Sustainable forest management in the tropics: between myth and opportunities

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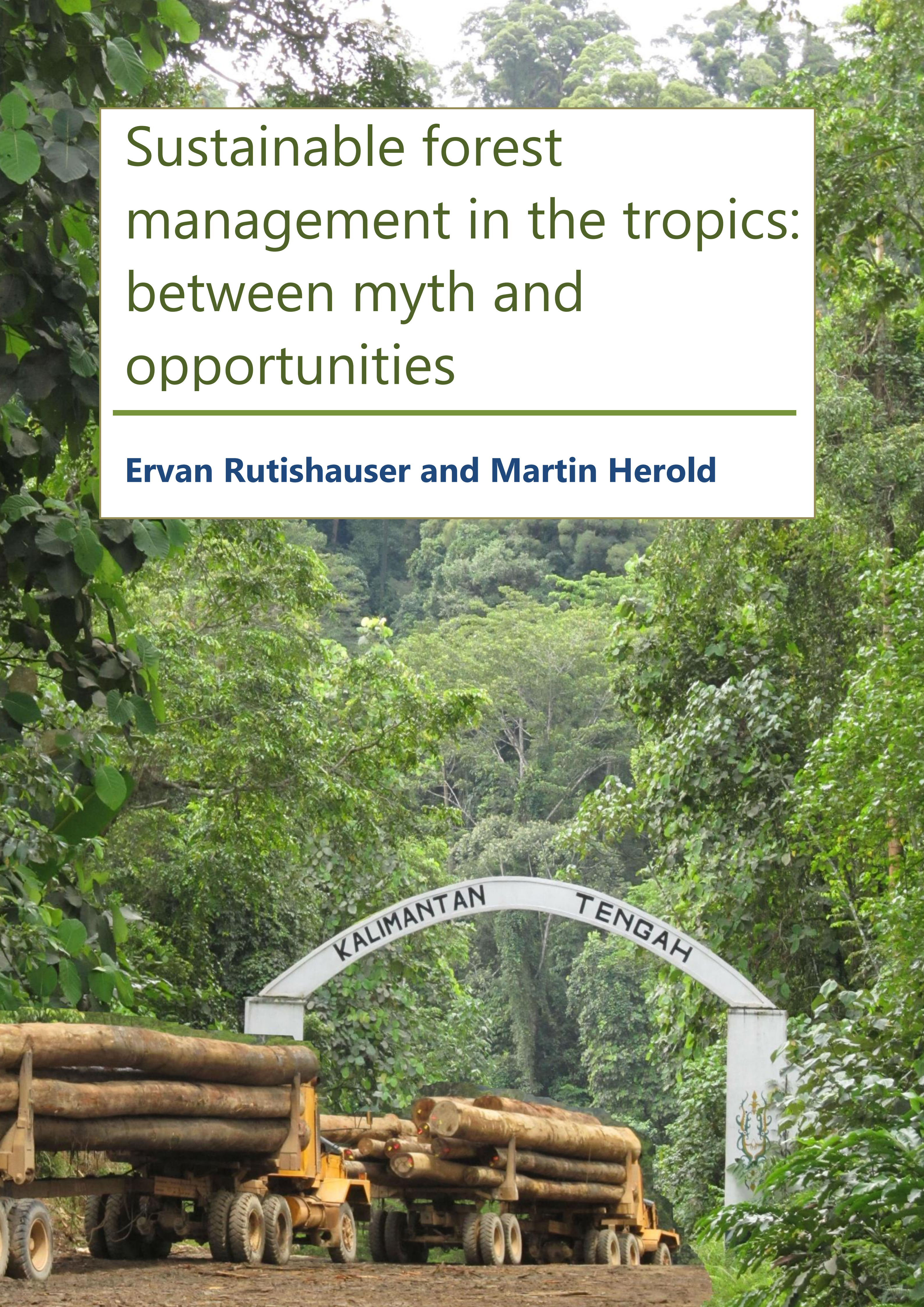

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Foreword

This review aims to provide a general overview of current trends, practices, knowledge and challenges in tropical silviculture. This review is not a systematic review, and is not intended to be exhaustive. The opinions and ideas exposed here shall only reflect the author's personal perception of tropical forestry.

Aim of this review

In 2007, the Bali Action Plan's wording on REDD+ inter alia, endorsed the role of "conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries" for climate change mitigation. Sustainable Forest Management (SFM) is wider defined as "a dynamic and evolving concept aiming at maintaining and enhancing the economic, social and environmental value of all types of forests, for the benefit of present and future generations" (UNFCCC, 2011a). Concretely, SFM regroups a beam of actions (e.g. improved planning, better harvesting techniques, protection of areas of high ecological value, certification) aiming at reducing negative ecological impacts of logging, while promoting long-term economic viability of the forestry sector. While there is growing agreement on REDD+ and financial opportunities to maintain tropical forests carbon stocks, very little is known on efficient ways to maintain and enhance those stocks in either natural, or managed forests. Still, several developing countries are looking to include SFM in some form in their REDD strategies, either as interventions aimed at reducing emissions, or as parts of their REDD+ investment frameworks. The aim of this review is to provide **an objective assessment of the effects of wood harvest in tropical forests** and **identify current knowledge gaps**.

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Executive Summary

Tropical forest ecosystems are playing a key role in climate regulation and the global carbon cycle, sequestering annually 2.2–2.7 Gt of carbon[1]. At the same time tropical forests are still disappearing releasing more carbon than these ecosystems are sequestering[2]. Forest degradation (i.e. logging, shifting cultivation and fuelwood harvest) is estimated to contribute up to 3% of annual emission related to human activities. Decades of no or poor forest management has left millions of hectares of forests degraded, and prone to rapid agricultural conversion. Re-assessing the values of logged forest and benefits of sustainable management could help both conserving the remaining 'primary' forests and maintaining high ecosystem and economic values in production forests. Reducing deforestation and improving forest-related activities are among the most economically feasible and cost-effective mitigation strategies. However, how to conceal commercial exploitation of tropical forests with their conservation remains an open-question. This report aims to provide a brief overview of state-of the-art in forest science and management practices in the tropics. Ten key facts are summarized below:

1. More than 85% of the remaining tropical forests have been affected by some sort of human activities; most of them leading to widespread forest degradation and loss of carbon stocks.
2. Whereas planned management is reported in the majority (80%) of forests available for harvest, lack of training of field crew and external controls favour detrimental practices.
3. Despite its known advantages, Sustainable Forest Management (SFM) is carried out in about 18% of active production forests in the tropics.
4. Detrimental logging practices and lack of institutional regulation further enables the rapid expansion of illegal logging and conversion of degraded forests to other land uses.
5. Even though some progresses were made towards better forest governance and regulation, long-term investments required by SFM are hampered by low timber prices, lack of financial incentives and unsecured land tenure.
6. There is a lack of studies assessing the whole range of benefits (i.e. social, environmental and economic) when implementing SFM; providing little evidence of synergies when changing to SFM.
7. SFM could play a significant role in climate change mitigation efforts in reducing the negative environmental impacts (e.g. loss of biodiversity, carbon emission) of industrial logging.
8. Implementation of a strong and adequate policy framework is required to ensure that SFM is effectively implemented in the field.

[1] Pan et al. (2011) A Large and Persistent Carbon Sink in the World's Forests. *Science*, **333**, 988–993.
[2] Baccini A. et al. (2017) Tropical forests are a net carbon source based on aboveground measurements of gain and loss. *Science*.
[3] Lands abandoned by agriculture or left to the recovery of shrubs or invasive herbaceous species.

9. Emerging markets and trade agreements, such as FLEGT or timber certification schemes, are showing encouraging results in integrating economic, social and environmental aspects, but represent only 10% of production forests.
10. Preventing opening of intact forests remains a priority and could be achieved by enhancing the recovery and proper management of managed forests.

Overall, this report points out that preserving intact forests, encouraging sustainable management of production forests and developing a restrictive forest policy framework appear as a best (but hard to attain) compromise. Enforcement of SFM at national-level could be generalized through better forest regulation and control, notably in REDD+ Country participants that have already pledged to reduce deforestation and improve forest management. Identifying pathways for successful inclusion of SFM in REDD+, however, requires further studies looking at social, environmental and economic dimensions of SFM, involving the relevant stakeholders, to shift towards better practices in tropical forestry.

1. Overview of wood harvest in the tropics

Forests are a source of food, fuel, and income for millions of people globally (FAO, 2016a). Interactions between forests and people are of significant interest to government agencies, private sector actors, and NGOs, who fund and implement conservation and development projects to improve environmental and socio-economic outcomes in and around forests. Such interest is mounting, particularly in the context of forest certification, payments for environmental services programs, and forest-based climate change mitigation mechanisms (e.g. REDD+) that aim to achieve both forest conservation and socio-economic development (Kanowski et al., 2011). While there is a plurality of human interactions with forests, this synthesis will mainly focus on activities that maintain forests standing, as opposed to conversion to agriculture or other land-uses.

Different forest products and usages have different ecological consequences. While non-timber forest products are generally harmless for forest ecosystems, fuelwood and timber harvest may have strong negative effects. While being circumscribed to some regions of Africa and Brazil, fuelwood collection has been reported to be a major threat for dry and small-area forests (Hosonuma et al., 2012; Rüger et al., 2008; Specht et al., 2015). Operating at wider scale and in all tropical forests, industrial timber harvest, also referred hereafter to as "logging", has received more attention over the past decades. Indeed, the commercial extraction of timber remains a major source of national income in several developing countries (Agrawal et al., 2013).

1.1 Deforestation versus forest degradation

While deforestation in the tropics has been widely addressed, forest degradation remains challenging to define and assess (Simula, 2009). The main difficulty lies in current limitation in accurately capturing the temporal and spatial extent of forest degradation (Thompson et al., 2013). If logging is generally considered as the main driver of forest degradation across the Tropics (Hosonuma et al., 2012), it may or not trigger forest conversion to other land uses. The fate of logged forests depends on a complex set of factors, such as distance to settlements, land tenure, law enforcement or global demand for commodities (Asner et al., 2006; Hosonuma et al., 2012; Hurtt et al., 2006). In many countries, degraded forests are poorly perceived by decisions makers and are generally devoted to agriculture expansion (Foley et al., 2011). If logging is often seen as a precursor of conversion to other land uses (Griscom et al., 2009; Pacheco et al., 2011), some studies provide a contrasting view where logging concessions exhibit lower deforestation rates than other surrounding forests (Gaveau et al., 2013; Karsenty et al., 2017).

1.2 Extent & role of timber production forests

Over 761 million ha of natural forests in International Timber Trade Organization (ITTO) member countries[3], 403 million ha (52%) have been designated to timber production by national governments; the rest being protected (Table 1, Blaser et al., 2011). On average 18.5% of actively managed forests is considered as sustainably managed, i.e. verifying that long-term (ten years or more) forest management plans are being implemented effectively. However, these figures mainly depict the industrial logging sector, omitting illegal logging. A broader, but probably more realistic, view of total forest extent under some form of human pressure is given by the Intact Forest Landscapes (IFL) initiative that maps 'continuous expanse of natural ecosystems within the zone of current forest extent, showing no signs of significant human activity' (Potapov et al., 2009). In 2013, between 86.4 and 93.4% of all forests found in the three main tropical basins were affected by human activities, allowing to conclude that managed forests are nowadays probably more abundant than unmanaged forests (Laurance and Edwards, 2014).

Region	Natural	Protection		Production		Available for harvesting		With management plans		Certified		Sustainably managed	
	mio ha	mio ha	(%)[a]	mio ha	(%)[a]	mio ha	(%)[b]	mio ha	(%)[c]	mio ha	(%)[c]	mio ha	(%)[c]
Africa	112	43.7	39.0	68.2	60.9	45.7	67.0	28	61.3	4.63	10.1	6.56	14.4
Latin America*	482	256	53.1	227	47.1	56.9	25.1	44.7	78.6	6.02	10.6	9.51	16.7
Asia/Pacific	167	58.4	35.0	108	64.7	62.8	58.1	58	92.4	6.37	10.1	14.5	23.1
Total	761	358	47.0	403	53.0	165	40.9	131	79.4	17	10.3	30.6	18.5

Table 1 : Categories of permanent forest estate (PFE) among ITTO producers (representing c. 85% of world's tropical forests) by region in 2010 (Blaser et al., 2011). Natural PFE (100%) are divided into protection and production forests. Detailed of production forests is given in light blue. ꜛ : allocated as concessions, under harvesting licences, or communities management. *a*, *b* and *c*: relative to total natural forests, total production forests, total available for harvesting, respectively. * incl. the Caribbean

1.3 Socio-economical role of tropical forestry

The socioeconomic benefits from forests are mostly derived from the consumption of forest goods and services. The number of people that use forest outputs to meet their needs for food, energy and shelter is in the billions (FAO, 2014). Globally, human populations are all indirectly benefiting from forest services, such as climate regulation, carbon sequestration or water purification. Narrowing down to the

[3] ITTO member countries producing tropical timber are Benin, Cameroon, Central African Republic , Congo, Côte d'Ivoire, Democratic Republic of the Congo, Gabon, Ghana, Liberia, Madagascar, Mali, Mozambique, Togo, Cambodia, Fiji, India, Indonesia, Malaysia, Myanmar, Papua New Guinea, Philippines, Thailand, Vietnam, Brazil, Colombia, Costa Rica, Ecuador, Guatemala, Guyana, Honduras, Mexico, Panama, Peru, Suriname, Trinidad and Tobago. ITTO members represent about 85% of the world's tropical forests and over 90% of the global tropical timber trade.

forestry sector, more than 13 million people are employed in the formal forest sector (i.e. production and sale of sawn wood). This number increases to 40-60 million people when the informal sector (i.e. woodfuel and unrecorded forest products used for construction) is included, contributing to nearly 1% of global GDP in 2011 (FAO, 2014). However, the lack of systematic data makes it near impossible to estimate closely how many people are employed in the forest sector (Agrawal et al., 2013). Beyond employment, where such data are reliably available, the non-cash economic contributions of forests to household and national economies range between 3 and 5 times the formally recognized cash contributions. Thus, forest management for timber production in natural forests still play an important role in the economic development strategies of many tropical countries, where the forestry sector generates significant revenue for public institutions and governments. For instance in Cameroon, forests generate 25% of public revenue through timber taxes and other fiscal instruments (OECD, 2008).

2. Logging in the tropics

2.1 Past and current practices

Forest management planning is the core element of forestry. In its simplest way it applies planned "cut and wait" management, but could also imply biometrics or growth and yield information in more sophisticated management. Forest management planning generally start at national level, by zoning forests in broad categories (often defined in national legislations): productive, conservation, and/or socioeconomic functions.

Once forest functions are identified, they are grouped according to their compatibility with timber production. Two groups of functions are distinguished: (1) functions that preclude logging and (2) functions that allow logging, but with some restriction on silvicultural and harvesting technology. This process is called forest zoning. Once production areas have been identified and mapped, yield regulations are defined and consist in calculating the amount of timber that may be harvested annually, or periodically, from a specified forest area over a stated period of time in accordance with the principle of sustained yield and other management objectives. It includes the calculation of an *annual allowable cut* that generally correspond to the volume increment of live standing trees over a year in a production area (Pancel et al., 2015). For instance, in South America, *annual allowable cut* ranges between 10-30 m^3 ha^{-1} over a cutting cycle of 30-60 years (Blaser et al., 2011). However, several countries do not have set annual allowable cut (M. Peña-Claros, personal communication). Between 2005 and 2010, the area of natural forest under some sort of management plans in ITTO producer countries increased by 69 million hectares to 183 million hectares, corresponding to c. 50% of total production forest extent (Blaser et al., 2011). The overarching objective of forest management in the tropics is "the sustainable production of timber to provide a perpetual flow of wood products and revenue, whilst maintaining environmental quality and social responsibility". However, forest management in the tropics has traditionally concentrated on timber harvesting, based on the principles of sustained yield management using low intensity selective harvesting and natural regeneration as a silvicultural tool (Knoke, 2015). The vast majority of current timber extraction remain "conventional", and consists in selectively harvesting a few commercial species. Despite relatively low intensity of extraction (i.e. 1-10 trees per hectare), conventional logging generates considerable damages to the surrounding forest, either due to the fall of large trees, incidental damages, extraction of logs or the creation of logging roads (e.g. Picard et al., 2012; Pinard et al., 2000; Sist and Nguyen-Té, 2002). In order to minimize those negative effects, Reduced-Impact Logging (RIL) techniques were put in force in the 90's (see 4.2).

2.2 Sustainability of conventional timber production

Sustainability is here broadly defined as 'the capacity of a forest ecosystem to recover the amount of wood that has been extracted within a cutting cycle (or maintain the yield from first cutting-cycle over time)'.

a) Timber stocks

While we lack insight in long-term forests response to logging, most studies that have explored the sustainability of logging, in terms of recovery of initial timber stocks, are generally concluding that conventional logging is unsustainable. All studies pointed out that the recovery of initial timber stocks were lasting (much) longer than the usual 30-60 year cutting cycle enforced in most tropical countries (Dauber et al., 2005; Keller et al., 2007; Macpherson et al., 2012; Sasaki et al., 2012). On the other hand, when harvesting was done with care through implementation of Reduced Impact Logging techniques, timber stocks were almost fully recovered over 2-3 decades (Putz et al., 2008; Roopsind et al., 2017; Vidal et al., 2016).

b) Biodiversity

If logging remains generally highly detrimental for the environment in the tropics, it is usually done extensively and allows the retention of a large fraction of initial carbon stocks and biodiversity (Edwards et al., 2014b; Putz et al., 2012). In a recent meta-analysis, Burivalova and colleagues (2014) found that the species richness of invertebrates, amphibians, and mammals decreased as logging intensity increases, with a magnitude that varies with taxonomic group and continental location. In particular, mammals and amphibians would suffer a halving of species richness at logging intensities of 38 m^3 ha^{-1} and 63 m^3 ha^{-1}, respectively. Similarly, the repeated harvest of a few commercial species is altering their capacity of reproduction and genetic diversity (Jalonen et al., 2014). By creating large gaps, fast-growing light-wood species are also favoured, having uncertain consequences on the future ability of managed forest to produce hardwood and to cope with climate changes (Fargeon et al., 2016; Macpherson et al., 2012)

c) Carbon cycle

In a recent assessment of greenhouse gas emissions from tropical forest degradation in 74 tropical countries, Pearson et al. (2017) found that emissions associated with timber harvest accounted for more than half of the total degradation emissions (53%), followed by woodfuel (30%) and fire (17%). Emissions from forest degradation represent a quarter of total emissions from deforestation and forest degradation. Globally, deforestation and forest degradation were identified among the most important single sources of global greenhouse gas emissions (GHG), contributing up to 12% of total annual anthropogenic emissions (Van der Werf et al., 2009). Thus, the expansion of logging in the tropics could challenge efforts to mitigate climate change. When 2 million ha of Amazonian forests are disturbed by selective logging each year, more than 90 Tg of carbon (C) is emitted to the atmosphere. But those emissions are counterbalanced by forest regrowth over a few decades (Piponiot et al., 2016). For instance, in well managed Amazonian forests, post-logging regeneration was found to be relatively fast, and losses of 10, 25 or 50% of pre-logging C stocks requires 12, 43 or 75 years, respectively, to recover (Rutishauser et al., 2015). Under current forest management regulations (e.g. 30–60 years of cutting cycle & harvest intensity of 10–30 m^3 ha^{-1}), managed forests require between 7 and 21 years to recover their initial carbon stocks. High logging intensity, as in Borneo where it can reach 150 m^3 ha^{-1}, and post-logging disturbances (e.g., fire or illegal logging), that many logged forests are experiencing, will undoubtedly threaten forests resilience to logging. Most recent studies on impacts of logging on carbon storage remain circumscribed to alive, and sometimes dead, trees, but omit other carbon pools, such as coarse wood debris (CWD), litter, dead roots or soil organic carbon. However, half of tropical forest carbon is found in above-ground plant biomass (AGB), the remainder being found in below-ground biomass (BGB), coarse woody debris (CWD), litter and topsoil (Malhi et al., 2009). Moreover, a recent multi-site study revealed that harvested trees form only 20-40% of living biomass loss (or direct carbon emissions) related to logging (Pearson et al., 2014). The remaining lies into biomass left on side as coarse wood debris (e.g. crown, left-over felt trees, stumps) and post-logging mortality of damaged trees. Logging activities are likely to drastically affect all carbon pools by removing immediately a large fraction of AGB (Sist et al., 2014), generating large amount of CWD, litter and dead BGB (Keller et al., 2004), compacting soil (Pinard et al., 2000) and affecting nutrients balance (Olander et al., 2005). Accounting for the whole carbon budget of timber harvest is required to get a full understanding of the impact of current practices and the role played by logged forests in sequester carbon on the long-run.

2.3 Outlook of logging concessions & practices by region

In 2015, FAO, in partnership with ITTO, CIFOR and CIRAD, lead an initiative entitled "*Making forest concessions work to sustain forests, economies and livelihoods*" aiming to positively influence political dialogue at the international and regional levels on the role of forest concessions, and to provide practical guidance to countries in the design, implementation and evaluation of forest concession systems that better respond to their economic, social, institutional and environmental goals. Broadly defined, concessions are 'a legal arrangement whereby a government (or authority in control) concedes a grant or privilege which allows the concession holder some form of benefits'. Detailed country profiles were done through interviews of different local stakeholders, and most information summarized below arises from those regional reports (FAO, 2016b, 2016c, 2016d).

2.3.1. Africa

Concessions are covering almost 56 million ha in West and Central Africa (30% of the total tropical moist area). Altogether, the concessions produce around 10 million m^3 of roundwood each year. A similar volume of timber is likely to be mobilized by the artisanal/informal sector, sourced principally outside the concessions but with significant encroachments inside the concessions when those are surrounded by large population. In African moist tropical natural forests, logging is highly selective, due to the high diversity of species and their heterogeneity with respect to their processing aptitude and market demand; and the high transport costs, often dependent on road operations. Depending on the road infrastructure and transport costs, extraction range between 10 and 40 m^3/ha, likely to decrease while concessions are entering their second cutting cycle. Indeed, most 'primary' production forests have been exploited within the 'perimeter of profitability' (depending mainly on transport infrastructures) of forest estate in Central Africa. Management plans are mandatory in all African countries and are generally prepared by the concessionaires themselves. Although the implementation of management plans should be seen as an absolute precondition for keeping the concession, in reality, the majority of non-certified concessions (or those having certification of legal sourcing or timber, even though this is less stringent) does not implement fully their management plans, and many do not implement it at all.

With reduced availability of traditional commercial species, the industry has started to diversify its timber resource. These will require important investments in both processing and marketing, but concessionaires do not appear to have the resources to make such investment. Carbon credits will probably not benefit forest concessions in Africa, despite the eligibility of 'Sustainable Forest Management' into REDD+ scheme. Increasing minimum harvestable diameter, and, to a lesser extent, extending the cutting cycle length could increase carbon stocks, but at high opportunity costs (i.e. loss of timber volume extracted and income). Given the current difficulties with the carbon markets and the low carbon credits' prices, perspectives are limited. In addition, the issue of non-permanence is a serious one, given the frequent changes in ownership of the concessions – and also the risk of conversion, though this risk is often lower than in forest areas outside concessions.

2.3.2. Asia

A typical characteristic of Southeast Asian forests is the prevalence of the Dipterocarpaceae family of trees, predominant in the forests of Borneo, Sumatra, Java, Peninsula Malaysia and moister parts of the Philippines. Timbers from the family dominate the Southeast Asian timber industry as it produces long, straight and knot free logs which are ideal for plywood and sawn timber. The dense commercial stocking of forests in Southeast Asia have made it the world's leading tropical log

producing region (85.56 million m^3 in 2012 to be compared to tropical Africa that produced 28.50 million m^3 and Latin America 39.94 million m^3).
All countries in Southeast Asia have developed their own selective logging systems under some sort of forest management planning. Licensed areas are divided into annual coupes (or areas to be logged in a year) where both logging and harvesting is mostly mechanized. In most South East Asian countries, information on allocation of forest areas is hard to get, due to lack of transparency, or lack of official data (i.e. no record of the number and size of concessions). Land tenure was also reported to be a major issue, as concessions often take place on lands of local communities (i.e. indigenous or forest dependant people). If some locals are hired by concessionaires, local communities are generally evicted from concessions, with little or no support from governments. Logging practices are still largely perceived as unsustainable, remaining detrimental for the environment and creating wide social conflicts. The biggest obstacle to SFM is the security of land tenure. Fearing to lose their permit, concessionaires are reluctant to invest in infrastructure and implement sustainable forest management; favouring a 'cut and run' approach to maximize profits. As a consequence, forest area under certification is still very low, representing only 3% of total forest estate in the region.

2.3.3. South America

Almost half of the total area of Latin America is covered by forests, representing approximately 22% of global forest cover. The main challenge for governments in the region is to address deforestation, which has declined in recent years, but remains high (Hansen et al., 2013). Encouragingly, by contrast, the forest area designated for the conservation of biodiversity has grown by 3 million hectares per year since 2000. From 2000 to 2010, 16.9 million ha of Amazonian forest were converted to human-dominated land uses, such as agriculture (Souza et al., 2013). In the time, an additional 5 million ha of forest was directly altered by timber harvesting and/or fire, equivalent to 30% of the area converted by deforestation. While deforestation declined by 46% from 2000-2005 to 2005-2010, annual forest degradation increased by 20% (Souza et al., 2013). Predatory forest exploitation and conversion are often financially more attractive than planned management (Pearce et al., 2003). Further, societal pressure for improved forest management is dampened because forest resources are perceived as being abundant in the region.
Most countries in the region have robust forest industries sustained by concession systems that provide consistent volumes of logs, thus generating employment, government revenues and development impacts in under-serviced areas. Log volumes from Brazil's state and federal concessions are increasing and concessions in Suriname, Mexico and Guatemala maintain regular volume levels. Over the past decades, forest policy reforms endeavoured to promote SFM by clarifying rights to forest resources and by promoting the adoption of reduced-impact logging practices. Unfortunately, the new rules were complex, imposing a single "fit-them-all" management model to both timber companies and local forest users (including

indigenous people and smallholders), that greatly increased the transaction costs for small holders and favoured illegal logging (Nasi et al., 2011).

2.4 Policy regulations and institutional tools

Although there are large regional discrepancies in forest regulation and policies, a few common outlines emerge at global scale. The main innovations in forest policies involved regulating the standardisation of management instruments, more specifically management plans that optimise logging activities and improve sustainability. The objective, structure and even implementation of management plans are often detailed in national forest law or through specific regulatory decrees. Most government have defined permanent forest estates (i.e. state-owned) that are mandated to remain as forest, representing 86% of the global forest cover (Agrawal et al., 2008). Most countries have regulation that somehow encourage SFM in their permanent forest estate, and recommend the implementation of management plan. However the way those regulations are effectively implemented on the ground remains largely unassessed. Whereas 70% of active production forests is reported to be under management plans (Table 1, Blaser et al., 2011), only 28% of the world tropical forests is under planned management (MacDicken et al., 2015). Thus, most tropical forests remain without legal status and could be designated in the future for production, protection or agriculture expansion.
The development of forest laws has also made it possible to secure commercial timber harvest by facilitating the procedures for exploiting and allocating exploitable areas. The dominant model of allocation is based on forest concessions that have become a full-fledged forest management tool through the gradual consolidation of legal reforms. Although a variety of logging concessions arrangements exists worldwide, they are a dominant form of forest governance in tropical forests, and notably in Central and West Africa, where at least 75 million hectares (45% of tropical forests in the region) are under concession to logging companies (Karsenty, 2007).

a) Community forestry

Another major trend driven by reforms in the forestry sector has been to create and institutionalise norms for community-based management of forest ecosystems. Community involves transferring rights and management tools from government to local communities, in ways that vary with the degree of decentralization. Effective forest management by indigenous and local communities is often constrained by increasingly complex and normative technical requirements. In most countries though, community-based exploitation of forest resources complies with the same forest law and formal management plans. Those technical skills are often not mastered by local communities, and counter traditional practices (Alexiades et al., 2013). Moreover, even though communities do benefit from increased incomes in a first step, those benefits and welfare rapidly bust once forest resource become overexploited (Rodrigues et al., 2009).

b) Legal vs illegal/informal wood production

There is no clear definition of "illegal logging", but illegal logging is often equated with unsustainable forest harvesting practices. However, logging may be technically legal, yet unsustainable (and vice & versa). In a narrower connotation, illegal logging occurs when timber is harvested in unauthorised ways, or in violation of established laws and regulations. For example, wood may be harvested in excess of legal limits, or in places where harvest is prohibited (e.g. forest reserves) (Contreras-Hermosilla et al., 2008). As for deforestation, the vast majority of illegal logging occurs in the tropics. Recent studies addressing the extent of illegal logging have estimated that it forms up to 50-90% of traded wood in key producer tropical countries, and 15-30% globally. International mechanisms aiming at tackling illegal logging, such as FLEGT or certification, apply to timber traded internationally (i.e. exportation/importation). However, local markets fall out of those mechanisms, and remain hard to reach. For instance, the Brazilian industry produced in 2014 about 162 million m^3 of logs, of which only 1.3% was exported (ITTO, 2015). Globally, only 6% of the wood produced in ITTO countries is exported, confirming that the majority of wood consumption is domestic. Meanwhile, the economic value of global illegal logging, including processing, is estimated to be worth between US$ 30-100 billion, equal to 10-30% of global wood trade (Nellemann et al., 2012). It is worth mentioning that in most producer countries, the majority of wood is consumed locally, likely to fall out any international regulation or certification scheme.

c) Monitoring legality

Despite progresses in clarifying the legal and institutional frameworks of the forestry sector, enforcement of forest law and governance are still an issue in many countries. Controlling illegal practices has often been identified as one of the major stumbling blocks to the implementation of SFM. Support from various initiatives, development agencies and donors has led to various actions aimed at reinforcing national institutional and regulatory capacities, and improving the quality of forestry sector governance. Among those we can cite the Forest Law Enforcement, Governance and Trade (FLEGT) initiative, developed in 2003 by the European Commission, building up on the FLEG initiative from World Bank. The main actions launched by the FLEGT initiative focussed on strengthening governance regarding supplies from the timber-producing countries (mostly from ITTO). The main mechanism lies in the implementation of bilateral voluntary partnership agreements (VPAs) between the European Union (EU) and timber-supplying countries. A VPA specifies commitments and actions by both signatory parties with the aim of developing a legality assurance system to license timber and timber products for export to the EU (Oliver, 2015). In 2013, about 42% of the global production of industrial hardwood log arose from a VPA-signing country.

3. Sustainable forest management (SFM)

3.1 Past and current practices

The initial focus of forestry management was to achieve sustained production of a single commodity, almost always timber (sustained-yield forestry). Over time, this concept has proved inadequate both conceptually and practically in satisfying either existing societal demands on forests (e.g., sustaining local livelihoods) or emerging ones (e.g., recreation, ecosystem service provision) (Nasi and Frost, 2009). Since the 80's, increasing international concern on the conservation and management of tropical forests have placed forestry in the context of poverty alleviation and sustainable human development. In 2007, the Bali Action Plan's wording on REDD+ inter alia, endorsed the role of "conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries" for climate change mitigation (UNFCCC, 2010). The United Nations describe sustainable forest management (SFM) as "a dynamic and evolving concept aiming at maintaining and enhancing the economic, social and environmental value of all types of forests, for the benefit of present and future generations".

Concretely, SFM regroups a beam of actions (e.g. improved planning, better harvesting techniques, protection of areas of high ecological value) aiming at reducing negative ecological impacts of logging, while promoting long-term economic viability of the forestry sector. Although there is growing agreement on REDD+ and financial opportunities to maintain tropical forests carbon stocks, few is known on efficient ways to maintain and enhance carbon stocks through forest management. To date, less than 5% of total tropical forest area is under some form of SFM, and the remainder is left to unplanned, destructive or illegal logging (Blaser et al., 2011).

A set of criteria and indicators (C-I) for SFM were developed by ITTO for operationalizing the SFM concept (given in Annex 1, ITTO, 2016). These criterion address the following four main topics that are supposed to ensure sustainable forest management and human welfare:

- Providing the enabling conditions for SFM
- Ensuring forest ecosystem health and vitality
- Maintaining the multiple functions of forests to deliver products and environmental services
- Integrating social, cultural and economic aspects to implement SFM

When monitored over time, C-I enable to track changes and trends in the biophysical, socioeconomic and policy conditions relevant to SFM.

3.2 Mechanisms favouring SFM

Mechanisms promoting SFM can be broadly categorized into three groups aiming at: (a) improving logging practices; (b) enhancing carbon storage and (c) promoting involvement of local communities. Obviously some mechanisms overlap and are not mutually exclusive.

3.2.1. Improving logging practices

a) Reduced impact logging (RIL)

Numerous studies have explored the benefit of RIL in (i) reducing incidental damages (Pinard and Putz, 1996; Sist et al., 2014; Sist and Ferreira, 2007), (ii) maintaining tree species diversity (Gourlet-Fleury et al., 2013), (iii) enhancing biomass regeneration (Mazzei et al., 2010; West et al., 2014) or post-logging carbon budget (Blanc et al., 2009; Huang and Asner, 2010). However, RIL is somehow limited to silvicultural recommendations that lack to account for the ecological complexity of tropical forests. It is, therefore, essential to develop new and practical guidelines integrating both the production of timber and the provision of environmental services on the long run.

Even though RIL was designed to reduce carbon emissions, FSC-certified concessions appeared not to have lower overall CO2 emissions from logging activity than non-certified concessions (Griscom et al., 2014). This was essentially due to poor knowledge and training in RIL practices (Francis E Putz, personal communication). The authors of that study have nonetheless proposed new guidance to avoid carbon emissions in certified forests, denoted as 'RIL-C' methods. This method has become a Verified Carbon Standard for Indonesia (VCS, 2017). Among those, the most conspicuous opportunity to reduce felling emissions is avoidance of felling trees from which no logs is extracted (that range from 8 to 44% in the 9 concessions sampled). Although cutting lianas on trees to be harvested at least 6 months prior to logging is commonly included in RIL guidelines, it was observed in only one certified concessions. Another major way of improvement lies in improved planning of bulldozer skid trails to reduce their overall length and hence, impacts per unit length.

b) Forest management certification

The certification of forest management is a market-based mechanism that promotes SFM among loggers and to the public. It recognizes responsible management through independently verified compliance with a set of underlying principles, criteria and indicators that delineate the ecological, social, economic and policy impacts resulting from forest management for specific objectives (Romero et al., 2013). The emergence of certification in the late 1980s was motivated by failures of other efforts to halt deforestation and improve forest management.

The two largest international certification bodies are the Programme for the Endorsement of Endorsement of Certification (PEFC) and the Forest Stewardship Council (FSC). Despite no clear Despite no clear data for the tropics, both certification scheme were estimated to cover cover between 25-40 million hectares in 2014 (MacDicken et al., 2015), about 7-10% of total total area of production forests. Several other national or regional certification schemes exist, schemes exist, sometimes considered as confusing for consumers and jeopardizing the credibility of certification. If certified forest management is expanding through northern countries, that encompass c. 90% of all certified forests (

Figure 1), only a small number of concessions operating in tropical countries comply with international certification standards (Kraxner et al., 2017).

A clear methodology to pinpoint the positive impacts of certification on forest and society still need to be developed. So far, a critical evaluation of the empirical impacts of forest certification has gone unfulfilled (Romero et al., 2017, 2013), preventing to raise general and robust conclusions. A positive example is found in Central Africa were 5 out of the 6 main logging companies are now FSC-certified. Certification has pushed companies to legal auto-regulation, and implementation of best logging practices. However, getting certified requires significant investments, excluding de facto small-scale operators, who often resort to remain "informal" to avoid overregulation.

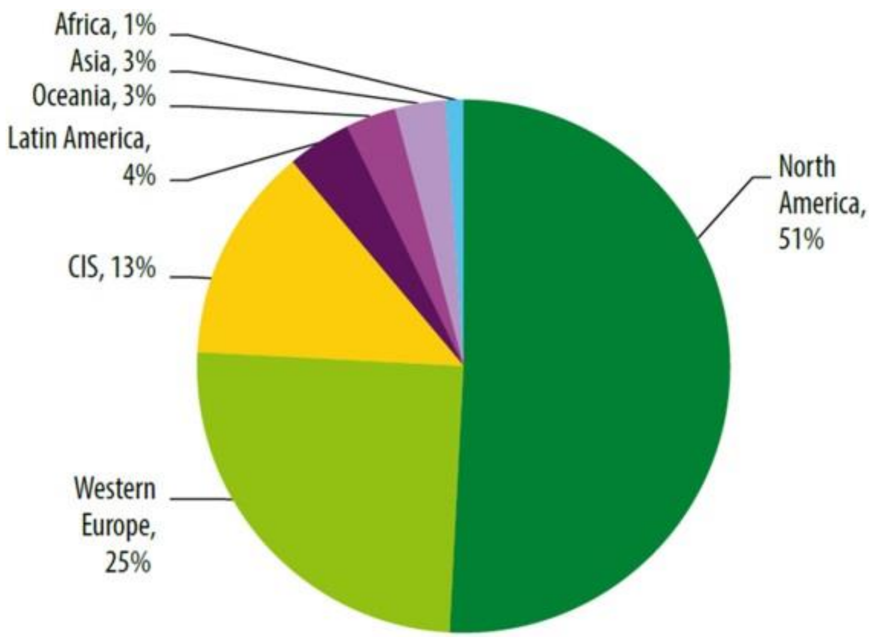

Figure 1 : Total certified forest area by regional share (2014) (Fernholz, 2014).

c) Improved Forest Management (IFM)

Improved Forest Management (IFM) is a recent conceptual framework aiming at integrating most efficient silvicultural techniques to comply with the interest of several stakeholders (i.e. NGOs, loggers, local communities). IFM generally consists in (a) preserving and better harvesting available resource; (b) protecting high value forests and local communities and (c) enhancing future timber stocks (Figure 2, Griscom and Cortez, 2013). Among others, liana/vine cutting is often reported to be a cost-effective silviculture treatment that promote tree growth (Lussetti et al., 2016; Peña-Claros et al., 2008)

Figure 2 : Improved Forest Management 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 (Source: Griscom and Cortez, 2013).

d) Increased efficiency in timber harvesting and processing operations

In selectively logged tropical forests globally, an estimated 30 to 50% 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 (FAO, 2001). Logger training is a key factor in reducing logging waste and value loss. Mill process yields have also been reported to be as low as 35% of delivered log volume (Barreto et al., 1998; Nasi et al., 2011). Data on harvesting and processing efficiency are scarce, but technical efficiency improvement has the potential of significantly decrease the volume of raw material (logs) required to produce a given quantity of processed wood products.

3.2.2. Enhancement of carbon storage

By signing the Kyoto Protocol in 1992, industrialised countries committed to reduce their emissions of green-house gases compared to the 1990 baseline levels. Despite the crucial role played by forests in climate, international negotiations on climate were slow to integrate forest in carbon mechanisms (UNFCCC, 2011b).

a) Reduction of Emissions due to Deforestation and Forest Degradation

The Reduction of Emissions due to Deforestation and Forest Degradation (REDD) concept is an international initiative to provide developing countries with financial incentives and help them voluntarily reduce national deforestation rates and associated carbon emissions below a baseline (based either on a historical reference case or future projection) (UNFCCC, 2010). Countries that demonstrate emissions reductions may be able to sell those carbon credits on the international carbon market or elsewhere. These emissions reductions could simultaneously combat climate change, conserve biodiversity and protect other ecosystem goods and services. The REDD+ scope of application today includes activities aimed at (UNFCCC, 2011b):

- reducing emissions from deforestation
- reducing emissions from forest degradation
- conserving forests
- enhancing forest carbon stocks
- managing forests sustainably

b) Voluntary carbon market

Forest finance for climate change has recently advanced on the global financial market, offering an opportunity for entities wishing to support climate-smart forestry and agriculture to purchase carbon offsets[4] towards financial support of forest-related mitigation projects. Offsets come from on-the-ground projects and activities to reduce carbon emissions; for example, by switching to more sustainable fuel sources, or by planting trees that soak up CO_2 from the air. The co-benefits, e.g. biodiversity conservation or enhanced livelihood, have made those projects appealing for the private sector, to meet their corporate social responsibility goals or to demonstrate climate leadership. In compliance markets, a government agency makes the rules about what types of offsets are permitted; whereas offsets sold on the voluntary carbon markets typically follow rules prescribed by voluntary standard bodies, such as the Verified Carbon Standard (VCS), the Gold Standard, Plan Vivo or the Clean Development Mechanism (CDM). After having pecked in 2008, the voluntary carbon market and price of offset has recently slowdown to average 63 $MtCO_2$ equivalent transacted in 2016 (Figure 3, Forest Trends, 2017). Several forest-related activities can give the right to issue carbon credits: activities involving Afforestation/Reforestation, REDD+, Agriculture, Forestry and Other Land Uses (AFOLU) and Improved Forest Management (IFM). In 2016, most investments were made in REDD+ projects that accounted for 16% the volume traded.

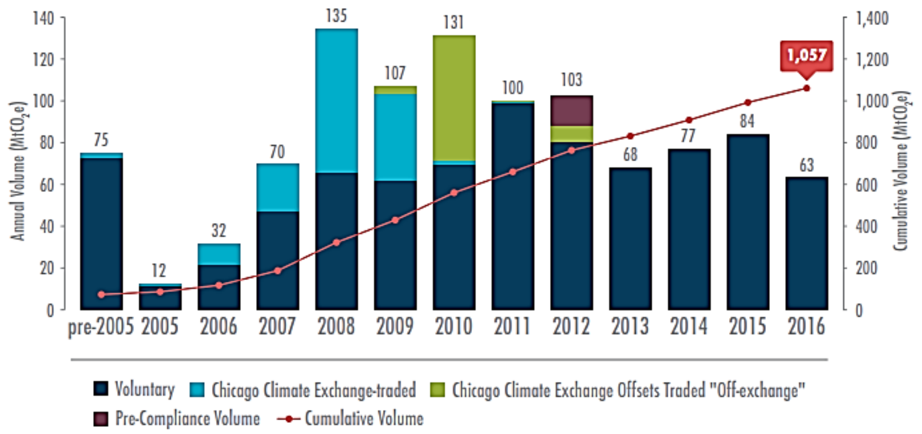

Figure 3: Historical market-wide voluntary offset transaction volumes (Source: Forest Trends, 2017)

[4] A carbon offset represents one tonne of carbon dioxide equivalent (tCO2 e) that hasn't been emitted into the atmosphere.

c) Payments for environmental services

Given that only 12% of the global IFL area and a quarter of tropical forests are supposedly protected, there is urgent need for investments in carbon sequestration and biodiversity conservation efforts that target the most valuable remaining forests. While the role of payment for environmental services (PES) has long been debated as a conservation tool in the Tropics (Wunder, 2006), effective payments are still scarce, as it is hard for funders to know exactly what is being paid for (Wunder, 2007). The central idea of PES is that the stewards of the ecosystem services should be compensated by those who benefit. PES that secure the continued provisioning of critical resource, such as water supply, to local livelihoods were found to be rather successful (Grima et al., 2016). However, less obvious benefits, as the conservation of biodiversity, remain hard to be funded.

3.2.3. Integration of local communities

The livelihoods of an estimated 300 million people living close to tropical forests depend on tree or forest products for daily subsistence worldwide (FAO, 2016a). Community forest management (CFM) encompasses a quite diverse set of locally generated forestry practices, going from collection of non-timber forest products, agro-forestry or timber harvest. Forest products are harvested from forest stands or single trees, to be sold or exchanged when needed. Involving local communities in the forestry sector can take various forms, depending on what place is given to the effective involvement of local communities in resource governance (Agrawal et al., 2008). Since many individuals and communities in the tropics do not have formally-designated rights to forests, how these rights are defined at project- and national-levels will determine the equity of forest carbon projects (Naughton-Treves and Wendland, 2014). For incentive-based carbon forest projects to have positive impacts on carbon sequestration and forest-dependent peoples, land tenure must be defined and secure for the duration of the project. Apart of land-tenure, the success of community forestry is influenced by a complex range of factors, such as effective governance, administrative and management knowledges and social equity (Baynes et al., 2015).

Brazilian forest reserves, Reservas extrativistas (extractivist reserves) and Reservas de Desenvolvimento Sustentável (sustainable development reserves) are both managed by communities since 2000, where they only have access and withdrawal rights. A major challenge faced by community and smallholder development initiatives is a persistently limiting institutional and political environment in all Amazonian countries. In nearly all Amazonian countries, producers need to get a formal title of their lands or to register their existing rights, and have to develop forest management plans and annual operational plans. Those operational and administrative issues have plagued community forestry in the Amazon. A comparative study in Peru, Bolivia, Ecuador and Brazil, revealed that considerable external resources are needed to overcome the technical, legal and financial barriers inherent in the current community forestry framework (Pokorny and Johnson, 2008). To enable smallholders in effectively using their forests, appropriate investments in training, education, infrastructure and equipment should be done. Policy needs to better capture the specificity of community management, disseminate locally appropriate practices and strengthen local capacity for regulation and control.

3.3 Current critiques of SFM as a concept

The role of SFM as a conservation strategy in the tropics has long been debated. In the 90's, the World Bank and other international institutions tried to answer those simple questions: Will new investment in logging operation help to curb deforestation? Can SFM be brought into this? At the same time, ITTO adopted an objective of bringing all tropical timber production to sustainable levels by 2000 (Bowles et al., 1998). Despite numerous studies, the benefit of direct investments in conservation initiatives could not be ascertained and a shift towards market-based mechanisms, such as best management certification, has been operated since then. The common thread between both initiatives is SFM. The notion that SFM can be an effective conservation tool rests in part on the premise that it can stabilize wood production in a given area, and hence reduce pressures on other primary forests. However, most extractors of tropical timber follow a logic of cut and move on, because resource is abundant and the outlays for long-term management are often excessive (Wunder, 2006). While "unsustainable" logging can generate 20 to 450% more profit, it becomes economically uninteresting to plan for even a second cut (Pearce et al., 2003). Further, higher operational costs and the cost of certification itself make SFM less economically attractive (Savilaakso et al., 2017). Beyond direct investments in the forest sector, political instability and/or lack of institutional capacities are precluding efficient enforcement of SFM in many tropical forest-rich countries. Thus, beyond SFM, lie complex socio-political aspects, and more efforts should be put to tackle the corruption and enhance institutional capacities (Nellemann et al., 2012).

3.3.1. Opening intact forests to SFM

About 50% of the world tropical forests are designated as protected (Blaser et al., 2011), but only a tenth is strictly protected, e.g. reserves or national parks (Nelson & Chomitz, 2011 in Griscom et al., 2014). While timber extraction has either reached its limit, or will do so in 10-20 years (Figure 4), some countries may reassigned part of their forest estate to production or agricultural extension. Globally, the area of protected forests has increased from 7.7% in 1990 to 16.3% in 2015, with a strong upward trend in protected areas in the tropical domain (from 12% in 1990 to 26.3% in 2015). But this raise coincides with the overall decline of natural tropical forests that shrunk by 10% over the same period (Morales-Hidalgo et al., 2015). Even if tropical forest loss could be halted, the current area and distribution of quality forest habitats is already insufficient for many forest species (Sloan and Sayer, 2015), and global biodiversity hotspots retain only 15% of intact natural vegetation. As protected areas won't be sufficient to avoid a rapid collapse of the biodiversity (Laurance et al., 2012), the concept of **Intact Forest Landscapes** (IFL) has emerged. IFL are defined as 'an unbroken expanse of natural ecosystems within the zone of current forest extent, showing no signs of significant human activity and large enough that all native biodiversity, including viable populations of wide-ranging species, could be maintained' (Potapov et al., 2009). Indeed, small forest areas, even if pristine, have less potential for preserving wide-range species populations and have lower resilience to natural disturbance and effects of climate change.

After years of lobbing from NGOs, FSC has recently (January 2017) included the concept of IFL in its Policy and Standards, stating that "forest management operations within IFLs, including harvesting and road building, can only proceed if they do not impact more than 20% of IFLs within the Management Unit and do not reduce any IFLs below the 50,000 ha threshold in the landscape" (FSC, 2017). Interestingly, the integration of IFLs may have unexpected consequence in Africa, where concessionaires are thinking that this new clause will prevent exploitation of many central African forests. For instance, 42, 54, 63 and 74% of IFLs are included into logging concessions in Congo, Cameroon, Gabon and Central African Republic, respectively (FAO, 2016b). Consequently, some consider abandoning the FSC, looking for a PEFC alternative. If this happens, it could have a significant impact for FSC-certified exports in Europe and North America, since opponents to industrial concessions will certainly claim that PEFC certificates do not provide the same environmental guarantees. Moreover, the certification of logging concessions under responsible management had only a negligible impact on slowing IFLs fragmentation worldwide (Potapov et al., 2017). Worst, this study revealed that selective logging was the dominant driver of IFL loss in Africa and Southeast Asia, encompassing respectively 77 and 75% of IFL loss. Globally, the fragmentation of IFLs by logging and establishment of roads and other infrastructure initiates a cascade of changes that lead to landscape transformation and rapid loss of conservation values.

Central & South America				Africa				Asia & Pacific			
	pri.	sec.	pla		pri.	sec.	sec.		pri.	sec	pla.
Brazil	16	10	14	S. Africa	p	3	7	Malaysia	p	7	+
Chile	p	p	12	Cameroon	d	33	19	Indonesia	30	20	24
Uruguay	p	p	9	Côte d'Ivoire	p	+	+	Philippines	p	+	24
Paraguay	p	d	10	Ghana	-	+	+	India	p	p	21
Argentina	p	d	11	Congo	p	+	21	Thailand	p	-	9
Guyana	+	p	1	Nigeria	d	2	11	S.Korea	d	d	+
Colombia	d	d	12	DRC	d	d	+	Vietnam	d	+	26
Ecuador	23	13	4	Tanzania	d	23	8	PNG	24	+	d
Cuba	p	p	+	Tunisia	d	d	+	Myanmar	p	21	19
Honduras	d	d	d	Senegal	25	23	+	Pakistan	d	4	10
Trinidad	+	13	+	Gambia	d	+	5	Sri Lanka	d	5	+
Peru	+	+	+	CAR	+	-	-	Nepal	9	2	31
Mexico	d	d	9								
Suriname	+	+	+								
Guatemala	9	+	+								
Dom. Rep.	-	p	+								

Key: d = depleted; 8 = 10 yrs or less remaining; 18 = less than 35 yrs remaining; + = more than 35 yrs remaining; p = protected; - = not applicable

Figure 4: Modelling of years remaining before depletion of timber resource. Countries presented in order of significance to the UK economy by value of total timber trade flow (> US$5 m). Pri = primary forests; sec = secondary forests; pla.= plantations. (Source: WWF, 2016).

3.3.2. How to conceal wood production and SFM

A general adoption of SFM practices in tropical forests would result in a net decrease of wood production (per area), due to lower logging intensity and extended cutting cycles, and income, due to lower merchantable volume and high operational costs. The minimum technical standards necessary for approaching ecological sustainability directly contravene the prospects for financial profitability (Zimmerman and Kormos, 2012). As the demand for wood is expected to increase over the coming decades (FAO, 2009), timber extraction in production forests is likely to either increase, or remain stable at midterm. Two competing logging strategies have been proposed to meet timber demands with the least impact on biodiversity: land sharing, which combines timber extraction with biodiversity protection across the concession; and land sparing, in which higher intensity logging is combined with the protection of intact primary forest reserves. Ground-based experiments have reported that two taxonomic groups (birds and dung beetles/ants) had higher abundances in land-sparing concessions (Edwards et al., 2014a). This poses the question of an intensification of silviculture in some areas to preserve others from any human activities. While it is always environmentally beneficial to minimize unnecessary damage, more intensive silviculture could be necessary, especially for the regeneration and growth of commercially valuable timber species that are favoured in open forests (Fredericksen and Putz, 2003).

Despite a beam of evidences that demonstrate the benefits of post-logging silvicultural treatments, such as vine cutting or understorey clearing (e.g. De Graaf et al., 1999; Gourlet-Fleury, 2009; Peña-Claros et al., 2008; Villegas et al., 2009), they are rarely applied in concessions. Indonesia has become an exception when the Ministry of Forestry has allowed silvicultural intensification in some 65 million ha of natural forests (reviewed in Ruslandi et al., 2017) in direct contradiction with former recommendations (Sist et al., 2003). The Indonesian Ministry of Forestry also permitted strip planting of nursery-raised dipterocarp seedlings along cleared lines. Additionally, the minimum cutting cycle is reduced from 30 to 25 years where enrichment planting is carried out, increasing the area open for harvests each year. Preliminary assessment of those enriched intensively-logged forests revealed that carbon stocks recovered to primary forests levels in 25 years, with increased representation of commercial species; while conventionally logged forests did not (Ruslandi et al., 2017). However, the long-term consequences of this practice and the fate of enriched forests, notably in response to climate changes, remain unknown.

On the opposite direction, the general adoption of reduced-impact logging and enhanced wood processing technologies (RIL+) along with financial incentives could have the potential to significantly reduce forest degradation, while maintaining timber production and carbon stocks (Sasaki et al., 2016). The overall cost for the adoption of RIL+ for the whole tropical production forests is estimated to be US$ 2 billion a year.

4. Conclusions

a) Speeding up a shift toward SFM

Despite recent initiatives across the Tropics to trigger a shift in forest management, one cannot but to admit that current logging practices remain in their vast majority detrimental for the environment. While about two third of active production forests are declared under some form management plan (§ 3.1), implementation in the field remains hard to assess. As a consequence, only a fifth can be considered as sustainably managed. While forest certification is progressing worldwide, only a small fraction (5-10%) lies in the Tropics (§ 3.2.1), forming an even smaller amount of wood produced and traded annually. Therefore, most of the wood harvested falls out of any international standard, and is either sold on local markets, or illegally (§ 2.4).

These facts probably reflect slim concerns from the forest industry, and to some extent from decision makers, about sustaining forest functions and the long-term provision of goods and services. While SFM has been increasingly integrated into legal frameworks (§ 3.3.2), it seems to remain poorly applied in practice, and most commercial logging remain stuck into the paradigm of “sustainable income”, instead of progressing towards “sustainable provision of goods and services” (§ 3.1). Poor forest-related law enforcement in producer countries (§ 2.4) and low prices of wood or carbon credits are creating uncertainties among stakeholders, who generally prefer fast return on investment.

b) Supporting better wood production in tropical forests

Increasing international concerns about the socio-environmental aspects of tropical timber production have led to numerous market-based initiatives aiming at speeding up the transition toward SFM. Increased operational costs and reduced wood harvest implied by SFM could be partially compensated by increased wood processing efficiency (§ 3.2.1.d), the diversification of timber species, or payment for reduction of carbon emissions or environmental service (§ 3.2.2). However, the vast majority of wood consumption is domestic (§ 2.4), falling out of any international regulation scheme. Addressing this issue implies increasing political and social awareness about forest conservation, supporting capacities to develop and enforce regulations and combating corruptions (§ 3.3).

Whereas the logging sector still plays a vital role in the economy of several emerging countries (§ 1.3), benefits seems unequally shared. If local communities are employed by logging companies, they are generally expelled from logging concessions, generating numerous conflict for land tenure in Brazil, Africa or Indonesia (§ 2.3). Moreover, once the surrounding forest has been depleted, forest-dependent communities are left without mean of subsistence (§ 2.4). Projections tend to show that many countries have already exploited their whole forest resource (Figure 4), and most tropical forests are affected by human activities (§ 3.3.1).

c) Alternative production of wood

Natural forests still contribute to a large fraction of the wood produced annually, but plantations are becoming increasingly important in wood production (Warman, 2014). For instance, in 2012, 65% of the roundwood production in the tropics and sub-tropics arose from plantations (Payn et al., 2015). However, if plantation are generally perceive as an efficient way to reduce the pressure exerted on tropical forests, it is not necessarily the case (Pirard et al., 2016). For instance, forest clearance for installation of fast wood plantations for pulp and paper accounted for more deforestation between 2000 and 2010 in Indonesia than did both oil palm plantations and coal mining (Abood et al., 2014). Forest clearance is certainly the worst case scenario, while plantations growing on bare land or old pasture are more economically and environmentally sound (Elias and Boucher, 2014).

Wood production for either industrial plantations or logged natural forests can have adverse environmental impacts. Unsustainable industrial plantations ultimately can cause deforestation and deplete soil and water resources. The demand for sawnwood is expected to steadily increase by 2060, while the consumption of softwood (i.e. fibre and paper), essentially arising from plantations, will boom (FAO, 2009). These projections indicate that forest management decisions to meet such rising demands could have a profound impact on tropical forests. Without enhanced protections, tropical forests will become increasingly susceptible to destructive logging and clearing. In contrast, properly managed plantations could help release the pressure exerted on natural forests (Elias and Boucher, 2014).

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Annex 1 : Criteria and indicators for sustainable forest management in tropical regions (ITTO, 2016)

Criterion 1: enabling conditions for sustainable forest management

Policy, legal and governance framework

1.1 Policies, laws and regulations for governing forests

1.2 Forest tenure and ownership

1.3 Forest governance

Institutional framework

1.4 Institutions responsible for, and supportive of, forest management

1.5 Availability of professional and technical personnel to perform and support forest management

Planning and monitoring framework 1

1.6 Integration of forests in national and subnational land-use planning

1.7 Capacity and mechanisms for management planning and the periodic monitoring of implementation

1.8 Long-term projections, strategies and plans for production PFE and protection PFE

1.9 Stakeholder participation in land-use and forest management planning, monitoring and assessment **Economic framework**

1.10 National, subnational and international public and private funding committed to SFM

1.11 Incentives to encourage SFM

Criterion 2: extent and condition of forests

2.1 Extent and percentage of total land area under comprehensive land-use plans

2.2 Extent of forests committed to production and protection

2.3 Extent and percentage of total land area under each forest type

2.4 Multiyear forest management plans in FMUs

2.5 Forest area in compliance schemes

2.6 Change in forested area

2.7 Forest condition

2.8 Forest carbon stock

Criterion 3: forest ecosystem health and resilience

Addressing threats to, and vulnerabilities of, forests

3.1 Treats to forests caused directly by human activities

3.2 Vulnerability of forests to natural disturbances

3.3 Forest resilience and climate-change adaptation

Restoration of degraded forests and lands

3.4 Degraded forests and landscapes restored

3.5 Area of formerly degraded forest or forest land restored

Criterion 4: forest production

Resource assessment

4.1 Natural production forest inventories, by product
4.2 Actual and allowable harvest of wood and non-wood products in natural forests
4.3 Actual harvest of wood and non-wood products in planted forests
4.4 Forest carbon stock

Harvesting planning and control procedures

4.5 Timber harvesting arrangements in natural production forests
4.6 Forest product tracking systems or similar control mechanisms
4.7 Historical records on the extent, nature and management of forests

Silviculture in natural and planted forests

4.8 Reduced impact harvesting and silvicultural operations
4.9 Silvicultural management in planted forests
4.10 Strategic monitoring of silvicultural systems in natural and planted forests

Criterion 5: forest biological diversity

Ecosystem diversity

5.1 Forest extent in protected areas
5.2 Buffer zone management and connectivity of protected forest areas

Species diversity

5.3 Threatened forest-dependent species
5.4 Procedures for conserving tree species diversity in natural tropical forests

Genetic diversity

5.5 In situ conservation of genetic variation within specified forest tree species

Biodiversity conservation in production forests

5.6 Biodiversity conservation measures in natural production forests
5.7 Biodiversity conservation in planted forests

Criterion 6: soil and water protection

Extent of protection

6.1 Forest area managed primarily for the protection of soil and water
6.2 Protection of downstream catchment values at the landscape level

Protective functions in production forests

6.3 Soil productivity and water retention capacity in production forests
6.4 Area of production PFE considered environmentally sensitive and protected
6.5 Forest engineering for soil and water protection

Criterion 7: economic, social and cultural aspects

Economic aspects

7.1 Contribution of the forest sector to gross domestic product
7.2 Value of domestically produced forest products and environmental services
7.3 Wood and non-wood forest product processing capacities and efficiency

Social and cultural aspects

7.4 Capacity building of the workforce in forest management and forest industry
7.5 Procedures to ensure the health and safety of forest workers
7.6 Mechanisms for the equitable sharing of the costs and benefits of forest management

7.7 Mechanisms for resolving disputes between forest stakeholders
7.8 Local livelihoods and forest management
7.9 Forests reserved for specific cultural, research or educational purposes

Community and indigenous peoples' rights and participation in forest management

7.10 Tenure and user rights of indigenous peoples and local communities over publicly owned
7.11 Involvement of indigenous peoples and local communities in forest management
7.12 Recognition and value of forest-management knowledge and skills of local people