Compatibility of timber and non-timber forest product management in natural tropical forests: perspectives, challenges, and opportunities

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Review

Compatibility of timber and non-timber forest product management in natural tropical forests: Perspectives, challenges, and opportunities

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ABSTRACT

Tropical forests could satisfy multiple demands for goods and services both for present and future generations. Yet integrated approaches to natural forest management remain elusive across the tropics. In this paper we examine one combination of uses: selective harvesting of timber and non-timber forest product (NTFP) extraction. We analyze the current status of this combination and speculate on prospects and challenges regarding: (i) resource inventory, (ii) ecology and silviculture, (iii) conflict in the use of multipurpose tree species, (iv) wildlife conservation and use, (v) tenure, and (vi) product certification. Our conclusions remain preliminary due to the relative paucity of published studies and lessons learned on what has worked and what has not in the context of integrated management for timber and NTFPs. We propose at least three ways where further research is merited. One, in improving 'opportunistic' situations driven by selective timber harvesting that also enhance NTFP values. Two, to explicitly enhance both timber and NTFP values through targeted management interventions. Three, to explicitly assess biophysical, social, regulatory and institutional aspects so that combined benefits are maximized. Interventions for enhancing the compatibility of timber and NTFP extraction must be scaled in relation to the size of the area being managed, applied timber harvesting intensities, and the dynamics of multi-actor, forest partnerships (e.g., between the private sector and local communities). In addition, training and education issues may have to be re-crafted with multiple-use management approaches inserted into tropical forestry curricula.

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1. Introduction

Tropical forests have the potential to satisfy multiple demands for timber and non-timber forest products (NTFPs), marketed and non-marketed ecosystem services, while including industrial and non-industrial actors—both for present and future generations (Kant, 2004). To accommodate these requirements, sustainable forest management (SFM) emerged in the early 1990s (Poore, 2003), and multiple-use forestry became entrenched within SFM as a way to achieve socially and environmentally driven development models in the tropics (Panayotou and Ashton, 1992). Yet, clearly defined multi-use approaches to natural forest management remain elusive (García-Fernández et al., 2008). The application of Reduced impact logging (RIL) guidelines (reviewed in Putz et al., 2008) largely contributed to an increase in the area of natural forest under SFM from less than one million ha in 1988 (Poore et al., 1989) to about 36 million ha by 2005 (ITTO, 2006). However, this quest for sustainability was largely disconnected from other forest goods and services, including NTFPs which are still treated in relative isolation (Lawrence, 2003). Clearly, SFM is about more than RIL, and there is now renewed interest in developing multiple-use tropical forestry (e.g., Sist et al., 2008 and accompanying papers; Shanley et al., 2008).

Diversified forest demands can be met either by spatially segregating uses for particular goods and services (Vincent and Binkley, 1993; Binkley, 1997; Zhang, 2005), or by managing forest stands to meet multiple objectives from the same area. The latter model is widespread across the tropics (Sayer and Byron, 1996; Poore, 2003; Nittler and Tschinkel, 2005), but whether or not multiple-use of forest goods and services facilitates sustainability still generates much debate. For example, skeptics question the extent to which economic returns from NTFPs and/other values are sufficient to outweigh the financial costs of modifying and/or applying RIL norms (Barreto et al., 1998; Pearce et al., 2003) and silvicultural practices needed for sustaining timber production over the long term (e.g., enrichment planting, Schulze, 2008; liberation thinning, Wadsworth and Zweede, 2006). Advocates of multiple-use forest management emphasize that by incorporating many forest goods and services, including the voices of different stakeholders, a social and financial edge can be gained over timber-dominated models (Ashton et al., 2001; Campos et al., 2001; Hiremath, 2004; Wang and Wilson, 2007). This paper examines one of the possible combinations for multiple-use: extraction and management of timber and NTFPs. We discuss the current status of this combination, speculate on both the barriers and opportunities for integrated management for timber and NTFPs as a land use option, and provide insights on moving forward. Our paper focuses on mechanized, selective logging as this remains the dominant and most profitable option in natural tropical forests and excludes agroforests, regenerating fallows, and/or planted forests (where timber and NTFPs may also be managed concurrently; e.g., Toledo et al., 2003; Belcher et al., 2005; Michon et al., 2007).

2. Examining the compatibility of timber and NTFP management

The degree of compatibility between management of timber and NTFPs can be discerned along different axes. A simple framework (Titus et al., 2006) has been proposed which covers a continuum of management actions that either indirectly benefit NTFP values (‘‘passive’’ or ‘‘opportunistic’’ compatibility), or that are explicitly applied to enhance both timber and NTFP values concurrently (‘‘active’’ compatibility). Examples on one end of this continuum are (i) the establishment of timber concessions with the *potential* to secure long-term access to NTFPs; and (ii) the positive effects of increased light levels on a given NTFP species after selective logging. An example on the other end is the extension of RIL guidelines to minimize collateral damage to NTFP-bearing trees during timber extraction. Although much of this paper may well fit into the above framework, we emphasize six topics: (i) resource inventory, (ii) ecology and silviculture, (iii) conflict in the use of multipurpose tree species, (iv) wildlife conservation and use, (v) tenure and access rights, and (vi) product certification. These topics are key components of SFM (e.g., Durst et al., 2005), and encompass the most relevant published information and examples in the context of our analysis. However, we recognize that other factors (e.g., seasonality, legal frameworks, gender) may cut across the above topics. We provide an indicative list of these additional set of factors and the way they may affect compatible management outcomes of timber and NTFPs in Table 1.

2.1. Resource inventory

Based on a global assessment, Vantomme (2003) concluded that national statistics on NTFPs, including data on the resource base, are absent for all but a few internationally traded products (where data are usually limited to export quantities). It is therefore not surprising that little effort may have been directed at integrating inventories of NTFPs into timber censuses. When implemented, these inventories concentrate more on tallying the *presence* of locally important NTFPs than on estimating yields for guiding management. In the Congo Basin, NTFPs including bushmeat and/or evidence of bushmeat hunting are routinely recorded in timber inventories, but in most cases this information (e.g., Van Vliet and Nasi, 2008) is rarely used in informing the design of multi-use management plans. Mapping the presence of locally important NTFP species before logging may, nevertheless, be necessary to ensure that they are maintained in forests managed primarily for timber. In Indonesian Borneo, for example, the palm *Eugeissona utilis*, one very important emergency forest food for the Punan hunter gatherers, grows along ridge tops and is often damaged when opening skid trails (Sheil et al., 2008). In this context, local knowledge is potentially critical in informing NTFP inventories alongside timber (Cunningham, 2001; Lawrence et al., 2005; Shanley and Stockdale, 2008).

Even in cases where timber and NTFPs have high commercial value, the cost-effectiveness of implementing integrated inventories of timber and NTFPs may depend on the extent of biological similarity between both types of product. Despite early efforts (e.g., Pineda, 1996) in the community forestry concessions of Petén, Guatemala, in designing integrated inventory protocols for timber and NTFPs, including the fronds of high-valued *xate* (*Chamaedorea* spp.) understory palms, their implementation has been limited to date (Louman et al., 2008). Timber in the Petén is harvested from annual compartments of fixed area under decades-long rotations, while *xate* palms take only 4–6 months to regain pre-harvest yields. Because of its wide distribution across the entire forest *xate* can therefore be harvested more frequently and over larger areas than within annual logging blocks; hence a different inventory protocol was designed (outlined in Godoy et al., 2009). Moreover, the size of plots used for timber inventory was insufficient for concurrent, reliable estimates of sustainable harvest rates of *xate* leaves that were needed to fulfill FSC-certification standards currently enjoyed by this NTFP (see Section 2.6). In contrast, arborescent palms or other NTFP-bearing trees are more amenable for integrated timber–NTFP inventories since little deviation is needed from common practice. For example, the management potential of both timber and NTFPs derived from palms and trees (fruit, seed oils, latex) in Amazonian floodplain forests was determined through standard, tree inventory assessment (Fortini et al., 2006). Another advantage of shared biological similarity is that, in the case of arborescent life forms, logging damage to NTFP-bearing trees can be easily minimized by marking them during routine, pre-harvest timber inventories (Guariguata et al., 2009).

Table 1
An indicative list of factors (left column) and the way these may affect compatible extraction and management of timber and non-timber forest products (NTFPs) in tropical forests.

Factor	Compatibility influenced by
Seasonality	-Production peaks for a given NTFP
Habitat overlap	-Extent of spatial segregation of timber and NTFPs due to edaphic/disturbance factors
Growth habit and product type	-Lianas, shrubs, epiphytes, palms; or fruits, foliage, resin, bark, *vis a vis* timber -Relative timber/NTFP values
Silvicultural practices	-Application thinning, liana removal, reduced impact logging norms, enrichment planting, site preparation -Whether the NTFP benefits from felling gaps
Length of timber rotation cycles	-Time to recover to pre-harvest levels
Pre-harvest timber inventories and marking of future crop trees	-NTFP growth habit (if it is an arborescent palm or a tree, rather than understory plants)
Access to NTFP resources	-Extent of protection of NTFPs from logging and/or logging damage
Local knowledge	-Interaction between loggers and NTFP harvesters
Gender	-Who is involved in collecting NTFPs and local decision-making during sales
Seasonality	-How it influences labor availability for harvesting timber and/or NTFPs
Property rights	-Modes of access (legal vs. customary, cooperative members vs. open access, determined by gender) -Extent to which some users are excluded -How management plans for timber respect property boundaries
Local governance	-Degree of organization among producers -Extent of differences between established mechanisms to distribute revenues from timber and NTFPs
Training and education	-Degree to which NTFPs are incorporated into forestry curricula, and loggers and forest managers are aware of NTFP values
Legal frameworks	-Extent to which government-designed management plans for timber harmonize NTFP issues or vice versa -Enforcement of hunting bans or NTFP theft
Income diversification	-Extent to which timber and NTFP diversify income sources
Market chains	-Extent to which market chains for timber and NTFPs are complementary or divergent

2.2. Ecology and silviculture for timber and NTFP management

From a biophysical standpoint, the compatibility of management for timber and NTFP harvesting may be positively or negatively affected by the wide range of logging intensities applied across the forested tropics (Putz et al., 2001; Sist and Ferreira, 2007), direct post-logging impacts such as increased tree mortality rates (Gourlet-Fleury et al., 2004; Schulze and Zweede, 2006), overall changes in forest structure (Jonkers, 1987; Johns et al., 1996), increased levels of solar radiation (Webb, 1999; Pereira et al., 2002), the presence of disturbed or otherwise compacted soil (Hendrison, 1990; Pinard et al., 2000), and the ecological attributes of the NTFP in question. For example, climbing palms (many of which are high-value NTFPs such as *Desmoncus* spp. and rattans such as *Calamus* spp.) usually benefit from logging-related canopy opening (Siebert, 1993, 2000; Asseng Ze, 2008). Similarly, understory plants with NTFP value may survive better and elevate their reproductive activity after logging gaps are created (e.g., Costa and Magnusson, 2003); although not all of these may benefit from high-light environments (e.g., Ocampo Sánchez, 2004). Post-logging, tree fruit production due to improved crown illumination is also possible (Johns, 1988; Guariguata and Sáenz, 2002; but see Fonseca et al., 2009). However, any beneficial post-logging effects on NTFP growth and yield are expected to be both localized and possibly short-lived, in the context of the long rotation cycles in selectively logged tropical forests (not less than 30–40 years) if no silvicultural treatments are further applied.

The few published works on the effects of selective logging on NTFP yields point to compatibility at the stand level, at least under experimental conditions. In lowland Nicaragua, Salick et al. (1995) reported that the density of locally useful woody plants was comparable in both logged and unlogged plots. Similarly, 9 years after RIL was applied in a Costa Rican montane forest, the harvestable biomass of non-vascular epiphytes (a locally important NTFP) equaled that of adjacent, unlogged plots (Romero, 1999). In the eastern Amazon, Menton et al. (2009) concluded that smallholder (∼90 ha) forests that were selectively logged under RIL norms showed, after 18 mo, no discernible difference in harvest yields of both game and tree fruits when compared to smallholder forests where no logging took place. The authors hypothesized that low NTFP harvest rates and minimal logging impacts both accounted for the observed compatibility of timber and NTFP management at the landscape scale (although they reported high inter-household variation). Similar studies along these lines are currently few in number yet necessary to better inform the design of compatible management interventions for timber and NTFPs. However, RIL may not always favor compatibility. For example, both number and size of logging gaps in forests logged under RIL norms in Amazonian forests may be insufficient for light-demanding timber trees, including those with concurrent NTFP value, to regenerate (Schulze, 2008; Schulze et al., 2008a; see Section 2.3 below).

Some operational norms applied in forests managed for timber may facilitate NTFP management objectives. For example, lianas in tree crowns can reduce tree fruiting (Wright et al., 2005) including timber species (Fonseca et al., 2009). Liana cutting, applied primarily as a way to reduce logging damage to residual trees and to improve worker's safety (Putz et al., 2008), could be extended in managed forests to enhance fruit production in NTFP-bearing trees as suggested for Brazil nut (*Bertholletia excelsa*, Lecythidaceae; Kainer et al., 2006, 2007). Silvicultural treatments after selective tree harvest such as removing tree neighbors from future crop trees (De Graaf et al., 1999; Wadsworth and Zweede, 2006) and stand refinement and soil scarification in logging gaps (e.g., Peña-Claros et al., 2008) may be adequate for either natural regeneration or enrichment planting of light-demanding NTFPs. Harvest systems typically applied in Asian dipterocarp forests such as shelterwood cutting (which remove or reduce the overstory) also appear ecologically and economically amenable for managing timber and light-demanding NTFPs (Ashton et al., 2001). However, existing silvicultural treatments may require adjustment. For example, the current Indonesian regulation on timber cutting

(TPTI) requires companies to slash all undergrowth and climbers every year for 5 years in each compartment following timber extraction in order to control weeds and promote the regeneration of timber species. High-value or else locally important NTFPs are usually slashed (e.g., rattans, food and medicinal plants; Sheil et al., 2006). Meijaard et al. (2005) suggested revoking this policy as it is largely perceived as both technically and socially questionable. In contrast to the above examples, very little seems to be reported on how silviculture of NTFPs affects timber values. Trauernicht and Ticktin (2005) showed in southern Mexico how the planting the understory *xate* palm *Chamaedorea hooperiana* under natural forest cover led to a reduction of the density of saplings of timber species (probably due to slashing during site preparation). An extreme case occurs during planting and tending the saplings of benzoin trees (*Styrax* spp., tapped for trunk resin) in the understory of montane forests in Indonesia, which leads over time to species-poor tree canopies (García-Fernández et al., 2003).

2.3. Conflict of use

Conflict of use arises when the same tree species provides both timber and NTFP values. And it exacerbates when different stakeholders are involved in the extraction of each (Laird, 1999; Menton, 2003; Shanley and Luz, 2003). Herrero-Jáuregui et al. (2009) observed that 47% of all timber species currently traded in the Amazonian state of Pará in Brazil also have documented non-timber uses. As expected, the greater the resources values, the greater the conflict. Four species scored specially high in this respect: *Dipteryx odorata*, *Hymenaea courbaril* (both Fabaceae), *Tabebuia serratifolia* and *Tabebuia impetiginosa* (both Bignoniaceae). Medicinal plant collectors greatly value the bark of *T. impetiginosa* and *H. courbaril* trees, whereas the oil from the seeds of *D. odorata* is widely extracted for cosmetic and medicinal purposes. In the particular case of *T. impetiginosa* and *H. courbaril*, conflict of use is acute because both species regenerate poorly due to their light-demanding attributes, low population densities, and low growth rates (Schulze, 2008). The long-term population persistence and the capacity of local people to collect bark of *T. impetiginosa* for local medicinal and public health purposes (Gómez-Castellanos et al., 2009) may disappear over time if post-logging enrichment planting is not applied (Schulze et al., 2008a,b).

Conflict of use is also widespread in Central Africa. In Cameroon, out of the 23 top timber species being exported, over half of these also have NTFP value (Ndoye and Tieguhong, 2004). In both Cameroon and Central African Republic, the three most exploited timber species, *Triplochiton scleroxylon* (Sterculiaceae), *Entandrophragma cylindricum* (Meliaceae) and *Milicia excelsa* (Moraceae) are also sources of medicine and food (Tieguhong and Ndoye, 2007). In both Cameroon and the Democratic Republic of Congo, the Forestry Laws have clarified logging companies' obligations towards local people with provisions to avoid timber exploitation obstructing villagers in exercising their user rights. To meet this objective, local communities and timber companies work together to reach agreements on maintaining tree species with conflict of use. Yet, at least in Cameroon, inventorying (plant) NTFPs as part of timber censuses is done at the discretion of the concessionaire (GTZ, 2006). Others have suggested that government agencies assign harvest quotas for those timber species with high NTFP value and compensate timber companies for any forgone revenue (Tieguhong and Ndoye, 2007).

An alternative intervention for minimizing conflict of use includes legal protection from logging when both the NTFP economic and social value equals or exceeds the timber value. Such protection is currently extended for the Brazil nut tree in Brazil, Peru, and Bolivia, due to its pivotal role in sustaining rural livelihoods (Ortiz, 2002; Peres et al., 2003). However, the extent of conflict of use is often culturally and geographically specific, thus complicating any necessary steps towards legal protection at broad spatial scales. For example, in the Pokola–Kabo–Loundoungou forest concession in Congo, five species extracted for timber were noted as having no NTFP value yet they were commonly used as NTFPs in southwestern and eastern Cameroon. Conversely, one of the most commercially valuable timber species (*E. cylindricum*), is used as a medicine in central and eastern Cameroon, but not in the south west (N'Zala, 2002).

Another intervention is the spatial separation of management units for either timber or NTFPs (e.g., da Silva Dias et al., 2002). The feasibility of this option will depend, among other factors, on the nature of the NTFP in question and its habitat requirements. For example, the locally valuable, multipurpose tree *Carapa guianensis* (Meliaceae) shows higher adult densities in seasonally flooded than *terra firme* forests in the southwestern Brazilian Amazon (Klimas et al., 2007). Management objectives for either timber or the high-quality oil extracted from its seeds can be spatially segregated if seed harvest intensities are anticipated to be high. In this case, allocating flooded forest areas only for seed collection may be a sensible alternative. Yet, areas destined for tree seed collection need to be extensive enough to compensate for interannual and/or inter-tree variability in seed production, a typical trait of many tropical forest trees (Wright et al., 2005) including those bearing NTFPs (Wadt et al., 2005). A related issue to consider in multipurpose tree species is the nature of the relationship between individual size and NTFP yields. For example, if fruit production peaks at intermediate (instead of large) diameter classes (e.g., Soehartono and Newton, 2001; Kainer et al., 2007), the largest (i.e., less fecund) individuals are amenable to harvesting or otherwise setting aside during multi-use planning. The copaíba tree (*Copaifera* spp., Caesalpiniaceae), an Amazonian timber species, is a similar case. The intermediate-sized individuals yield the highest amount of tapped oleoresin while the largest (usually with hollow trunks) produce negligible amounts (Plowden, 2003).

2.4. Wildlife conservation and use

Most vertebrate species can persist in selectively logged forests as long as most indirect effects such as hunting, forest fragmentation, and forest fires are controlled (Johns, 1997; Meijaard et al., 2005; Azevedo-Ramos et al., 2006). Yet, the indirect effects are widespread and pervasive (Laurance and Peres, 2006), particularly hunting for bushmeat. For example, per capita wildlife harvest rates in settlements adjacent to logging concessions are much higher than those away from concessions (Robinson et al., 1999; Auzel and Wilkie, 2000; Thibault and Blaney, 2003). Furthermore, bushmeat is usually hunted by outsiders at the expense of those who own prior, legitimate claims to forest wildlife (Poulsen et al., 2009). Regulating or banning hunting in timber concessions is now a widely agreed measure by national governments, researchers, concessionaires, non-governmental organizations and the international community (Bennett and Robinson, 2001; Meijaard et al., 2005; Nasi et al., 2008).

The compatibility of timber harvesting with the survival of wildlife may be contingent on other (interrelated) measures. One is to put pressure on timber concessionaires to control the activities of their own employees, such as banning them from purchasing bushmeat from forest villagers, and/or providing workers and families with alternative protein sources. Some companies are implementing such regulations in Congo, Gabon and Cameroon, in partnership with non-governmental organizations and usually with external funding support (Aviram et al., 2003). Another measure is allowing rural communities to sell bushmeat for local consumption in, or nearby, urban centers. An example is the *Congolaise Industrielle des Bois* timber concession in North Congo, where communal hunting areas were created for abundant and ecologically resilient species (i.e., with high intrinsic rates of population increase such as ungulates and rodents; Bennett and Robinson, 2000) while prohibiting the hunting of legally protected species (Elkan et al., 2006). These kinds of initiatives are likely to promote compatible timber and wildlife uses although further interventions may be needed. Some have suggested, for example, to locate sawmills in existing cities to avoid urbanization in, or adjacent to, logging concessions (Poulsen et al., 2009).

Besides terrestrial vertebrates, the effects of selective logging on aquatic wildlife for human consumption appear less studied. In the hilly landscapes of Borneo, many locally important fish species are known to be sensitive to disturbance due to enhanced stream sediment levels after logging roads are built (Meijaard et al., 2005). Locating logging roads away from streams and minimizing their width may help to reduce sediment loads into streams and rivers. The application of RIL guidelines (which include minimizing soil damage) in an Amazonian timber concession revealed no medium-term loss of fish species from forest streams compared to unlogged areas, although changes in the abundance of some species were detected (Dias et al., 2009).

2.5. Tenure and access rights

In addition to the topics discussed above, moving towards compatibility of timber and NTFP management requires understanding of who has rights and responsibilities for management decisions for both types of product. Rather than individual and comprehensive ownership rights, forest property in many contexts is an overlapping 'bundle of rights' including those to access and harvest the resource, to manage it and exclude others, and to sell or transfer resource rights to others (Schlager and Ostrom, 1992). Typically, local stakeholders hold only a partial set of rights while others have rights over the same resource or property (Meinzen-Dick and Mwangi, 2008). The type of right held and the presence of multiple rights holders will influence the compatibility of integrated management approaches for timber and NTFPs, and the prospects for enforcing norms and agreements.

For example, the community forest concessions in Petén, Guatemala, were superimposed by the government on pre-existing rights regarding to NTFPs such as the fronds of *xate* understory palms. Rights over *xate* are largely held by stakeholders outside community concession organizations and conflicts between some community concessionaires and outside harvesters are not uncommon (Nittler and Tschinkel, 2005). In northern Bolivia, conflict and confusion over tenure rights have resulted from industrial timber concessions being superimposed on customary properties such as forest estates called *barracas* and agro-extractive communities who are dependent on Brazil nut extraction (de Jong et al., 2006). In both cases, even if selective timber harvesting and NTFP extraction are biophysically compatible, the potential for excluding legitimate rights holders from forest benefits may undermine the prospects of an integrated management regime from a social standpoint (Guariguata et al., 2008).

2.6. Product certification

The proliferation of different certification standards, the presence of different groups of harvesters for either timber or NTFPs and the inherent diversity of NTFPs (Shanley et al., 2002), currently hampers the development of cost-efficient, harmonized labelling procedures for timber and NTFPs in a given forest. Lack of consumer awareness about the environmental and social aspects of NTFP extraction, compared to timber, may also become a barrier (Shanley et al., 2008). Furthermore, NTFP certification is usually product-specific (food, personal care, or medicine), and its standards focus on issues of 'product quality', 'organic production' 'good agricultural practices' and/or 'source of origin' (Pierce and Laird, 2003). In contrast, tropical timber certification through Forest Stewardship Council (FSC, 1996) standards is holistic and granted at the level of the forest stand without guarantees that each timber species is extracted sustainably (Schulze et al., 2008b). The many differences in information needs, economic value and management procedures for timber and NTFP certification (highlighted in Table 2) suggest that much work lies ahead in moving towards compatibility from a certification standpoint.

Another constraint to compatible certification approaches is that knowledge on population density, regeneration rates, and optimum management practices for most NTFPs is scant. This knowledge is needed for delineating management standards, including sustainable harvest regimes. Whereas guidelines for timber management in tropical forests date back to more than a century of research and development (Dawkins and Philip, 1998), formal management principles for NTFPs have a more recent history (Peters, 1996; Wong et al., 2001; Stockdale, 2005; Medicinal Plants Specialist Group, 2007); while informal principles need further integration into certification procedures and forest management (Shanley and Stockdale, 2008). Overall, few such principles have yet been validated or widely adopted.

A key variable influencing the harmonization of certification procedures for NTFPs and timber is whether or not a given NTFP involves human consumption. For example, organic certification of Brazil nuts gathered from the Bolivian Amazon needs to follow strict international standards for collection, handling, and storage (e.g., European Union Regulation 2092/91; SIPPO, 2005). Some

Table 2
Main factors and characteristics influencing the management of timber and non-timber forest products (NTFPs) when developing integrated product certification approaches. Modified from Shanley et al. (2008).

Factor	Timber	NTFPs
Technical	-Relatively well-established guidelines -Standards relatively uniform and globally accepted (e.g., Forest Stewardship Council) -No hygiene/quality control issues for human consumption	-Incipient guidelines with multiple standards (organic, fair trade) -Quality control compliance issues for edible and medicinal products
Ecological	-Good amount of technical data for developing management plans	-Except for a few species, ecological data for developing management plans is lacking
Economic	-Moderate to high economic returns -Relatively stable, national and international markets -Certification affordable for large industries but challenging for smaller operations	-Low economic return for most species -Local markets predominate, while large fluctuations are the norm in international markets -Certification usually unaffordable unless combined either with timber or heavy subsidies

Brazil nut cooperatives in Bolivia now prohibit members from harvesting timber in organically-certified Brazil nut stands. The fact that organic labelling drives Brazil nut certification in Bolivia may explain the fact that, for example, FSC-certified timber concessions have not yet attempted to certify Brazil nuts under the current FSC standards developed for this NTFP (FSC norms for Brazil nut are also perceived as too complicated to implement; Pacheco and Cronkleton, 2008). In contrast, FSC standards for management of *xate* fronds in Guatemala were recently appended to those of (FSC) timber in three different concessions covering about 190,000 ha of forest (Smartwood, 2007). This is expected to facilitate and harmonize the auditing process while reducing the costs of applying multiple certification schemes. The fronds of *xate* are used in floral arrangements and are not consumed by humans thus facilitating compatibility of certification of timber and *xate* under FSC principles.

3. Looking forward: towards compatibility of timber and NTFP management

Given the growing demands on tropical forests regarding the many goods and services they provide, effective guidelines for multiple-use management systems are essential. Here we used timber as the 'primary' output upon which tradeoffs and management challenges could be identified when adding NTFPs as a 'secondary' output (Panayotou and Ashton, 1992); hence our discussion above and below needs to be interpreted in this context. One obvious outcome from our analysis is that compatible management of timber and NTFPs is inherently multifactorial and context-dependent (Table 1). In some situations, compatibility is possible and in others, it may prove difficult to achieve. This conclusion remains, however, speculative due to the paucity of published studies on integrated management approaches for timber and NTFPs across the tropics. We provide some suggestions for making progress.

García-Fernández et al. (2008) hypothesized that governance conditions relating to land-devolution policies, effective collective institutions and the design of multi-stakeholder management models are important enabling factors for multiple forest use to succeed in the tropics. An example offering partial support comes from Guatemala. When the community forestry concessions were created in the lowlands of the Petén during the early 1990s, multiple objectives (production of timber and NTFPs) were explicitly defined from the outset. Since then, concerted efforts by the national authority responsible for overseeing the implementation of sustainable management, forest managers, researchers, and organizations providing technical assistance have contributed towards compatibility of timber and NTFP management (Pinelo, 2009). In particular, by enforcing good management practices for the harvest of timber and commercially valuable *xate* fronds. The lessons learned from the Petén (see Carrera et al., 2004; Nittler and Tschinkel, 2005) may be useful in other tropical locations where concurrent management of timber and NTFPs is sought.

Others have argued (e.g., Sands, 2005; p. 159) that a major predictor of success in implementing multiple forest use is ownership, or else direct oversight, by governments (whereas private companies would favor specialization over a single commodity). The eleven cases (out of 28 cases) of 'exemplary management' in Asia and the Pacific listed in Durst et al. (2005) and that included multiple-use objectives, are all forests being managed by government agencies. Testing pilot management systems for timber and NTFPs in forests where governments exert a direct role may prove fruitful. The Central Africa regional norms (FAO et al., 2008) developed for managing NTFPs indicate how countries can incorporate NTFPs in policy, legal, fiscal and institutional frameworks and provides a working model *vis a vis* timber production.

We suggest three (interrelated) ways to move forward when compatibility of timber and NTFP extraction is a management goal. One is to improve "passive" or "opportunistic" compatibility situations. For example, by enforcing the mitigation of logging impacts on the NTFP resource base (Tieguhong and Ndoye, 2007; Guariguata et al., 2009). Another alternative is to explicitly enhance both timber and NTFP values. Recent calls for researching and implementing silvicultural intensification in forests managed under RIL guidelines to ensure long-term timber production in tropical forests (Fredericksen and Putz, 2003; Peña-Claros et al., 2008; Schulze et al., 2008d), may open avenues for concurrent management of locally important NTFPs. Third, assessing biophysical, social, regulatory and institutional aspects so that trade-offs are minimized among stakeholders regarding timber and NTFPs (Purnomo et al., 2005; Lawrence, 2007; Lynam et al., 2007). Ros-Tonen et al. (2008) provide examples from the Brazilian Amazon where partnerships between local forest users, the private sector, non-governmental organizations, and the civil society could facilitate the insertion of NTFPs into timber-oriented models. The practicalities and effectiveness of the above proposals will also depend on the scale of management, timber harvesting intensities and mode of extraction (e.g., RIL vs. conventional logging), and the NTFP harvesting intensities among others. For example, from extensive industrial timber concessions where NTFPs are allowed to be harvested by local people (e.g., Guariguata et al., 2009), to small, multi-use forests that are managed communally or by individual families (e.g., Rockwell et al., 2007a,b; Menton et al., 2009).

Finally, tropical forestry training and education institutions may have to be re-crafted. Any formal insertion of multi-use management into tropical forestry curricula, especially in developing countries, will require financial and human resources and the development of innovative training and educational material (Temu et al., 2008). Otherwise we run the risk of perpetuating a timber bias when NTFP management plans are drafted. For example, the current technical norms for Brazil nut management in Bolivia require forest owners to establish 'no take' zones of up to 6% of the total production area for up to 5 years (Ministerio de Desarrollo Sostenible, 2005). The norms provide little guidance as to where in the forest this should be done thus disregarding the very high-light habitat requirements of Brazil nut trees for seedling and sapling establishment (Cotta et al., 2008). The norms also call for carrying out detailed Brazil nut tree inventorying and to measure commercial bole height and degree of crown illumination, with no obvious connection to nut harvest and management practices. In contrast, NTFP norms and regulations developed at the national level often disregard timber harvesting as a potentially overlapping activity. Although there are documented initiatives in Brazil at training tropical foresters in bridging the gap between timber and NTFP use, ecology and management (Pinto et al., 2008; Shanley and Medina, 2005), there is apparently little happening in other tropical locations. To conclude, given the millions of hectares of natural forest allocated for timber production in the Amazon (Schulze et al., 2008c) and Congo basins (Nasi et al., 2006; Laporte et al., 2007), and the equally vast area of natural tropical forest under control of rural communities (Sunderlin et al., 2008), there may be plenty of opportunities for designing and validating integrated management approaches that include timber and NTFPs.

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References

Ashton, M.S., Mendelsohn, R., Singhakurama, B.M.P., Gunatilleke, C.V.S., Gunatilleke, I.A.U.N., Evans, A., 2001. A financial analysis of rain forest silviculture in southwestern Sri Lanka. Forest Ecology and Management 154, 431–441.

Asseng Ze, A., 2008. Gestion durable des produits forestiers non ligneux dans la concession forestière de Pallisco. Etude Pilote sur les Techniques d'Exploitation Forestiere no. 24. Organisation des Nations Unies pour l'alimentation et l'agriculture, FAO, Rome.

Auzel, P., Wilkie, D.S., 2000. Wildlife use in Northern Congo: hunting in a commercial logging concession. In: Robinson, J.G., Bennett, E.L. (Eds.), Hunting for Sustainability in Tropical Forests. Columbia University Press, New York, pp. 413–426.

Aviram, R., Bass, M., Parker, K., 2003. Extracting hope for bushmeat: case studies of oil, gas, mining and logging industry efforts for improved wildlife management. Bushmeat Crisis Task Force. http://www.bushmeat.org/docs.html, cited 23 February 2009.

Azevedo-Ramos, C., de Carvalho, O., do Amaral, B.D., 2006. Short-term effects of reduced-impact logging on eastern Amazon fauna. Forest Ecology and Management 232, 26–35.

Barreto, P., Amaral, P., Vidal, E., Uhl, C., 1998. Costs and benefits of forest management for timber production in eastern Amazonia. Forest Ecology and Management 108, 9–26.

Belcher, B., Michon, G., Angelsen, A., Ruiz-Pérez, M., Asbjornsen, H., 2005. The socioeconomic conditions determining the development, persistence, and decline of forest garden systems. Economic Botany 59, 245–253.

Bennett, E.L., Robinson, J.G., 2000. Hunting for sustainability: the start of a synthesis. In: Robinson, J.G., Bennett, E.L. (Eds.), Hunting for Sustainability in Tropical Forests. Columbia University Press, New York, pp. 499–519.

Bennett, E.L., Robinson, J.G., 2001. Hunting of wildlife in tropical forests. Environment Department Paper no. 76. The World Bank, Washington, DC.

Binkley, C.S., 1997. Preserving nature through intensive plantation forestry: the case of forestland allocation with illustrations from British Columbia. Forestry Chronicle 73, 553–559.

Campos, J.J., Finegan, B., Villalobos, R., 2001. Management of goods and services from neotropical forest biodiversity: diversified forest management in Mesoamerica. In: CBD Technical Series No. 3, Secretariat of the Convention on Biological Diversity (SCBD), Montreal, pp. 5–16.

Carrera, F., Stoian, D., Campos, J.J., Morales, J., Pinelo, G., 2004. Forest certification in Guatemala. In: Proceedings of the Symposium on Forest Certification in Developing and Transitional Societies, Yale School of Forestry and Environmental Studies, New Haven, USA, pp. 363–405.

Costa, F.R.C., Magnusson, W.E., 2003. Effects of selective logging on the diversity and abundance of flowering and fruiting understory plants in a Central Amazonian forest. Biotropica 35, 103–114.

Cotta, J.N., Kainer, K.A., Wadt, L.H.O., Staudhammer, C.L., 2008. Shifting cultivation effects on Brazil nut (*Bertholletia excelsa*) regeneration. Forest Ecology and Management 256, 28–35.

Cunningham, A.B., 2001. Applied Ethnobotany. Earthscan, London.

da Silva Dias, A., Campos, J.J., Villalobos, R., Louman, B., Gonçalvez, L., 2002. Manejo forestal diversificado en una comunidad ribereña de la Amazonía brasileña: consideraciones sociales y silviculturales. Revista Forestal Centroamericana 38, 78–84.

Dawkins, H.C., Philip, M.S., 1998. Tropical Moist Forest Silviculture and Management: A History of Success and Failure. CAB International, Wallingford, UK.

De Graaf, N.R., Poels, R.L.H., Van Rompaey, R.S.A.R., 1999. Effect of silvicultural treatment on growth and mortality of rainforest in Surinam over long periods. Forest Ecology and Management 124, 123–135.

de Jong, W., Ruiz, S., Becker, M., 2006. Conflicts and communal forest management in Northern Bolivia. Forest Policy and Economics 8, 447–457.

Dias, M.S., Magnusson, W.E., Zuanon, J., 2009. Effects of reduced-impact logging on fish assemblages in Central Amazonia. Conservation Biology, doi:10.1111/j.1523-1739.2009.01299.x.

Durst, P.B., Brown, C., Tacio, H.D., Ishikawa, M., 2005. In Search of Excellence: Exemplary Forest Management in Asia and the Pacific. Food and Agriculture Organization of the United Nations Regional Office for Asia and the Pacific, Bangkok.

Elkan, P.W., Elkan, S.W., Moukassa, A., Malonga, R., Ngangoue, M., Smith, J.L.D., 2006. Managing threats from bushmeat hunting in a timber concession in the Republic of Congo. In: Laurance, W.F., Peres, C.A. (Eds.), Emerging Threats to Tropical Forests. University of Chicago Press, Chicago, pp. 393–415.

FAO–GTZ–COMIFAC, 2008. Directives sous-regionales relatives a la gestion durable des produits forestieres non-ligneux d'origine vegetale en Afrique Centrale. Document GCP/RAF/398/GER. Yaounde, Cameroun.

Fonseca, M.G., Vidal, E., dos Santos, F.A.M., 2009. Intraspecific variation in the fruiting of an Amazonian timber tree: implications for management. Biotropica 41, 179–185.

Fortini, L.B., Rabelo, F.G., Zarin, D.J., 2006. Mixed potential for sustainable forest use in the tidal floodplain of the Amazon River. Forest Ecology and Management 231, 78–85.

Fredericksen, T.S., Putz, F.E., 2003. Silvicultural intensification for tropical forest conservation. Biodiversity and Conservation 12, 1445–1453.

FSC, 1996. FSC Principles and Criteria for Forest Stewardship. Document FSC-STD-01-001 (version 4-0). Bonn, Germany.

García-Fernández, C., Casado, M.A., Ruiz Pérez, M., 2003. Benzoin gardens in north Sumatra, Indonesia: effects of management on tree diversity. Conservation Biology 17, 829–836.

García-Fernández, C., Ruiz Pérez, M., Wunder, S., 2008. Is multiple-use forest management widely implementable in the tropics? Forest Ecology and Management 256, 1468–1476.

Godoy, C.E., Madrid, J., Manzanero, M., 2009. Guía y formato para la elaboración de planes de manejo integrados de recursos forestales no maderables (RFNM). Rainforest Alliance, Petén, Guatemala.

Gómez-Castellanos, J.R., Prieto, J.M., Heinrich, M., 2009. Red lapacho (*Tabebuia impetiginosa*)—a global ethnopharmacological commodity? Journal of Ethnopharmacology 121, 1–13.

Gourlet-Fleury, S., Favrichon, V., Schmitt, L., Petronelli, P., 2004. Consequences of silvicultural treatments on stand dynamics at Paracou. In: Gourlet-Fleury, S., Guehl, J.-M., Laroussinie, O. (Eds.), Ecology and Management of a Neotropical Rainforest. Lessons Drawn from Paracou, a Long-term Experimental Research Site in French Guiana. Elsevier, Paris, pp. 254–280.

Guariguata, M.R., Sáenz, G., 2002. Post-logging acorn production and oak regeneration in a tropical montane forest, Costa Rica. Forest Ecology and Management 167, 285–293.

Guariguata, M.R., Cronkleton, P., Shanley, P., Taylor, P., 2008. The compatibility of timber and non-timber forest product extraction and management. Forest Ecology and Management 256, 1477–1481.

Guariguata, M.R., Licona, J.C., Mostacedo, B., Cronkleton, P., 2009. Damage to Brazil nut trees (*Bertholletia excelsa*) during selective timber harvesting in Northern Bolivia. Forest Ecology and Management 258, 788–793.

GTZ, 2006. Etude comparative de 20 plans d'aménagement approuvés au Cameroun. Coopération Technique Allemande. Bureau Regional Yaoundé, Cameroun.

Hendrison, J., 1990. Damage Controlled Logging in Managed Rain Forest in Suriname. Agricultural University, Wageningen, The Netherlands.

Herrero-Jáuregui, C., García-Fernández, C., Sist, P., Casado, M., 2009. Conflict of use for multi-purpose tree species in the state of Pará, eastern Amazonia, Brazil. Biodiversity and Conservation 18, 1019–1044.

Hiremath, A.J., 2004. The ecological consequences of managing forests for non-timber products. Conservation and Society 2, 211–216.

ITTO, 2006. Status of tropical forest management 2005. ITTO Technical Series no. 24. Yokohama, Japan.

Johns, A.D., 1988. Effects of selective timber extraction on rain forest structure and composition and some consequences for frugivores and folivores. Biotropica 20, 31–37.

Johns, A.D., 1997. Timber Production and Biodiversity Conservation in Tropical Rain Forests. Cambridge University Press, UK.

Johns, J.S., Barreto, P., Uhl, C., 1996. Logging damage during planned and unplanned logging operations in the eastern Amazon. Forest Ecology and Management 89, 59–77.

Jonkers, W.B.J., 1987. Vegetation Structure, Logging Damage and Silviculture in a Tropical Rain Forest of Suriname. Agricultural University, Wageningen, The Netherlands.

Kainer, K.A., Wadt, L.H.O., Gomes-Silva, D.A.P., Capanu, M., 2006. Liana loads and their association with *Bertholletia excelsa* fruit and nut production, diameter growth and crown attributes. Journal of Tropical Ecology 22, 147–154.

Kainer, K.A., Wadt, L.H.O., Staudhammer, C.L., 2007. Explaining variation in Brazil nut fruit production. Forest Ecology and Management 250, 244–255.

Kant, S., 2004. Economics of sustainable forest management. Forest Policy and Economics 6, 197–203.

Klimas, C.A., Kainer, K.A., Wadt, L.H.O., 2007. Population structure of *Carapa guianensis* in two forest types in the southwestern Brazilian Amazon. Forest Ecology and Management 250, 256–265.

Laird, S., 1999. The management of forests for timber and non-wood forest products in central Africa. In: Sunderland, T., Clark, L., Vantomme, P. (Eds.), Non-wood Forest Products of Central Africa: Current Research Issues and Prospects for Development and Conservation. FAO, Rome.

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

Laurance, W.F., Peres, C.A. (Eds.), 2006. Emerging Threats to Tropical Forests. University of Chicago Press, Chicago.

Lawrence, A., 2003. No forest without timber? International Forestry Review 5, 87–96.

Lawrence, A., Phillips, O.L., Reategui Ismodes, A., Lopez, M., Rose, S., Wood, D., Farfan, A.J., 2005. Local values for harvested forest plants in Madre de Dios, Peru: towards a more contextualised interpretation of quantitative ethnobotanical data. Biodiversity and Conservation 14, 45–79.

Lawrence, A., 2007. Beyond the second generation: towards adaptiveness in participatory forest management. CAB Reviews: Perspectives in Agriculture, Veterinary Sciences, Nutrition and Natural Resources, doi:10.1079/PAVSNNR20072028.

Louman, B., García-Fernández, C., Sabogal, C., Ehringhaus, C., Salazar, M., Villacrés, D., 2008. Capacidades técnicas y desafíos del manejo forestal comunitario. In: Sabogal, C., de Jong, W., Pokorny, B., Louman, B. (Eds.), Manejo forestal comunitario en America Latina: experiencias, lecciones aprendidas y retos para el futuro. Centro para la Investigación Forestal Internacional (CIFOR), Bogor, Indonesia, pp. 75–112.

Lynam, T., de Jong, W., Sheil, D., Kusumanto, T., Evans, K., 2007. A review of tools for incorporating community knowledge, preferences and values into decision making in natural resources management. Ecology and Society 12 (1), 5 [online] URL: http://www.ecologyandsociety.org/vol12/iss1/art5/

Meijaard, E., Sheil, D., Nasi, R., Augeri, D., Rosenbaum, B., Iskandar, D., Setyawati, T., Lammertink, M., Rachmatika, I., Wong, A., Soehartono, T., Stanley, S., O'Brien, T., 2005. Life after Logging: Reconciling Wildlife Conservation and Production Forestry in Indonesian Borneo. Center for International Forestry Research, Bogor, Indonesia.

Medicinal Plant Specialist Group, 2007. International Standard for Sustainable Wild Collection of Medicinal and Aromatic Plants (ISSC-MAP). Version 1.0. Bundesamt für Naturschutz (BfN), MPSG/SSC/IUCN, WWF Germany, and TRAFFIC (BfN-Skripten 195).

Meinzen-Dick, R., Mwangi, E., 2008. Cutting the web of interests: pitfalls of formalizing property rights. Land Use Policy 26, 36–43.

Menton, M., 2003. Effects of logging on non-timber forest product extraction in the Brazilian Amazon: community perceptions of change. International Forestry Review 5, 97–105.

Menton, M., Merry, F.D., Lawrence, A., Brown, N., 2009. Company-community logging contracts in Amazonian settlements: impacts of livelihoods and NTFP harvests. Ecology and Society 14 (1), 39 [online] URL: http://www.ecologyandsociety.org/vol14/iss1/art39/

Michon, G., de Foresta, H., Levang, P., Verdeaux, F., 2007. Domestic forests: a new paradigm for integrating local communities' forestry into tropical forest science. Ecology and Society 12 (2), 1 [online] URL: http://www.ecologyandsociety.org/vol12/iss2/art1.

Ministerio de Desarrollo Sostenible, 2005. Norma Técnica para Elaboración de Planes de Manejo de Castaña (*Bertholletia excelsa* Humb. & Bonpl.). Resolución Ministerial no. 077/2005. La Paz, Bolivia.

Nasi, R., Cassagne, B., Billand, A., 2006. Forest management in Central Africa: where are we? International Forestry Review 8, 14–20.

Nasi, R., Brown, D., Wilkie, D., Bennett, E., Tutin, C., van Tol, G., Christophersen, T., 2008. Conservation and use of wildlife based resources: the bushmeat crisis. In: CBD Technical Series no. 33, Secretariat of the Convention on Biological Diversity, Montreal, Canada.

Ndoye, O., Tieguhong, J.C., 2004. Forest resources and rural livelihoods: the conflict between timber and non-timber forest products in the Congo Basin. Scandinavian Journal of Forest Research 19, 36–44.

Nittler, J., Tschinkel, H., 2005. Community forest management in the Maya Biosphere Reserve of Guatemala. Protection through profits. Submitted to the United States Agency for International Development (USAID) and the Sustainable Agriculture and Natural Resource Management (SANREM) Collaborative Research Support Program (CRSP), University of Georgia.

N'Zala, D., 2002. Conservation et gestion durable des écosystèmes des forêts tropicales humides de l'Afrique centrale. Etude de cas d'aménagement forestier exemplaire en Afrique centrale: La concession de Pokola-Kabo-Loundoungou, République du Congo. Document de travail FM/19F. Service de la mise en valeur des ressources forestières, Département des Forêts. Rome, FAO.

Ocampo Sánchez, R.A., 2004. Ipecacuana, *Psychotria ipecacuanha* (Brotero) Stokes: un producto no maderable cultivado bajo el bosque en Huetar Norte, Costa Rica. In: Alexiades, M., Shanley, P. (Eds.), Productos Forestales, Medios de Subsistencia y Conservación, vol. 3. CIFOR, Bogor, Indonesia, pp. 257–273.

Ortiz, E., 2002. Brazil Nut (*Bertholletia excelsa*). In: Shanley, P., Pierce, A.R., Laird, S.A., Guillén, A. (Eds.), Tapping the Green Market: Certification and Management of Non-Timber Forest Products. Earthscan, London, pp. 61–74.

Pacheco, P., Cronkleton, P., 2008. Developing standards for Brazil nuts in Bolivia. In: Shanley, P., Pierce, A., Laird, S., Robinson, D. (Eds.), Beyond Timber: Certification and Management of Non-Timber Forest Products. Center for International Forestry Research, Bogor, Indonesia, pp. 41–42.

Panayotou, T., Ashton, P.S., 1992. Not by Timber Alone: Economics and Ecology for Sustaining Tropical Forests. Island Press, Washington, DC.

Pearce, D., Putz, F.E., Vanclay, J., 2003. Sustainable forestry: panacea or folly? Forest Ecology and Management 172, 229–247.

Pierce, A., Laird, S., 2003. In search of comprehensive standards for non-timber forest products in the botanicals trade. International Forestry Review 5, 138–147.

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

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

Peres, C.A., Baider, C., Zuidema, P.A., Wadt, L.H.O., Kainer, K.A., Gomes-Silva, D.A.P., Salomão, R.P., Simões, L.L., Franciosi, E.R.N., Cornejo, F., Gribel, R., Shepard, G.H., Kanashiro, M., Coventry, P., Yu, D.W., Watkinson, A.R., Freckleton, R.P., 2003. Demographic threats to the sustainability of Brazil nut exploitation. Science 302, 2112–2114.

Peters, C.M., 1996. The ecology and management of non-timber forest resources. World Bank Technical Paper no. 322. The World Bank, Washington, DC.

Pinard, M.A., Barker, M.G., Tay, J., 2000. Soil disturbance and post-logging forest recovery on bulldozer paths in Sabah, Malaysia. Forest Ecology and Management 130, 213–225.

Pineda, P.A., 1996. Diseño y aplicación de un inventario forestal diversificado (maderables y no maderables) en Petén. M.Sc. Thesis. Centro Agronómico Tropical de Investigación y Enseñanza (CATIE), Costa Rica.

Pinelo, G., 2009. ¿Qué factores favorecen la compatibilidad del manejo para madera y la palma de xate (*Chamaedorea* spp.) en Guatemala? In: Guariguata, M.R., García-Fernández, C., Nasi, R., Sheil, D., Herrero-Jáuregui, C., Cronkleton, P., Ndoye, O., Ingram, V. (Eds.), Hacia un manejo múltiple en bosques tropicales: consideraciones sobre la compatibilidad del manejo de madera y productos forestales no maderables. CIFOR, Bogor, Indonesia, p. 18.

Pinto, L.F.G., Shanley, P., Gomes, A.P.C., Robinson, D., 2008. Experience with NTFP certification in Brazil. Forests, Trees and Livelihoods 18, 37–54.

Plowden, C., 2003. Production ecology of copaíba (*Copaifera* spp.) oleoresin in the eastern Brazilian Amazon. Economic Botany 57, 491–501.

Poore, D., Burgess, J., Palmer, J., Rietbergen, S., Synott, T., 1989. No Timber Without Trees: Sustainability in the Tropical Forests. Earthscan, London.

Poore, D., 2003. Changing Landscapes: the Development of the International Tropical Timber Organization and its Influence on Tropical Forest Management. Earthscan, London.

Poulsen, J.R., Clark, C.J., Mavah, G., Elkan, P.W., 2009. Bushmeat supply and consumption in a tropical logging concession in Northern Congo. Conservation Biology 23, 1597–1608.

Purnomo, H., Mendoza, G.A., Prabhu, R., 2005. Analysis of local perspectives on sustainable forest management: an Indonesian case study. Journal of Environmental Management 74, 111–126.

Putz, F.E., Blate, G., Redford, K.H., Fimbel, R., Robinson, J., 2001. Tropical forest management and conservation of biodiversity: an overview. Conservation Biology 15, 7–20.

Putz, F.E., Sist, P., Fredericksen, T., Dykstra, D., 2008. Reduced-impact logging: challenges and opportunities. Forest Ecology and Management 256, 1427–1433.

Robinson, J.G., Redford, K.H., Bennett, E.L., 1999. Wildlife harvest in logged tropical forest. Science 284, 595–596.

Rockwell, C.A., Kainer, K.A., Staudhammer, C.L., Baraloto, C., 2007a. Future crop tree damage in a certified community forest in southwestern Amazonia. Forest Ecology and Management 242, 108–118.

Rockwell, C.A., Kainer, K.A., Marcondes, N., Baraloto, C., 2007b. Ecological limitations of reduced-impact logging at the smallholder scale. Forest Ecology and Management 238, 365–374.

Romero, C., 1999. Reduced impact logging effects on commercial non-vascular pendant epiphyte biomass in Costa Rica. Forest Ecology and Management 118, 117–125.

Ros-Tonen, M.A.F., van Andel, T., Morsello, C., Otsuki, K., Rosendo, S., Scholz, I., 2008. Forest-related partnerships in Brazilian Amazonia: there is more to sustainable forest management than reduced impact logging. Forest Ecology and Management 256, 1482–1497.

Salick, J., Mejia, A., Anderson, T., 1995. Non-timber forest products integrated with natural forest management, Rio San Juan, Nicaragua. Ecological Applications 5, 878–895.

Sands, R., 2005. Forestry in a Global Context. CABI Publishing, Wallingford, UK.

Sayer, J.A., Byron, N., 1996. Technological advance and conservation of resources. International Journal of Sustainable Development and World Ecology 3, 43–53.

Schlager, E., Ostrom, E., 1992. Property rights regimes and natural resources: a conceptual analysis. Land Economics 68, 249–262.

Schulze, M., Zweede, J., 2006. Canopy dynamics in unlogged and logged forest stands in the eastern Amazon. Forest Ecology and Management 236, 56–64.

Schulze, M., 2008. Technical and financial analysis of enrichment planting in logging gaps as a potential component of forest management in the eastern Amazon. Forest Ecology and Management 255, 866–879.

Schulze, M., Grogan, J., Uhl, C., Lentini, M., Vidal, E., 2008a. Evaluating ipê (*Tabebuia*, Bignoniaceae) logging in Amazonia: sustainable management or catalyst for forest degradation? Biological Conservation 141, 2071–2085.

Schulze, M., Grogan, J., Vidal, E., 2008b. Forest certification in Amazonia: standards matter. Oryx 42, 229–239.

Schulze, M., Grogan, J., Vidal, E., 2008c. Technical challenges to sustainable forest management in concessions on public lands in the Brazilian Amazon. Journal of Sustainable Forestry 26, 61–76.

Schulze, M., Grogran, J., Landis, M.R., Vidal, E., 2008d. How rare is too rare to harvest? Management challenges posed by timber species occurring at low densities in the Brazilian Amazon. Forest Ecology and Management 256, 1443–1457.

Shanley, P., Pierce, A.R., Laird, S.A., Guillen, A., 2002. Tapping the Green Market: Certification and Management of Non-timber Forest Products. Earthscan, London.

Shanley, P., Luz, L., 2003. The impacts of forest degradation on medicinal plant use and implications for health care in eastern Amazonia. Bioscience 53, 573–584.

Shanley, P., Medina, G. (Eds.), 2005. Frutíferas e plantas úteis na vida amazônica. Center for International Forestry Research, Bogor, Indonesia.

Shanley, P., Pierce, A., Laird, S., Robinson, D., 2008. Beyond Timber: Certification and Management of Non-timber Forest Products. Center for International Forestry Research, Bogor, Indonesia.

Shanley, P., Stockdale, M., 2008. Traditional knowledge, forest management, and certification: a reality check. Forest Trees and Livelihoods 18, 55–67.

Sheil, D., Puri, R., Wan, M., Basuki, I., van Heist, M., Liswanti, N., Rumiyati, Rachmatika, I., Samsoedin, I., 2006. Recognizing local people's priorities for tropical forest biodiversity. Ambio 35, 17–24.

Sheil, D., van Heist, M., Liswanti, N., Basuki, I., Wan, M., 2008. Biodiversity, landscapes and livelihoods: a local perspective. In: Moeliono, M., Wollenberg, E., Limberg, G. (Eds.), The Decentralization of Forest Governance: Politics, Economics and the Fight for Control of Forest in Indonesian Borneo. Earthscan, London, pp. 61–90.

Siebert, S.F., 1993. The abundance and site preferences of rattan (*Calamus exilis* and *Calamus zollingeri*) in two Indonesian national parks. Forest Ecology and Management 59, 105–113.
Siebert, S.F., 2000. Abundance and growth of *Desmoncus orthacantos* Mart. (Palmae) in response to light and ramet harvesting in five forest sites in Belize. Forest Ecology and Management 137, 83–90.
SIPPO-Swiss Import Promotion Programe, 2005. Guidance Manual for Organic Collection of Wild Plants. SIPPO, Zurich, Switzerland.
Sist, P., Ferreira, F.N., 2007. Sustainability of reduced-impact logging in the eastern Amazon. Forest Ecology and Management 243, 199–209.
Sist, P., García-Fernández, C., Fredericksen, T., 2008. Moving beyond reduced-impact logging towards a more holistic management of tropical forests. Forest Ecology and Management 256, vii–ix.
Smartwood, 2007. Adenda a los estándares interinos de Rainforest Alliance/Smartwood para la certificación del manejo de xate (*Chamaedorea* spp.) como NTFP en Guatemala. Documento FM-32-GUATEMALA. http://www.rainforest-alliance.org/forestry/documents/smartwoodguatemalaFMinterimstandardnov08spa.pdf, cited 12 February 2009.
Soehartono, T., Newton, A.C., 2001. Reproductive ecology of *Aquilaria* spp. in Indonesia. Forest Ecology and Management 152, 59–71.
Stockdale, M., 2005. Steps to sustainable and community-based NTFP management. Non-Timber Forest Products-Exchange Programme for South and Southeast Asia, The Philippines.
Sunderlin, W.D., Hatcher, J., Liddle, M., 2008. From Exclusion to Ownership? Challenges and Opportunities in Advancing Forest Tenure Reform. Rights and Resources Initiative, Washington, DC.
Temu, A.B., Chamshama, S.A.O., Kung'u, J., Kaboggoza, J., Chikamai, B., Kiwia, A. (Eds.), 2008. New Perspectives in Forestry Education. First Global Workshop on Forestry Education, September 2007. ICRAF, Nairobi, Kenya.
Thibault, M., Blaney, S., 2003. The oil industry as an underlying factor in the bushmeat crisis in Central Africa. Conservation Biology 17, 1807–1813.
Tieguhong, J.C., Ndoye, O., 2007. The Impact of Timber Harvesting on the Availability of Non-wood Forest Products in the Congo Basin. Forest Harvesting Case Study 23. Food and Agricultural Organization of the United Nations, Rome.
Titus, B., Kerns, B., Cocksedge, W., Winder, R., Pilz, D., Kauffman, G., Smith, R., Cameron, S., Freed, J., Ballard, H., 2006. Compatible management: a comprehensive overview of inactive to active tools and examples from North America. In: Cocksledge, W. (Comp.), Incorporating Non-timber Forest Products into Sustainable Forest Management: an Overview for Forest Managers. Royal Roads University, Victoria, Canada, pp. 49–72.
Toledo, V.M., Ortiz-Espejel, B., Corté, L., Moguel, P., Ordoñez, M.J., 2003. The multiple use of tropical forests by indigenous peoples in Mexico: a case of adaptive management. Ecology and Society, [online] URL: http://www.consecol.org/vol7/iss3/art9/.
Trauernicht, C., Ticktin, T., 2005. The effects of non-timber forest product cultivation on the plant community structure and composition of a humid tropical forest in southern Mexico. Forest Ecology and Management 219, 269–278.
Vantomme, P., 2003. Compiling statistics on non-wood forest products as policy and decision-making tools at the national level. International Forestry Review 5, 156–160.
Van Vliet, N., Nasi, R., 2008. Mammal distribution in a Central African logging concession area. Biodiversity and Conservation 17, 1241–1249.
Vincent, R., Binkley, C.S., 1993. Efficient multiple-use forestry may require land-use specialization. Land Economics 69, 370–376.
Wadsworth, F.H., Zweede, J.C., 2006. Liberation: acceptable production of tropical forest timber. Forest Ecology and Management 233, 45–51.
Wadt, L.H.O., Kainer, K.A., Gomes-Silva, D.A.P., 2005. Population structure and nut yield of a *Bertholletia excelsa* stand in Southwestern Amazonia. Forest Ecology and Management 211, 371–384.
Wang, S., Wilson, B., 2007. Pluralism in the economics of sustainable forest management. Forest Policy and Economics 9, 743–750.
Webb, E.L., 1999. Growth ecology of *Carapa nicaraguensis* Aublet. (Meliaceae): implications for natural forest management. Biotropica 31, 102–110.
Wong, J., Thornber, K., Baker, N., 2001. Resource assessment of non-wood forest products: experience and biometric principles. In: NWFP Series 13, Food and Agriculture Organization of the United Nations, Rome.
Wright, S.J., Jaramillo, M.A., Pavon, J., Condit, R., Hubbell, S.P., Foster, R.B., 2005. Reproductive size thresholds in tropical trees: variation among individuals, species, and forests. Journal of Tropical Ecology 21, 307–315.
Zhang, Y., 2005. Multiple-use forestry vs. forestland-use specialization revisited. Forest Policy and Economics 7, 143–156.