameworks for management and taxation. At the same time, other structural and institutional conditions need to be improved, such as those related to clarifying and

securing land tenure and ensuring law enforcement. In addition, we suggest that making progress towards good forest governance, including effective enforcement of management regulations backed by meaningful financial incentives, can contribute to a more widespread adoption of improved management practices. Some of the reforms we suggested would benefit directly from REDD+ funding injections (e.g., incentives for SFM, training or land-tenure reform) while others could, in principle, be cost-neutral but still indirectly benefit from REDD+ funding to alleviate the political economy obstacles that have impeded their implementation (e.g., forestry tax reforms or simplifying regulations). On aggregate, the use of compensation mechanisms linked to REDD+ might play a role in providing additional incentives, to the extent that improved forest management can have an important role in lowering net GHG emissions by decreasing rates of forest degradation and increasing carbon stock recovery in logged forests. Nonetheless, a package of incentives and disincentives promoting REDD+-led SFM needs to be well-designed so as to avoid perverse effects where timber subsidies at the extreme could be driving the logging frontier out into pristine areas that would otherwise not have been affected.

The potential carbon benefits of SFM related to REDD+ could be:

- First 'D' (reduction of emission from deforestation): Higher economic value of well-stocked residual stands and thus less incentive to convert them which would translate into less carbon released in the atmosphere;
- Second 'D' (reduction of emissions from forest degradation): Residual stands retain higher commercial value, regenerate more quickly, and are more resistant and resilient in regards to climate change, and less carbon is released in the atmosphere because of fewer fires;
- '+' (enhancement of carbon stocks): Better management generates co-benefits including biodiversity protection and maintenance of ecosystem services (e.g., watershed functions).

Readers familiar with the tropical forest management literature will have noticed that few of the problems we describe or recommendations we make are genuinely new. What is new is the attempt to provide a comprehensive analysis of the factors impeding progress towards SFM in the context of a renewed interested in tropical forests by the international community, thanks mostly to the growing importance of the climate change agenda and the resultant possibility of the use of REDD+ funds to promote improved forest management. To inform current debates, we suggest that avoided deforestation (the First D) will principally reward strict forest preservation efforts. Avoiding degradation (the Second D) and enhancing forest carbon stocks (the +) in SFM-based solutions can in turn provide attractive productive-sector complements to use-restricting avoided deforestation. For that potential to be realized, we recommend country-specific analyses of SFM adoption obstacles and the further quantification of SFM mitigation potentials *vis-à-vis* business-as-usual baselines.

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