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Assessing the extent of "conflict of use" in multipurpose tropical forest trees: A regional view

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A B S T R A C T

In the context of multiple forest management, multipurpose tree species which provide both timber and non-timber forest products (NTFP), present particular challenges as the potential of conflicting use for either product may be high. One key aspect is that the magnitude of conflict of use can be location specific, thus adding complexity to policy development. This paper focuses on the extent to which the potential for conflict of use in multipurpose tree species varies across the Amazonian lowland forests shared by Peru, Bolivia, Colombia, Ecuador and Venezuela, emphasizing the economic dimension of conflict. Based on a review of the current normative and regulatory aspects of timber and NTFP extraction in the five countries, the paper also briefly discusses the opportunities and constraints for harmonization of timber and NTFP management of multipurpose species across the region. It was found that about half of the 336 timber species reviewed across the five countries also have non-timber uses. Eleven timber species are multipurpose in all five countries: *Calophyllum brasiliense*, *Cedrela odorata*, *Ceiba pentandra*, *Clarisia racemosa*, *Ficus insipida*, *Jacaranda copaia*, *Schefflera morototoni*, *Simarouba amara* and *Terminalia amazonia*. Seven other multipurpose species occurred only in either Venezuela (*Tabebuia impetiginosa*, *Spondias mombin*, *Pentaclethra macroloba*, *Copaifera officinalis*, *Chlorophora tinctoria*, *Carapa guianensis*) or Ecuador (*Tabebuia chrysantha*). Four multipurpose tree species presented the highest potential of conflict of use across the region: *Dipteryx odorata*, *Tabebuia serratifolia*, *Hymenaea courbaril* and *Myroxylon balsamum* yet these were not evenly distributed across all five countries. None of the five studied countries have specific legislation to promote sustainable use of any of the multipurpose species reported here and thus mitigate potential conflict of use; nor documented management options for integration or else segregation of both their timber and NTFP values.

1. Introduction

Multiple forest management aims at harmonizing the economic, social, institutional and biophysical dimensions related to harvesting, utilization, and commercialization of a variety of goods and services. Previous research has suggested that the opportunity costs of maintaining forest cover between successive timber harvest rotations could be minimized if these dimensions are further elucidated (e.g., Guariguata et al., 2012 and papers cited therein). In the case of management for timber and non-timber forest products (NTFP) in the tropics, social, biophysical and market factors usually operate in conflict thus hampering integrated approaches (Herrero-Jáuregui et al., 2009; Guariguata et al., 2010). For example, a given tree species may have both high timber and NTFP value, thus generating potential "conflict of use" (Laird, 1999). These "conflict of use" species are typically those whose timber and NTFP values accrue to different stakeholders which in turn have contrasting degrees of power and technical knowledge, livelihood options and market access (Tieguhong and Ndoye, 2007). While much of the available literature on multiple forest management in the tropics

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Fig. 1. The approximate extent of Amazonian lowland forest across the five countries studied bounded by the administrative departments considered in the analysis (shaded in grey).

focuses on the impacts of logging on NTFP yields (Laird, 1995; Salick et al., 1995; Shanley, 2000, 2002; Menton, 2003; Guariguata et al., 2009; Rist et al., 2012), much less has been published to date on how to minimize conflicting uses for timber and non-timber in multipurpose species (but see Herrero-Jáuregui et al., 2011b, 2012; Klimas et al., 2012). And many technical and policy challenges remain largely unaddressed (Rist et al., 2012).

One challenge in particular is that the magnitude of conflict of use in multipurpose tropical forest trees may be location specific, thus adding complexity to policy development. Across wet African forests for example, five species commonly harvested for timber in Congo have no NTFP value there yet they are widely used as NTFPs in southwestern and eastern Cameroon. And one of the most commercially valuable timber species in the Congo Basin (*Entandrophragma cylindricum*) has medicinal value in central and eastern Cameroon, but not in the south west (N'Zala, 2002). Also, the degree to which forest communities within the National Forest of Tapajos in Brazil harvest and use a given NTFP varies as a function of distance to markets, or whether they receive support from non-governmental organizations for promoting NTFP commercialization (Herrero-Jáuregui et al., 2011a). Yet as a whole, studies dealing with ecological and socio-economic aspects of forest resource use, notably NTFPs, are rarely conducted at large spatial scales so to gauge potential variations (but see Varghese and Ticktin, 2008; Newton et al., 2012). By contrasting and comparing regional with national contexts, insights could be gained as how to adapt management practices to local realities while helping to promote dialogue on common policy and technical issues (e.g., Peres et al., 2003; Duchelle et al., 2012). More often than not, many forestry technical norms and regulations across the tropics are applied uniformly over vast areas sometimes ignoring local contexts and species biology (e.g., Schulze et al., 2008).

This paper focuses on the extent to which the potential for conflict of use in multipurpose tree species varies across the

Amazonian lowland forests shared by Bolivia, Colombia, Ecuador, Peru and Venezuela. We emphasize the economic dimension of conflict of use which is exacerbated when a given multipurpose tree has both high timber and non-timber value (Herrero-Jáuregui et al., 2009). It is not the scope of this paper to account for the social dimension of conflict of use (e.g., loggers capturing non-timber values while excluding other stakeholders or else disregarding non-timber values during logging when local communities depend on these). A cross-continental discussion on this topic was recently provided by Rist et al. (2012). We conclude the paper with a brief analysis of the opportunities and constraints for harmonization of timber and NTFP management of multipurpose species in the study region.

2. Methods

2.1. Geographical scope

The analysis focuses on major portions of the Amazonian tropical rainforest shared by Bolivia, Colombia, Ecuador Peru, and Venezuela. Brazil was excluded from the analysis as the degree of potential conflict of use in this country has been already analyzed elsewhere using a similar methodology (Herrero-Jáuregui et al., 2009). Based on current vegetation maps of each country, the political units whose natural vegetation comprises of *terra firme* rainforest cover were selected (Fig. 1). These were in Bolivia the Departments of Pando, La Paz, Beni, Cochabamba and Santa Cruz. In Peru, the Departments of Amazonas, Loreto, Ucayali, Madre de Dios, Junín, San Martín, Huanuco, Cusco and Pasco. In Ecuador, the Provinces of Orellana, Pastaza, Napo, Sucumbíos, Morona Santiago and Zamora Chinchipe. In Colombia, the Departments of Amazonas, Caquetá, Putumayo, Guainía, Guaviare, Vaupés; and in Venezuela, the States of Amazonas and Bolívar.

2.2. Selection of species

In order to determine the number of tropical timber species harvested in each country, bibliographical sources and websites of the different ministries responsible for forest use and management were consulted during 2011 (Appendix A). We are confident in having recorded all species that are officially recorded as harvested and commercialized at national and international levels. All taxonomic names were revised in their spelling and synonymy using Tropicos (Missouri Botanical Garden; www.tropicos.org), and The International Plant Names Index (www.ipni.org/index). Although we constrained our search to tree species only by using Latin binomials, we recognize that these databases often assume an unequivocal correspondence when in fact phenotypically similar tree species may fall under a given scientific name (Lacerda and Nimmo, 2010). We did not attempt to correct for these potential biases in our lists.

For each timber species, any documented (commercial and non-commercial) non-timber use was assessed through extensive bibliographical and internet searches (Baltazar Vela, 2011; BOLFOR, 1996; Cáceres, 2008; Cárdenas et al., 2002, 2007; Cárdenas and Salinas, 2006; Castaño et al., 2007; Cerón and Ayala, 1998; Figueroa et al., 2010; González, 2003; González and López, 2009; Lawrence et al., 2005; Reynel et al., 2003; Ríos-Torres, 2001, 2007; Van Looy et al., 2008; Appendix A). Reported non-timber uses were classified into four categories: food, medicinal, technological (i.e., products used for the cosmetics industry) and reforestation (seeds for their commercialization). The latter category was included since trading seeds from timber and non-timber species has recently become an important source of income for many local communities (e.g., Ferreira et al., 2004). The part of the

Table 1
Ecological traits of the species considered in this study.

	Categories			Gradient
	1	2	3	
Distribution	Only in the country where it is logged	In the whole Amazon region	South America, Central America or wider	Geographical range
Habitat	Dry habitats	*Terra firme*, *várzea*	All kind of habitats	Tolerance to disturbance
Ecological group	Shade tolerant	Light-demanding	Pioneer	
Wood density	>0.8 g/cm^3	0.5–0.8 g/cm^3	≤05 g/cm^3	Growth rate

The different categories indicate the degree of tolerance to logging, from 1 (low) to 3 (high).

plant harvested was also classified into three categories: vegetative structures (bark, leaves, roots), reproductive parts (flowers, fruits, seeds), and exudates (gums, resins and oleoresins).

Every multipurpose tree species was assigned an economic value both for its timber and non-timber attributes based on: (i) internet search (Appendix A) and (ii) questionnaires sent to one country expert in forest management from relevant research or governmental institutions in each of the five countries. Timber value was assigned to three categories at country level: "high" (export market), "medium" (national market) and "low" (local market only). Each species was further assigned an overall timber value across the study region according to the following criteria: the species was considered to have a "high" economic value if its timber was exported internationally in any of the five study countries; "medium" economic value if it was commercialized within more than one study country; and "low" economic value if it was commercialized in only one of the study countries. Likewise, each multipurpose tree species was assigned an overall regional economic value for its non-timber component: "high" (with an international export market in at least one country), "medium" (primarily for a national market) and "low" value which included both trading in local markets and subsistence use. For species with more than one commercial non-timber use, we considered the one with the highest economic value, by looking at the market prices of NTFP. We acknowledge the limitations of this approach to determine the value of non-timber uses, as many of the benefits provided by these are non-monetary. However, it allows comparisons with timber values (as applied in Herrero-Jáuregui et al., 2009). Species with medium or high overall regional value for either their timber or non-timber attributes were further characterized according to ecological traits (i.e., geographic distribution, habitat specificity, light requirements for natural regeneration and dry wood density). These characteristics have been previously used to guide species-specific management decisions for timber harvesting in the neotropics (e.g., Martini et al., 1994; Pinard et al., 1999), and were applied here to measure the degree of tolerance to selective logging. Ecological characterizations were based on information gathered from different bibliographic sources (Lorenzi, 1992; Hidayat and Simpson, 1994; Fearnside, 1997; Ribeiro et al., 1999; Wehncke et al., 2003; Carvalho et al., 2004; Ferraz et al., 2004; Arets, 2005; Gama et al., 2005; Poorter et al., 2005; Chave et al., 2006) and websites (Appendix A). Following Martini et al. (1994), the information on each ecological trait was grouped into three categories in a gradient from low-to-high potential to tolerate logging (Table 1), assigning a point value of '3' to ecological characteristics that could allow to resist logging impacts, a score of '1' for characteristics that may hinder the species' persistence in logged forest, and '2' for intermediate characteristics. The sum of

Table 2
Multiple use species in each country, taking the timber value for each country separately.

Country	Timber species (*N*)	Non-timber value		
		High	Medium	Low
Bolivia	116	15	18	35
Peru	112	14	12	33
Colombia	110	11	14	50
Ecuador	88	5	8	29
Venezuela	109	10	7	29

scores for all four ecological traits reflects the resilience of a given multipurpose species to harvesting pressure by simultaneous consideration of the different criteria (Martini et al., 1994). We define this as a vulnerability factor (VF), assigning its median value as the threshold under which species should be considered very vulnerable without post logging silviculture (Herrero-Jáuregui et al., 2009) (Appendix B).

2.3. *Forest legislation related to potential conflict of use*

Through an extensive bibliographical research and using the official information of the websites of the main forestry institutes and ministries, we examined the current normative and regulatory aspects of timber and NTFP extraction Bolivia, Colombia, Ecuador, Peru, and Venezuela (FAO, 2004, 2010; García, 2005; Pacheco, 2003; Appendix A).

2.4. *Statistical analyses*

Contingency analyses and chi-square tests were performed in order to assess whether there was an association between (a) timber and NTFP values; (b) NTFP values and the part of the plant harvested; (c) NTFP values and the type of use. Contingency tables were created by matching timber values for each species in a given country and using the overall timber value. Fisher's exact test was used to analyze the association between the value of the products and the ecological traits of the species (Sokal and Rohlf, 1995). All analyses were performed using the STATS package in R version 2.13.0 (R Development Core Team, 2011).

3. Results

3.1. *Country level*

Colombia and Bolivia showed the highest number of multipurpose tree species ($N = 75$ and $N = 68$, respectively, accounting for more than 50% of the total) while Venezuela had the lowest proportion ($N = 46$, Table 2). In contrast, Peru and Bolivia were the countries with the highest proportion of high-value multipurpose tree species ($N = 14$ and $N = 15$, respectively) while Colombia was the one with the highest proportion of multipurpose tree species with local markets or subsistence uses ($N = 50$, Table 2). Eleven timber species occurred across all five countries, nine of which were multipurpose: *Calophyllum brasiliense* (Calophyllaceae), *Cedrela odorata* (Meliaceae), *Ceiba pentandra* (Bombacaceae), *Clarisia racemosa* (Moraceae), *Ficus insipida* (Moraceae), *Jacaranda copaia* (Bignoniaceae), *Schefflera morototoni* (Araliaceae), *Simarouba amara* (Simaroubaceae) and *Terminalia amazonia* (Combretaceae). The species *Guarea guidonia* and *Swietenia macrophylla* (both Meliaceae) did not have non-timber values (Appendix C).

Table 4
Species with the highest potential of conflict of use in each of the countries analyzed: a) considering the overall timber value (P, present in the country); b) considering the timber value for each species in each country (X, species with high timber and NTFP value in each country).

Species	Country				
	Bolivia	Peru	Ecuador[a]	Colombia	Venezuela[b]
a)					
Dipteryx odorata	P	P		P	
Tabebuia serratifolia	P	P		P	P
Hymenaea courbaril	P	P		P	P
Myroxylon balsamum	P	P	P	P	
Bertholletia excelsa	P	P			
b)					
Dipteryx odorata	X	X		X	
Tabebuia serratifolia		X		X	X
Hymenaea courbaril		X		X	X
Myroxylon balsamum		X		X	
Bertholletia excelsa	X				
Tabebuia impetiginosa					X
Spondias mombin					X
Pentaclethra macroloba					X
Copaifera officinalis					X
Chlorophora tinctoria					X
Carapa guianensis					X
Tabebuia chrysantha			X		

[a] There are not multiple use species with high timber value (see Appendix 1)
[b] There are no timber species for export.

Only in Bolivia was there a significant association between the part of the plant harvested and the non-timber economic value ($\chi^2 = 13.450$, df $= 5$, $p = 0.036$). Exudates had the highest economic value while vegetative structures largely included low market values and/or subsistence purposes. Reproductive structures were used more often in multipurpose tree species with medium non-timber values. There was no statistically significant association in any of the other study countries, probably due to small sample sizes (Table 3).

Across the five study countries, the non-timber market value of species and their category of use were statistically associated (χ^2, $p < 0.050$ in all cases; Table 3). There were more technological uses in the low market value category, more seeds used for reforestation purposes in the medium market category, while medicinal uses were best represented in the non-timber high market value. Food uses varied, with Peru and Ecuador representing the highest market value and Venezuela the lowest (Table 3).

Table 3
Number of multiple use species harvested in each country by the part harvested and the type of use.

Country	Part extracted			Relationship with NTFP value		Type of use				Relationship with NTFP value	
	V	R	L	χ^2	*P*	F	M	T	S	χ^2	*P*
Bolivia	31	25	11	13.45	0.036	9	27	26	6	14.087	0.028
Peru	29	24	8	11.64	0.070	10	25	19	8	28.091	0.00009
Colombia	38	27	9	4.735	0.578	15	27	31	3	22.053	0.001
Ecuador	23	11	7	5.365	0.49	6	17	15	4	22.156	0.001
Venezuela	17	17	11	1.932	0.925	6	21	14	4	37.962	0.000001

Part extracted: (R) reproductive, (V) vegetative, (L) exudates; Type of use: (F) food, (M) medicinal, (T) technological, (S) seeds for reforestation.

Table 5
Relationship between timber and non-timber values and species ecological traits. It is presented the *P* value.

Ecological traits	Timber value	NTFP value
Distribution	1	0.365
Ecological group	0.164	0.234
Habitat	1	1
Timber density	0.68	0.504

The association is analyzed with the Fisher test, considering each category as independent.

The frequency of multipurpose tree species with high timber and high non-timber values was higher than expected. There was no statistical association between timber and non-timber economic value in Bolivia ($\chi^2 = 7.871$, df = 5, $p = 0.096$), Peru ($\chi^2 = 2.971$, df = 5, $p = 0.561$), Ecuador ($\chi^2 = 0.808$, df = 5, $p = 0.937$) or Venezuela ($\chi^2 = 8.765$, df = 4, $p = 0.067$). Yet for Colombia, a statistically significant association ($\chi^2 = 12.571$, df = 5, $p = 0.013$) was found. Venezuela stands out as the country with more multipurpose tree species in the category of both high timber and non-timber values (eight species), followed by Colombia, Peru, Bolivia and Ecuador (with only one species; Table 4b). *Dipteryx odorata* (Leguminosae), *Tabebuia serratifolia* (Bignoniaceae) and *Hymenaea courbaril* (Leguminosae) are geographically shared by at least three countries. *Myroxylon balsamum* (Leguminosae) is shared by Peru and Colombia and the rest of them are prone to conflict of use in just one country: *Tabebuia impetiginosa* (Bignoniaceae), *Spondias mombin* (Anacardiaceae), *Pentaclethra macroloba* (Leguminosae), *Copaifera officinalis* (Leguminosae), *Chlorophora tinctoria* (Moraceae) and *Carapa guianensis* (Meliaceae) in Venezuela and *Tabebuia chrysantha* (Bignoniaceae) in Ecuador (Table 4b). After analyzing the four ecological traits (Section 2.2 above), no statistical association was found with timber and non-timber values; such a pattern was maintained across the five countries studied (Table 5).

3.2. Regional level

A total of 336 timber species were found listed across the five countries. These were distributed within 180 genera and 56 families (Appendix C). The dominant families were *Leguminosae* (24.7% of all species), followed by the *Moraceae*, *Lauraceae*, *Lecythidaceae* and *Burseraceae*, which together accounted for 23.5% of all species. Of these 336 species, 150 (44.6%) are multipurpose; that is, with non-timber value (Table 2). Of these 150 multipurpose species, 30 species (20%) have medium and high market value. A total of 55 multipurpose tree species have both a low timber and NTFP value (Table 6).

Among the total 150 multipurpose tree species across the five countries, 55 were used for their flowers, fruits or seeds; 69 for their bark, leaves and roots; and 25 for their resins, oils and latex (Appendix D). There was a significant association between the part of the plant harvested and the non-timber economic value ($\chi^2 = 18.492$, df = 5, $p = 0.005$). Exudates had the highest economic

Table 6
Contingency table for timber and non-timber values of 336 timber species, in Bolivia, Peru, Colombia, Ecuador and Venezuela.

Timber value[a]	Non-timber value[a]			No NTFP use
	High	Medium	Low	
High	5	4	10	13
Medium	10	11	29	31
Low	11	15	55	142

[a] High: international market, medium: national market; low: local market, subsistence: auto consumption or very local market.

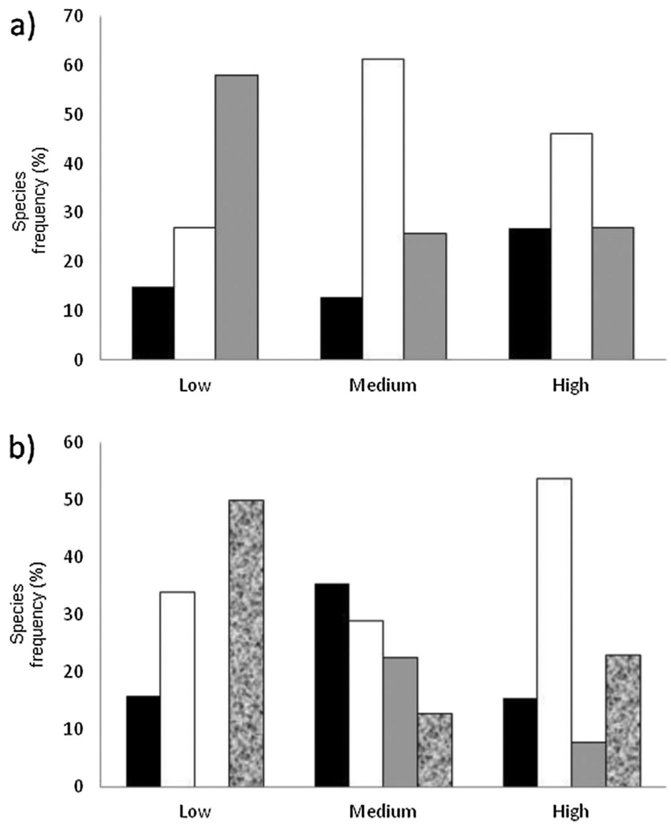

Fig. 2. Histogram representing the 132 species with multiple use in Bolivia, Colombia, Ecuador, Peru and Venezuela: (a) as a function of the part of the plant harvested (black bars: exudates; white bars: reproductive structures; grey bars: vegetative structures) (b) as a function of the main use of the product (black bars: food; white bars: medicinal; grey bars: reforestation; dotted bars: technological; see Methods). In both cases, each bar represents the percentage of species used for each category (exudates or food, for example), calculated on the number of species for each NTFP value class.

value while vegetative structures had mostly low market values and/or subsistence purposes. Reproductive structures were used more in multipurpose tree species with medium non-timber values (Fig. 2a).

There was a significant association between the non-timber market value and their category of use ($\chi^2 = 37.961$, df = 6, $p < 0.0001$), with more technological uses in the low market value category, more seeds used for reforestation purposes and food uses in the medium market value, while medicinal uses were best represented in the non-timber high market value (Fig. 2b). Medicinal and technological applications together comprised 74.61% of the non-timber uses registered for all 150 multipurpose tree species. Considering the 150 multipurpose tree species (Appendix D), there was no statistical association between timber and non-timber economic value ($\chi^2 = 3.880$, df = 5, $p = 0.421$). This pattern was maintained even when the 94 multipurpose tree species with only low non-timber value were excluded ($\chi^2 = 0.721$, df = 4, $p = 0.692$).

Four multipurpose tree species had the highest potential conflict of use in economic terms: *D. odorata* (Leguminosae), *H. courbaril* (Leguminosae), *T. serratifolia* (Bignoniaceae) and *M. balsamum* (Leguminosae). Because of the high economic value of its fruit (the Brazil nut; Peres et al., 2003), *Bertholletia excelsa* is legally protected from logging in Peru and Bolivia (and Brazil) hence, in theory, there is no conflict of use. We also found that the high degree of potential conflict of use in these four species however, is not evenly distributed across the region (Table 5a). Such is the case of *D. odorata* in Venezuela, where there is a long tradition of marketing the fruit (Pérez and Souto, 2011), but where its timber is not commercialized according to our records (although this may change due to more timber species eventually entering the market).

For the 30 multipurpose tree species that showed medium and high timber and non-timber values and for which ecological traits were assessed (see Section 2.2), more than half are widely distributed in South and Central America, 74% are light demanding, and 54% of them possess a medium timber density, among 0.6–0.8 g/cm^3 (Appendix B). The analysis of the ecological traits considered showed no statistical association with timber and non-timber values (Table 5). Six of these multipurpose species were found to be the most vulnerable (VF $<$ 8, Appendix B), including one (*D. odorata*) with high timber and non-timber values. *T. impetiginosa* also belongs to this group.

4. Discussion

In this paper we characterized multipurpose tree species of Amazonian Bolivia, Peru, Ecuador, Colombia and Venezuela. Multipurpose species can have a high commercial value or else have important non-monetary value for local livelihoods, either for their timber, NTFP or both. One key message is that the relative importance of these values and hence potential conflict of use varied across countries. Yet we recognize that our non-additive methodological approach may underestimate the value of those multipurpose tree species with more than one non-timber use.

4.1. Multipurpose tree species of livelihood importance

We found that about half of the timber species listed across the five study countries have non-timber use. This result is similar to that by Herrero-Jáuregui et al. (2009) where up to 62% of multipurpose tree species were harvested for subsistence purposes or commercialized only in local markets in the Brazilian Amazon. Even though subsistence uses vary across rural communities (Ambrose-Oji, 2003; Menton et al., 2009), our results are also similar to those of Herrero-Jáuregui et al. (2009), where the most common non-timber uses of livelihood importance and low economic value were those of a technological nature derived from non-reproductive components.

Two thirds of the medium-to-high value multipurpose tree species identified in this study are considered to demand light for their regeneration. The lack of statistical association found here between timber and non-timber values and particular ecological traits suggest that multipurpose tree species can be characterized by any of the ecological traits examined. This result implies that common ecological traits between high value multipurpose trees should facilitate integrated management of timber and non-timber uses. However, more studies are needed to characterize logging impacts on tree-derived NTFPs of livelihood importance from both ecological and social perspectives (Rist et al., 2012).

4.2. Multipurpose tree species of medium and high commercial importance

The four species identified in this study for having the highest potential conflict of use (both with high timber and non-timber value) are *D. odorata*, *T. serratifolia*, *H. courbaril* and *M. balsamum*. There are no legal measures for protecting any of the four species in any of the five study countries, although the harvesting of *T. serratifolia* and *H. courbaril* is prohibited by law in some administrative regions of Colombia, but not in the Amazon lowland forests (López and Cárdenas, 2002). All these species possess both high timber and NTFP values in most of the countries studied, and with the exception of *M. balsamum*, all of them also showed the highest potential conflict of use in Brazil (Herrero-Jáuregui et al., 2009).

D. odorata is an emergent tree (Phillips et al., 2002) which produces seeds known in the international market as “tonka beans”. The oil extracted from the seeds is highly prized in the perfume industry (Latchford, 2002). Although it was more actively commercialized in the past, it is still exported to Europe and the USA by several companies at prices that can reach US$2800 per liter (www.aromaluz.com.br). Also, its timber is highly valued and exported from Bolivia, Peru and Colombia to European, Asian and American markets at prices from US$798 to 871 per m^3 (ITTO, 2011). In the case of *T. serratifolia*, the seeds are marketed for reforestation purposes at a price of US$32 per kg (Funtac, 2002; García, 2003), and its timber for parquet flooring is exported at around US$1888 per m^3 (ITTO, 2011). The highly prized bark of *H. courbaril* is sold internationally at prices ranging from US$14 to 280 per Kg (www.naturesalternatives.com), and its resin is much more expensive, reaching prices of US$2700 per liter (www.aromaluz.com.br). Also, its timber is exported at US$ 883 per m^3 (ITTO, 2011). *M. balsamum* oil, internationally known as Balsam of Peru or Balsam of Tolu is also sold in the international market up to US$155 per liter (www.mountainroseherbs.com). Several companies also export its timber (http://macoldex.com).

Moreover, these four species are either light demanding or partially shade tolerant which may favor biophysical compatibility with selective logging (Ashton et al., 2001; Guariguata et al., 2010). However, valuable timber species with low adult densities and slow growth rates can be commercially depleted during selective logging operations (Martini et al., 1994; Herrero-Jáuregui et al., 2009). This is the case of *D. odorata* in Brazil (Herrero-Jáuregui et al., 2012) and Peru (Putzel et al., 2011) and of *T. impetiginosa* in Brazil (Schulze et al., 2008). Concurrent timber and NTFP extraction intensities should be re-assessed in these two species. Previous studies report local communities manage *D. odorata* in home gardens thus gaining easier access to the seeds (Pérez and Souto, 2011; Herrero-Jáuregui et al., 2012). This trend towards domestication of valuable NTFP species has been discussed elsewhere (Homma, 1992), and could mitigate the potentially high level of conflict of use as shown in the Brazilian Amazon (Shanley et al., 2012). Other multipurpose species with a high timber economic value in some countries are also prone to conflict of use. These are *T. impetiginosa*, *S. mombin*, *P. macroloba*, *C. officinalis*, *C. tinctoria* and *C. guianensis* in Venezuela, and *T. chrysantha* in Ecuador.

4.3. Implications for forest management practice and policy

In light of this assessment, and after examining the normative and regulatory aspects of timber and NTFP extraction in Bolivia, Colombia, Ecuador, Peru and Venezuela, we conclude that besides these regulations being essentially very similar, they enable the integration of timber and NTFP management approaches in the case of multipurpose tree species. For example, forest concessions can be granted both for timber and NTFP extraction, with local communities having usufruct rights for both resource types from the same species. However, previous studies show that some of these regulations can at times constrain integration as technical and managerial capacities usually differ for either timber or NTFP users. Further, local communities often face difficulties in adjusting their practices to official regulations which in turn are usually drafted with little harmonization of timber and NTFP objectives (Shanley and Stockdale, 2008; Guariguata et al., 2010; Cronkleton et al., 2012). For example, Herrero-Jáuregui et al. (2011a) found in the Brazilian Amazon that requirements of a formal management plan to harvest the seeds of *C. guianensis* and the oleoresin of *Copaifera reticulata* were not useful in supporting local objectives while timber from these two species could only be used from naturally fallen individuals. Local knowledge and local needs should be taken into account when developing management plans that could facilitate harvesting of multipurpose tree species (Cronkleton et al., 2012; Rist et al., 2012). None of the studied countries have concrete legislation regarding any of the multiple use species identified to minimize conflict of use or else maximize multiple use objectives including the four species with the highest potential conflict of use mentioned above.

Regarding the diverse possibilities of exploitation of multipurpose species, different management approaches could be implemented. In the case of fruit harvesting, individuals could be logged when fruit production decreases as a function of tree size (e.g., Kainer et al., 2007) while consistently good seed producers could be retained. If the non-timber resource relates to vegetative parts or exudates, these could be extracted either before or right after the tree is harvested. However if the same user (e.g., timber company) both extracts and benefits from timber and NTFP values at sawmills local communities could lose control of the NTFP resource while having a competitor in the market. To avoid this, a careful examination of the social dimension of conflict (not tackled in this paper) should be conducted. Other approaches include the coupling of economic models with ecological knowledge to optimize timber and NTFP returns as in the case of the multipurpose tree *C. guianensis* (Klimas et al., 2012). Management practices may include segregating timber and non-timber uses for a given multipurpose tree species when productivity is known to vary according to environmental factors such as soil type (Klimas et al., 2007; Newton et al., 2011). Yet we are only starting to obtain detailed knowledge on how the environment influence the yields of locally important NTFP species. In some of the study countries such as Venezuela, the paucity of documented information about management practices and uses of many NTFPs (particularly when these are associated to high-value timber species), is regarded as a constraint in promoting multiple use (Aymard, 2012).

5. Conclusions

In our analysis, only 4 out of 336 multipurpose tree species showed the highest degree of potential conflict of use in economic terms across the five study countries yet their geographical spread was not even. Other set of species showed contrasting (but lower) levels of degree of potential conflict of use both within and among countries. Clearly, both the nature and extent of potential conflict of use is multi-dimensional. It depends on factors such as the non-monetary and monetary importance of non-timber uses for local livelihoods (Menton, 2003, 2009), the ecological resilience of a given multipurpose tree species to logging (Martini et al., 1994) and the extent to which different user groups have a stake and control over either the timber or the non-timber resource. Particularly from a normative perspective, it is at present difficult to judge which of the five study countries is in a better position to ameliorate conflict of use of high value multipurpose tree species. We hope, however, that by contrasting and comparing regional vs. national dimensions (see also Duchelle et al., 2012), organizations involved in promoting sustainable use of tree and forest resources *via* regional cooperation are better informed. These include, among others, the Amazon Cooperation Treaty Organization (www.otca.info) and the Latin American Forest Genetic Resources Network (LAFORGEN; www.laforgen.org).

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jenvman.2013.08.044.

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