Provided for non-commercial research and education use. Not for reproduction, distribution or commercial use.



This article appeared in a journal published by Elsevier. The attached copy is furnished to the author for internal non-commercial research and education use, including for instruction at the authors institution and sharing with colleagues.

Other uses, including reproduction and distribution, or selling or licensing copies, or posting to personal, institutional or third party websites are prohibited.

In most cases authors are permitted to post their version of the article (e.g. in Word or Tex form) to their personal website or institutional repository. Authors requiring further information regarding Elsevier's archiving and manuscript policies are encouraged to visit:

http://www.elsevier.com/copyright

Ecological Economics 77 (2012) 158-165

Contents lists available at SciVerse ScienceDirect



Ecological Economics

journal homepage: www.elsevier.com/locate/ecolecon



Analysis Timber concessions in Madre de Dios: Are they a good deal?

Renzo Giudice ^{a,*}, Britaldo S. Soares-Filho ^a, Frank Merry ^b, Hermann O. Rodrigues ^a, Maria Bowman ^c

^a Centro de Sensoramiento Remoto, Universidade Federal de Minas Gerais, Av. Antônio Carlos 6627, Minas Gerais, 31270-901, Brazil ^b Virginia Tech, Department of Forest Resources and Environmental Conservation, 313 Cheatham Hall, Blacksburg, VA 24061, USA

^c College of Natural Resources, University of California, 207 Giannini Hall, Berkeley, CA 94720-3310, USA

ARTICLE INFO

Article history: Received 5 October 2011 Received in revised form 15 February 2012 Accepted 23 February 2012 Available online 15 March 2012

Keywords: Stumpage fees Timber rent Conservation Peruvian Amazon Spatially-explicit modeling

ABSTRACT

This study contributes to the design of public policies for the forestry sector in Madre de Dios, Peru. We developed a timber rent model that estimates optimal stumpage fees and compared three scenarios of harvestable areas access versus two harvest methods to calculate potential revenues to the State. We found that current stumpage fees undervalue timber resources and thus provide windfall profits to loggers. Annual forest revenues to the State could be increased from US\$1 million to a maximum annual average of US\$23.4 \pm 1.4 million over a 20-year period if the fee structure suggested from our estimations were adopted. Similarly, we show that the spatial distribution of current fees encourages timber harvesting outside of timber to markets. Our results suggest that timber harvesting should be limited to a maximum volume of 5 m³/ha inside Brazil-nut concessions and that timber harvesting in all Madre de Dios could be increased by up to ~200% over the next 20 years without threatening conservation areas. This would in turn provide additional revenues to the State that could be applied to better monitoring and forest management.

© 2012 Elsevier B.V. All rights reserved.

1. Introduction

Protecting forests is costly because management and monitoring spending, among others, require large amounts of financial resources (Balmford, 2003). Timber concessions, where the government leases the right to harvest timber on public lands, when well managed, provide one option to offset those costs (Merry et al., 2009; Young, 2005). Unfortunately, timber concessions are infamous for their mismanagement (Gray, 2002). The list of offenses is impressive: government patronage (Vincent, 1992); high-grading (Amacher et al., 2001); migration into the forest (Curran, 2004); biodiversity loss (Putz et al., 2001); overhunting (Robinson and Robinson, 1999); forest degradation (Nepstad et al., 1999); and others. None of these issues is, however, insurmountable; nor do they overwhelmingly detract from the possibility of economic and environmental benefits from well-managed timber concessions - especially as part of a comprehensive forest protection and management strategy (Merry et al., 2009; Putz et al., 2001; Soares-Filho et al., 2010). Within this context, concessions can complement a suite of forest policies and management choices but the question remains: how do we overcome the myriad of problems that plague timber concessions?

We posit that many of the problems associated with timber concessions and land-use management at the frontier thrive in the absence of information. This reality is norm rather than the exception

E-mail address: renzo@csr.ufmg.br (R. Giudice).

in regions such as our study area, and detailed information on standing commercial timber volumes and its values will be necessary to help governments design policies and monitor access and use of public lands. In this paper we contribute to this aim by providing the first comprehensive assessment of the economic value of forest concessions in the Peruvian Department of Madre de Dios. We believe that our estimates are a crucial component in granting and manage concessions more efficiently and effectively. This is especially important for the Southeast Peruvian Amazon, where a wave of megainfrastructure projects, such as the completion of the Interoceanica Sur Highway connecting Brazil to ports in the Pacific, are increasing the region's vulnerability to deforestation and forest degradation (Kirkby et al., 2011; Soares-Filho et al., 2006).

We conducted an economic analysis of the timber sector in Madre de Dios using a 20-year spatially-explicit simulation model that estimates the residual stumpage price on forested land. This research builds upon the work of Stone (1998) and Merry et al. (2009), who used spatial rent models to assess the timber industry growth and its relationship with forest conservation in the Brazilian Amazon. As such, we refined and adapted the model described in Merry et al. (2009) to the specificities of the timber industry in Madre de Dios (additional details about the differences between models are presented in the Supplementary Material). In addition to roundwood harvesting, the model estimates returns to production of lumber sawn on-site with chainsaws and mobile sawmills. This activity is common in the region (Galarza and La Serna, 2005), in spite of the fact that it is illegal to saw lumber with chainsaws (Decreto-Supremo-No. 006-2003-AG). This adaptation of the timber rent model (Merry et

^{*} Corresponding author at: CSR, Universidade Federal de Minas Gerais, Belo Horizonte, Minas Gerais, 31270-901, Brazil. Tel: +55 31 3409 5449.

^{0921-8009/\$ –} see front matter 0 2012 Elsevier B.V. All rights reserved. doi:10.1016/j.ecolecon.2012.02.024

al., 2009) allowed us to evaluate the economics of onsite processing in the Peruvian Amazon and, as a result, to propose policies that address this reality.

Previous studies found inconsistencies between regulations (Forestry and Wildlife Law of 2000 – Ley-No. 27308) and actual practices and outcomes in the field, due to governance failures and little involvement of local institutions (Sears and Pinedo-Vasquez, 2011; Smith et al., 2006). However, none of these studies addressed the economics of timber rents and their impact on current and future forest policy design for Madre de Dios.

According to the law, timber can be legally harvested from other public lands, such as Brazil-nut concessions, without regard for the economic or ecological impacts of such harvesting on existing timber concessions or Brazil-nut production. Brazil-nut concessions cover the second largest extent (≈ 1 million ha) of legally harvestable areas, and are located near major markets and the Interoceanica Sur Highway, making them more economically attractive for logging than the timber concessions, which are located in more remote areas.

Our study contributes to the design of public policies for the forestry sector in Madre de Dios, addressing the following questions:

- Is the Peruvian government correctly pricing its timber resource?
- If fees were correctly-set, what would the impact be for future forest revenues and harvest levels?
- How do forest revenues vary as a function of different harvest regimes in Brazil-nut concessions?
- · Should Peru make chainsaw lumbering legal?

By modeling scenarios of potential harvestable volumes and associated forest revenues within and outside timber concessions, our analyses therefore provide subsidies to the revision of the new Forestry and Wildlife Law (Ley-No. 29763) under discussion in Peru.

1.1. A Brief History and Context of Forest Management in Peru

In Peru, forests are national patrimony and can be harvested either on public or private lands by private actors only after acquiring forestuse rights (Ley-No. 27308). The State grants concessions on public lands, harvest permits on private and indigenous lands, and authorizations, a one-time collection permit for logs floating in rivers that fell from riverbank erosion (Sears and Pinedo-Vasquez, 2011), and collects stumpage fees.

Although Peru is home to the second-largest expanse of tropical forest in South America (\approx 68 million ha), forestry makes up only 1.1% of Peruvian Gross Domestic Product (FAO, 2011). The volume harvested in 2010 was approximately 1.6 million m³, with Virola spp., Iryanthera spp., Cedrelinga catenaeformis, Chorisia integrifolia, Dipteryx spp, and Calycophyllum spruceanum comprising the main species harvested (MINAG, 2010; Putzel et al., 2008). With a government budget of ~US\$0.50/ha/year, the public management and monitoring of forest resources is underfunded (Suárez de Freitas, 2009). Timber harvesting has traditionally been carried out as selective logging, with as much as 80% of all production considered to be illegal (Chirinos and Ruiz, 2003). Forest degradation due to logging has remained low (~65,000 ha/yr, Oliveira et al., 2007), however, negative social, economic, and ecological impacts are common (Suárez de Freitas, 2009). In recognition of these problems the Forest and Wildlife Law (No. 27308) was enacted in 2000.

This law introduced several changes to forest resource management (Galarza and La Serna, 2005; Hidalgo, 2003), specifying management practices, stumpage-fee structures, and concession allocation and duration. The law now requires that all concessionaires implement a management plan regardless of concession size – previously, management plans were not required for small concessions (<1000 ha) that represented the majority of contracts, and thus generating illegality (Smith et al., 2006). The law also changed the fees paid by concessionaries from a species-volume basis (US\$/m³) to an annual concession-area-based fee (US\$/ha). The new fees are determined in auctions, with a minimum bid (US\$0.40/ha/yr) established by the former INRENA (Instituto Nacional de Recursos Naturales) (Resolucion-Jefatural-No. 050-2003-INRENA), whose duties were transferred in 2010 to the departmental governments and other institutions as part of the decentralization process. To date, the mean fee within concessions is US1.50/ha/yr (min=0.65, max=1.80) (Galarza and La Serna, 2005). Conversely, outside timber concessions, fees are charged on a species-quality basis, varying from US\$0.37/m³ to US\$18/m³ (Resolucion-Ministerial-No. 0245-2000-AG). A minimum cutting cycle of 20-years in which no more than 5% of the total area can be harvested per year is mandatory within timber concessions (Resolucion-Jefatural-No. 109-2003-INRENA). Supposedly, this cycle would allow up to 30% timber volume recovery after the first cycle (Dauber et al., 2005). Forest revenues from fees are distributed between the government of Madre de Dios and local municipalities (50%), the Departmental Forestry Authority (25%), and the Organismo de Supervisión de los Recursos Forestales y de Fauna Silvestre (OSINFOR) (Reglamento-del-Decreto-Legislativo-No. 1085). In 2010, Madre de Dios charged~US\$1 million in fees (MEF, 2011). Although the new regime has contributed to an improvement in logging practices (Smith et al., 2006), unsustainable and illegal logging are still perceived as common (Gutierrez-Velez and MacDicken, 2008; Hidalgo and Chirinos, 2005; Sears and Pinedo-Vasquez, 2011; Smith et al., 2006). Moreover, the impact of harvesting in Brazil-nut concessions on the spatial distribution of harvesting in Madre de Dios has yet to be measured, as average harvested volumes from these concessions appear to be larger than those from timber concessions (Cossío-Solano et al., 2011), suggesting some level of competition that eventually could reduce potential revenues to the State from harvesting the timber concessions.

2. Materials and Methods

2.1. General Approach

We used a spatially-explicit simulation model to estimate yields and economic timber rents over a 20-year period, as well as future fees and sales tax revenues to the State in Madre de Dios. First, the model estimates the spatial distribution of commercial timber volumes. Then it calculates timber rents using local prices and costs and harvests the cells with the highest rents to project annual volume harvested under different scenarios. We used historical harvest levels in Madre de Dios and three milling centers (Puerto Maldonado, Iñapari, and Lima) to evaluate the outcomes from two scenarios of harvest methods: (SAW) in which roundwood is sawn on-site into boards (hereafter referred to as lumber) that are 5–10 cm thick, \geq 13 cm wide, and >1.8 m long, and transported to milling centers to be sold; and (LOG) where roundwood, once felled, is transported to milling centers where it will be processed and sold as lumber. We coupled these scenarios to three scenarios of access to harvestable areas: (S1) full access in legal harvestable areas (Brazil-nut concessions, reforestation concessions, and timber concessions, private and mining lots, native communities, and areas of unassigned use), (S2) no access to Brazil-nut concessions, and (S3) in which an annual harvest cap of 5 m³/ha is imposed within Brazil-nut concessions. Although harvesting in Brazil-nut concessions is allowed with no cap (Resoloucion-de-Intendencia-No. 254-2007-INRENA-IFFS) this may impair productivity of Brazil-nut trees (Bertholletia excelsa) (Guariguata et al., 2009). Therefore, S2 and S3 are employed to evaluate the economic impact of the different harvest levels within Brazilnut concessions on forest revenues provided by timber concessions and to compare the relative contribution of Brazil-nut concessions to these revenues. In no scenario does the annual harvest exceed 5% of available profitable volume (i.e. it returns revenues to the State);

R. Giudice et al. / Ecological Economics 77 (2012) 158-165

thus, the model is a conservative representation of the official Peruvian 20-year cutting cycle.

The model calculates timber rents as standing tree (stumpage) price (US\$/m³) for each land unit (25 ha) using a residual analysis that subtracts all harvest costs from the market prices of lumber (Whiteman, 2005). Stumpage price π_j , for a cell *j* in the SAW scenario is calculated as follows:

$$\pi_{j} = \left(p_{j} * \varphi * \left(1 - ST_{j}\right)\right) - \left[\left(TC_{j} * \varphi + HC + PC\right) * \left(1 + i\right)\right]$$
(1)

where p_j is the location-specific price of lumber, φ is the processing yield (% of roundwood processed to lumber), ST_j denotes the location-specific sales tax (%), TC_j is the transportation cost of lumber from a specific cell *j* to the location of the nearest milling center, *HC* and *PC* are the harvest and processing costs, respectively, and *i* is the market rate of interest.

In the LOG scenario, the stumpage price π_j is calculated using a variation of Eq. (1) in which transportation costs (*TC_j*) are not multiplied by the processing yield φ because the harvested timber is transported as roundwood; so that:

$$\pi_{j} = \left(p_{j} * \varphi * \left(1 - ST_{j}\right)\right) - \left[\left(TC_{j} + HC + PC\right) * (1 + i)\right]$$
(2)

Thus, total costs include felling, transportation and processing costs, sales tax, and capital investment opportunity costs (Table 1). Supplementary Material presents a detailed mathematical description of the model. We used an interest rate of 8% (the market rate paid by financial institutions in Madre de Dios; CMT, 2009), and applied it to total production costs. A sensitivity analysis for the interest rate produced no significant changes in forest revenues (see Supplementary Material). From a specific lumber price, based on timber quality and location of a milling center, the model deducts all costs to arrive at the stumpage price, which is equivalent to the maximum stumpage fee the State could charge a logger for harvesting. Processing yield was based on interviews with two forestry specialists in the region (Table 1).

We constrained a milling center's processing capacity to a maximum annual growth of 10%, which reflects the average growth rate of total timber harvested annually in Madre de Dios between 2001 and 2009 (MINAG, 2011). Processing capacity in the milling centers,

Table 1

Selected	model	variables	and	values	bv	harvest	method.
Sciected	mouci	variables	unu	vulues	U y	nui vest	methou.

Variable	Value	Unit				
Variable	value	OIIIt				
Harvest cost						
Lumber ^a	27.52	US\$/m ³				
Roundwood	29.92	US\$/m ³				
Processing cost						
Lumber ^a	24.00	US\$/m ³				
Roundwood	25.00	US\$/m ³				
Processing yield						
Lumber	35.00	%				
Roundwood	45.00	%				
Sale Tax						
Lumber	18.00	%				
Roundwood	NA	-				
Transportation cost (Lumber/Roundwood) ^b						
Navigable river	0.04 ^c / NA	US\$/m ³ /km				
Paved road	0.23 / 0.28	US\$/m ³ /km				
Dirt road	0.43 / 0.45	US\$/m ³ /km				
Deforested area	1.80 / 1.00	US\$/m ³ /km				
Logged forest	1.80 / 1.00	US\$/m ³ /km				
Untouched forest	2.32 / 2.00	US\$/m ³ /km				

 $^{\rm a}\,$ Lumber costs of harvesting and processing are expressed in US\$/m³ of the original log (roundwood).

however, increases or decreases annually as a function of the available profitable timber volume (See Supplementary Material for a description of the relationship between processing capacity and profitable volume).

As expected, improving access by expanding roads and logged forest will increase stumpage prices as a result of reduced transportation costs. Our model simulates the building of new roads every five years based on the expected locations of major logging tracks, new areas entering production, and the location and size of population centers (Kirkby et al., 2011). Furthermore, as cells are logged, the cost of traversing a cell is reduced and the local transportation cost surface updated.

Finally, we assumed a social discount rate of 5% to calculate net present values according to Merry et al. (2009). All model components were designed and implemented using Dinamica EGO freeware, an environmental analysis and spatial modeling platform (Soares-Filho et al., 2009).

2.2. Estimating Commercial Timber Volume

To derive a map of available commercial timber volume (CTV), we combined a map of 15 forest types of Madre de Dios (INRENA, 1996) with inventories of 34 annual cutting areas (ACAs) surveyed in 2008–2009 as part of the management plan implementation. The ACAs vary in size from 90 to 3310 ha, cover a total area of 25,000 ha, and contain 2663 geo-referenced trees with species identified and commercial volumes estimated.

To make the CTV map for the entire Department, we first converted individual tree volumes into volume per hectare for each ACA and then divided each ACA in half. We randomly selected one half of each ACA (called subsample-1) to derive the CTV map; the other half was used to validate our estimates (subsample-2). We overlaid the subsample-1 areas with the forest type map. For each forest type, we generated a histogram of volume and calculated its probability density function (PDF) – i.e. the likelihood of a certain volume-per-hectare class occurring in a forest type. We then estimated the statistical distribution that best matched the observed PDFs. We found that the Weibull PDF (Maltamo et al., 2004) with different parameters β and η for each forest type best approximated the observed distributions in our subsample-1. (Fig. S1 of Supplementary Material). Each forest type PDF was used to simulate our CTV map. For forest types not covered by ACAs, we assigned the Weibull PDF from the most similar forest type based on forest characteristics (Phillips et al., 1994). Also, a commercial timber volume of zero was assigned to non-commercial timber forests, such as mountain forests and palm swamp forests, and also to the deforested areas by 2005 (Oliveira et al., 2007). To match the quality of other available cartographic data (e.g. roads, rivers), we reduced the cell resolution of the CTV map to 500 m x 500 m.

To validate the CTV map, we used the observed volumes from subsample-2. Estimated volumes averaged $8.08\pm10.2~m^3/ha$ (mean \pm stdev), while observed averaged $8.39\pm12.03~m^3/ha$, thus validating our approach.

With the CTV map at hand, one final hurdle remained; our map was generated from inventories conducted in 2008–2009 inside ACAs that had been already selectively logged – mainly for mahogany (*Swietenia macrophylla*) and cedar (*Cedrela odorata*) (Chirinos and Ruiz, 2003). Similarly, other areas closer to roads and population centers have undergone logging for many years. Therefore, it is likely that our CTV map overestimates the commercial volume in Madre de Dios.

In order to account for historical logging activity and to deal with the potential for overestimation, we ran our model over the four past decades. In this run, demand was extrapolated backwards by decreasing current milling center capacity by 10% per year and then adjusting harvestable volume accordingly. At each step, the model harvests the cells with the highest stumpage prices, assuming that they were most

^b Transportation costs differentiate between either US\$/m³ of lumber and US\$/m³ of roundwood.

likely to have been harvested in the past. As a result, the final CTV map now accounts for past logging activity in the region.

2.3. Economic Parameters of the Model

Economic parameters include (1) processing capacity, (2) lumber prices, (3) harvest costs, (4) processing costs, (5) transportation costs, (6) capital investment opportunity costs, and (7) sales tax (Table 1). The total initial demand of roundwood (as determined from processing capacity) for Madre de Dios in 2009 was 290,450 m³ (MINAG, 2010). The model assumes this volume to be equal to the current capacity of the Department, distributed across three milling centers: Puerto Maldonado; Iñapari; and Lima (although Lima is not situated in Madre de Dios, a proxy for this center represents the demand for roundwood that is processed on site and sent from the forest directly to Lima). We located the milling center proxy for Lima at the closest cell to Lima on the Interoceanica Sur Highway at the border of the Madre de Dios map (Fig. 1). We subtracted the accumulated transportation cost from Lima to that point from the price of lumber in Lima and added this value to all cells of the transportation cost map of Madre de Dios.

To estimate the processing capacity of the mills in Puerto Maldonado, we used data collected from five sawmills and extrapolated this to all 22 mills, resulting in a capacity of 79,885 m³/yr. Similarly, we used data from four mills in Iñapari to come up with an initial capacity of 75,982 m³/yr. To estimate the potential demand for roundwood from Lima, we subtracted the total capacities of Puerto Maldonado and Iñapari centers from the total roundwood volume harvested in Madre de Dios in 2009 (290,450 m³; MINAG, 2010) to arrive at an estimate of 134,583 m³/yr. While in the SAW scenario, all three milling centers are active, in the LOG scenario only Puerto Maldonado and Iñapari are, hence reducing total capacity by 53%. The total demand of LOG is constrained by the capacities of these two centers, as roundwood cannot be transported to Lima because of extremely high transportation costs across the Andes, and thus, must be locally processed.

We calculated lumber prices in Lima and Puerto Maldonado based on a weighted average for five timber quality classes (very high, high, medium, potential species, and other species) and their corresponding percentages of total harvested volume in Madre de Dios for 2009 (Table 2). Lumber price for Iñapari was calculated by subtracting the total transportation cost of lumber from Iñapari to Lima (US \$191/m³) from its price in Lima (Table 2). In the absence of detailed data on price elasticity, we assumed a constant price throughout the simulation period following Merry et al. (2009).

Input costs of harvesting, processing, and transportation are those stated in the annual operational plans (AOP) of 42 concessions. These costs are differentiated by the type of harvest method (Table 1). Concessionaires clearly indicate whether they will harvest and transport timber as lumber or roundwood, which allowed us to identify costs for each method. Harvest costs include cutting and trimming, developing the AOP, maintaining and constructing logging tracks, labor, inputs, services, staff training, among others. It is uncertain whether concessionaires incur all these costs, or if they merely state these costs in the AOPs as a procedure. Nonetheless, we included them all to keep our results conservative. All concessionaires also indicate that they conduct reduced-impact logging (which could not be corroborated), and we assumed this to be true so as to make conservative estimates. Furthermore, we assumed costs were not inflated by concessionaires on the basis that the rent tax in Madre de Dios is reduced (-50%) in order to promote economic development (Ley-No. 27037). This could indicate that over-reporting is less prevalent.

Processing costs differ between harvest methods (Trujillo, 2008). Lumber can be processed on-site using mobile sawmills equipped with a circular saw or with modified chainsaws ("chainsaw lumbermaker"), which have a similar conversion efficiency (35%) but are considerably cheaper than stationary sawmills that use band saws (Trujillo, 2008). Processing yields vary by type of technology used (Table 1).

Transportation costs vary by land type and quality of infrastructure. Therefore, as forests are harvested or as roads expand, transportations costs decrease. The model allocates commercial timber to the nearest milling center using a least-cost pathway calculation (Soares-Filho et al., 2009), creating dynamic "milling-sheds" (areas of influence of each center). Transportation costs are calculated using a 'friction surface' where the cost of transporting roundwood across each of six land uses varies by use (Table 1). Roundwood is not transported in rivers because most rivers in Madre de Dios are shallow (even during the rainy season) and narrow at several points, which makes the transportation of roundwood very difficult, whereas lumber is often tied together and drifted down rivers to markets (Trujillo, 2008). Transportation on paved and dirt roads is always more expensive for roundwood than for lumber, due to higher equipment depreciation costs for the former. On the other hand, it is more expensive to transport lumber than roundwood inside forests because lumber is usually transported on tractors or carts pooled by human or animal power, whereas transportation of roundwood employs skidders and trucks, which makes the transport of lumber more expensive per unit of wood, as skidders can transport the same amount of wood as much as 15-times faster (León and Mego, 2007). Finally, lumber prices at the milling gate are applied to all cells in the associated milling-shed.



Fig. 1. Positive stumpage prices (US\$/m³) of standing roundwood in harvest scenarios SAW (a) and LOG (b).

Author's personal copy

R. Giudice et al. / Ecological Economics 77 (2012) 158-165

Table 2

Prices for lumber at the three processing and market centers.

Processing center	Weighted mean price	Lumber c	ategory mean price (US\$/m ³) ^a			Total harvest by quality category (%) ^b					
	(US\$/m ³)	A ^c	В	С	D	E	A	В	С	D	E
Lima	464.12	2,031	1,100	524	463	354	0.52	1.00	41.1	21.7	35.7
Puerto Maldonado	321.70	1,422	675	337	323	276					
Iñapari	273 05 ^d										

^a Prices given by the Cámara Nacional Forestal 2009–2010 [http://www.cnf.org.pe].

^b Harvest percentages were calculated from 2009 official figures by species and categories. (MINAG, 2010).

^c Quality categories: A = Very high value; B = High value; C = Medium value; D = Potential species; E = other species. RM-No. 245-2000-AG.

^d Iñapari's weighted mean price was calculated by subtracting from the Lima's weighted mean price, the total transportation cost from Iñapari to Lima (US\$191.06/m³).

We validated costs and prices by comparing private profits from concessionaires, published in their AOPs, to profit estimated for output from the first year of our model. Although the data presented by concessionaires might not accurately represent true profits, it is the only available data we have and thus our results should be taken carefully. Our modeled private profits did not include the opportunity cost of capital investment because that parameter is not provided by concessionaires. We compared the published total private profits in 2009 from 26 concessionaires that process roundwood into lumber on-site with their corresponding modeled total profits. We did the same for nine concessionaires that harvest timber as roundwood. We found no significant differences between the two groups in either harvest method (LOG: Mann–Whitney *U* test p = 0.43, SAW: Mann–Whitney *U* test p = 0.22), thus validating the costs and prices used in our model.

3. Results and Discussion

3.1. Stumpage Volume and Stumpage Prices

We estimate that there is approximately 69 million m^3 of commercial timber (roundwood) in Madre de Dios if all land uses were open to harvest (Fig. S2, Supplementary Material). Almost all of this volume (99%) presented positive stumpage prices when roundwood was processed on-site and transported as lumber to milling centers (Sawing scenario – SAW). However, only 21% of this volume presented positive stumpage prices when logs were transported as roundwood (Logging scenario – LOG) (Fig. 1; and Table S1 of Supplementary Material), demonstrating a significant economic incentive for allowing loggers to process the harvested roundwood to lumber on-site. The total value of potential stumpage fees (positive stumpage prices times available volume per land unit) at 2009 prices amounted to US\$2.75 billion in SAW, and US\$0.59 billion in LOG.

This large difference in value between scenarios can be ascribed to the ease of access to forests resulting from differences in transportation costs. Roundwood is sawn before being transported to milling centers in SAW, whereas in LOG, roundwood is transported on trucks. This precludes transportation of roundwood across and within rivers, effectively closing the access to several watersheds that lack road and bridge infrastructure. On the other hand, in SAW, lumber can float down rivers to a port nearby a milling center. Moreover, SAW uses three milling centers: Lima, Puerto Maldonado, and Iñapari; whereas LOG only uses the latter two, thus reducing total profitable volume and, as a result, total forest value in LOG. Note that transporting roundwood all the way to Lima does not pay off due to the extremely high transportation costs across the Andes.

Stumpage prices for each land use (Table S2, Supplementary Material) were higher for areas adjacent to milling centers, rivers, and roads in both scenarios (Fig. 1), which suggests that the government could charge higher fees there. Of the region's land uses (Fig.S2), protected areas and timber concessions made up 61% of all profitable volume in SAW; while in LOG, Brazil-nut concessions and timber concessions contained the largest profitable volume (54%) (Table S1).

In the SAW simulation, Brazil-nut concessions and ecotourism concessions had the highest average stumpage prices (US $$46.1 \pm$ $7.7/m^3$ and US\$45.1 \pm 10.3/m³, respectively), indicating that these concessions would provide the highest revenues if harvesting is allowed there. Nevertheless timber harvesting may reduce the value of Brazil-nut and ecotourism concessions (Guariguata et al., 2009; Kirkby et al., 2010). On the other hand, conservation concessions, indigenous reserves, and protected areas presented the lowest average stumpage prices (<US\$30/m³), suggesting that these areas would provide relative low revenues to the State if opened to harvesting. The average stumpage price within timber concessions was US 34.5 ± 9.3 / m³. This indicates that stumpage fees for timber concessionaires should not exceed this value otherwise there will be no economic incentive to harvest. Our results also point out that timber concessions were located in areas with relatively lower stumpage prices when compared to areas closer to milling centers, such as Brazil-nut concessions.

In LOG, we found a similar result. Areas closer to milling centers presented the highest stumpage prices (Table S2). In turn, positive stumpage prices inside timber concessions were the lowest of all land uses (US\$27.8 \pm 15.4/m³). These stumpage prices were considerably reduced because the constraint on river transport for roundwood increases transportation costs at a greater rate than in SAW as distance from the milling center increases. Hence, our results indicate that stumpage fees for timber concessionaires must not exceed US \$27.8/m³, if timber is harvested as roundwood.

Our results point out that different land uses require differentiated levels of stumpage fees. Likewise, different harvest methods also require different stumpage fees. However, fees in Madre de Dios do not account for this spatial distribution of rents or differences in harvest methods. Timber concessionaires pay fees of, on average, US\$1.5/ ha/yr on the area of the concession (Galarza and La Serna, 2005), but only 1/20 of a concession's total area is subject to harvesting in any particular year due to the 20-year cutting cycle. This implies that the annual stumpage fee is equivalent to US\$30/ha/yr per cutting area. If we consider the 2005 mean harvest rate of 2.71 m³/ha of all annual cutting areas in Madre de Dios (Bonifaz and Urrunaga, 2008), timber concessionaires are paying approximately US\$11.1/ m³; therefore, much less than our estimated maximum stumpage prices of US\$34.5/m³ and US\$27.8/m³ for timber concessions under both LOG and SAW.

Furthermore, outside timber concessions the stumpage fee charged varies according to each harvested timber class and its volume. Using the harvested volume from each class as a percentage of total harvested roundwood volume in Madre de Dios in 2009 (MINAG, 2010) and the official stumpage fees (Resolucion-Ministerial-No. 245-2000-AG), we calculated a weighted average stumpage fee currently charged in areas outside timber concessions of US\$1.57 \pm 2.8/m³, which is far lower than the estimated stumpage prices for all land uses in both modeled scenarios.

In sum, model results show that current stumpage fees are below stumpage prices, and suggest that the government is losing revenues while providing windfall profits to loggers. For example, the weighted average stumpage fee charged outside timber concessions (US\$1.57/

162

m³) lies well below the estimated range of stumpage prices found inside Brazil-nut concessions, when roundwood is processed on-site (US\$46.1/m³), providing, on average, US\$44.5/m³ of windfall profits. Moreover, timber concessions are currently subject to higher fees than any other land use in Madre de Dios, what provides an economic incentive to harvest outside timber concessions, especially in areas situated closer to milling centers, such as the Brazil-nut concessions (Fig. S2). This perverse incentive may explain why current harvest levels appear to be higher in Brazil-nut concessions than in timber concessions (Cossío-Solano et al., 2011). In the same way, this could partially explain why timber concessions are perceived to be unprofitable by the general public (Galarza and La Serna, 2005) and even by the last Peruvian president (García, 2007).

3.2. Potential Future Forest Revenues in Madre de Dios

Harvest simulations for the next 20-years (2009–2029) enabled us to assess the potential trend of harvest volumes and associated forest revenues under either SAW or LOG for three additional harvestable areas scenarios: (S1) full access, (S2) no access to Brazil-nut concessions, and (S3) a harvest cap of 5 m³/ha in Brazil-nut concessions. Our simulations did not consider timber harvesting that does not pay fees (i.e. illegal harvesting).

3.2.1. S1

In SAW-S1 and LOG-S1, we estimated that by 2029 total harvested roundwood volume would amount to 12.5 million m^3 and 7.7 million m^3 , respectively. Annual harvested volume would peak at 848,019 m^3 in 2028 in SAW-S1, a 165% increase from the initial annual harvest of 320,481 m^3 . In LOG-S1 the annual harvest would peak at 512,749 m^3 in 2026 – a 198% increase from the initial harvest of 171,983 m^3 (Fig. 2). Note that SAW's total capacity is 53% larger than the LOG's, because of the assumed transportation constraints. Total discounted forest revenues would be US\$279 million in SAW-S1, and US\$190



Fig. 2. Annual harvested volume showing potential growth in harvest scenario SAW (a) and in harvest scenario LOG (b), under timber-resource access scenarios: (S1) full access in legal harvestable areas, (S2) no access to Brazil-nut concessions, and (S3) in which an annual harvest cap of $5 \text{ m}^3/\text{ha}$ is imposed within Brazil-nut concessions.

million in LOG-S1, with an annual average of US\$24.55 \pm 8.02 million and US\$16.54 \pm 5.28 million, respectively. These results suggest that, over the long run, it is more profitable to process lumber on-site rather than transporting roundwood, because the high costs associated with transporting roundwood more than offset the higher processing yields of stationary band-saws when compared to chainsaws and mobile sawmills.

Sales tax (at 18%) would generate total discounted revenues of US \$69 million in SAW-S1. Note that LOG-S1 generates no sales tax revenues since sales are tax exempt in Madre de Dios (Ley-No. 27037).

3.2.2. S2

Table 3

We found a decrease of one million m^3 in total harvest volume when we compared SAW-S2 to SAW-S1 (-8%) and of 1.9 million m^3 when we compared LOG-S2 to LOG-S1 (-25%) (Fig. 2, Table 3). The larger decrease in the latter was due to the greater relative importance of Brazil-nut concessions for timber harvesting to the LOG scenario. In addition, we estimated that discounted forest revenues would be reduced by US\$23 million from SAW-S1 (-8%), and by US\$50 million from LOG-S1 (-27%) (Table 3) and would present an annual average of US\$21.80 \pm 5.31 million and US\$11.27 \pm 2.06 million, respectively.

Constraining harvesting inside Brazil-nut concessions imposes opportunity costs in terms of reduced forest revenues to the State. However, these opportunity costs are not a direct effect of closing the Brazil-nut concessions for harvesting. To compensate for their timber supply, the model accounts for leakage arising from timber being harvested from other profitable areas. Reduction in revenues is more drastic in LOG than in SAW because Brazil-nut concessions are one of the few sources of positive revenues for harvesting roundwood, whereas lumber revenues are abundant elsewhere (Fig. 1). Hence, the government has a financial justification to allow harvesting inside these concessions since it apparently stands to lose revenues if they make them off-limits to loggers. Notwithstanding, in 2007 INRENA allowed harvesting with no volume cap, (previously set at $5 \text{ m}^3/\text{ha}$) in Brazil-nut concessions (RI-No. 254-2007-INRENA-IFFS). INRENA did not analyze the impact of this decision on the productivity of Brazil-nut trees, nor on the forest industry as a whole, even though these concessions compete with timber concessions to supply timber (Cossío-Solano et al., 2011). At that time INRENA justified the decision by saying that there was no evidence that timber harvesting affected Brazil-nut collection (RI-No. 254-2007-INRENA-IFFS; Peña, 2010), although a recent study showed that low harvest levels $(4-5 \text{ m}^3/\text{m}^3)$ ha) have relatively low impact, but higher levels $(5-12 \text{ m}^3/\text{ha})$ may cause severe damage to Brazil-nut trees (Guariguata et al., 2009).

Iotal harvested volume (HV), discounted forest revenues (FR), discounted total gro	oss
product (GP), and discounted sales tax (18%) revenues (T) by harvest scenario (SA	١W
and LOG) and access scenario (S1, S2, and S3) for the 20-yr simulation period.	

Scenario	HV (million m^3)	FR (million US\$)	GP (million US\$)	T (million US\$)
SAW-S1	12.54	221.16	728.85	131.19
SAW-S2	11.54	205.52	700.64	126.12
SAW-S3	12.19	218.56	723.77	130.28
S1-S2	1.00	15.64	28.21	5.08
S1-S3	0.35	2.60	5.08	0.91
LOG-S1	7.68	150.56	374.10	-
LOG-S2	5.78	114.37	300.77	-
LOG-S3	6.96	138.91	349.29	-
S1-S2	1.90	36.19	73.32	-
S1-S3	0.72	11.64	24.81	-

SAW: harvest scenario where logs are sawn in forests and transported as lumber to milling centers. LOG: harvest scenario where logs are transported as roundwood to milling centers. Access Scenarios: S1: all areas from which harvesting is legal are open to access; S2: Brazil-nut concessions are closed; and S3: only 5m³/ha could be harvested from Brazil-nut concessions. S1–S2 shows the difference between SAW/LOG-S1 and SAW/LOG-S2. S1–S3 shows the difference between SAW/LOG-S3.

In SAW-S1 and LOG-S1, annual average harvested volumes inside Brazil-nut concessions were 10.1 ± 0.11 m³/ha and 10.22 ± 0.13 m³/ha, respectively, suggesting that Brazil-nut tress might suffer damage from harvesting.

Decrease in total harvest of SAW-S2 from SAW-S1 would reduce US\$8 million in sales tax discounted revenues (-5%).

3.2.3. S3

This scenario produced a smaller reduction of total harvested volumes and corresponding forest revenues when compared to S1 than when compared to S2. Total harvest over 20 years is 354,165 m³ lower in SAW-S3 (-3%) when compared to SAW-S1, and 716,193 m³ lower in LOG-S3 (-9%) when compared to LOG-S1 (Fig. 2, Table 3). We estimated that SAW-S3 would generate discounted forest revenues of US\$274 million, a reduction of US\$5 million from SAW-S1 (-2%). This reduction represents the opportunity cost of imposing a cap in timber harvesting in Brazil-nut concessions. This opportunity cost was 79% lower than that of completely banning harvesting inside Brazil-nut concessions (S2). In absolute terms, SAW-S3 increased discounted forest revenues by US\$18 million when compared to SAW-S2 (Table 3) and averaged an annual revenue of US 23.78 ± 6.75 million. LOG-S3 would generate discounted forest revenues of US\$173 million, a reduction of US\$17 million (-9%) from LOG-S1, an opportunity cost 67% lower than the estimated opportunity cost of LOG-S2. LOG-S3, as a result, increased discounted forest revenues by US\$34 million when compared to LOG-S2 (Table 3) and averaged an annual revenue of US\$14.68 \pm 3.90 million. Thus, keeping harvest levels low (5 m³/ha) inside Brazil-nut concessions imposes a smaller opportunity cost when compared to the case of no harvest cap. This implies that a cap of 5 m³/ha, as opposed to completely banning timber harvesting in Brazil-nut concessions, incurs a smaller opportunity cost and might mitigate the potential impacts of timber harvesting among Brazil-nut trees (Guariguata et al., 2009).

3.3. Impact of Timber Harvesting in Brazil-nut Concessions on Timber Concession Revenues

To assess the economic impact on timber concessions' revenues of allowing timber harvesting in Brazil-nut concessions, we estimated the contribution from both concession types to total discounted revenues. In SAW-S1, timber and Brazil-nut concessions provided the greatest total discounted revenues: US\$80 million and US\$69 million, respectively. However, when Brazil-nut concessions were completely closed to timber harvesting (SAW-S2), discounted revenues in timber concessions grew to US\$108 million, an increase of 35%. This was due to leakage, as the timber supply from Brazil-nut concessions was compensated from elsewhere. In fact, in this scenario, timber concessions contained sufficient profitable volume to compensate the loss from closing Brazil nut concessions, indicating a high level of competition between these two concession types. In other words, the estimated discounted revenues to the State from timber concessions might be higher if Brazil-nut concessions were closed to timber harvesting.

In LOG, reduction in timber concessions' revenues was much lower (3%), indicating that these concessions did not provide enough profitable volumes to replace the loss of revenues from Brazil-nut concessions, because of the higher transportation costs from timber concessions. This also explains why total discounted revenues in LOG-S2 were significantly lower than those in LOG-S1. In turn, when a harvest cap was established in SAW-S3, discounted revenues from harvesting in timber concessions also rose to US\$87 million (+9%), though not as much as in SAW-S2. This scenario would diminish competition between the two concession types and would be a sound policy choice.

Our results show that Brazil-nut and timber concessions compete when timber is harvested as lumber — the most common harvest method in Brazil-nut concessions. This result indicates that banning timber harvesting from Brazil-nut concessions would increase revenues from timber concessions, adding value to those forests. This outcome, however, would come at a cost of reducing revenues from harvesting in Brazil-nut concessions, which could be alleviated by applying the harvest cap of 5 m^3 /ha.

4. Conclusions

Our results suggest that the timber resource in Madre de Dios is not correctly priced by Peruvian forestry authorities. Loggers appear to be paying low stumpage fees and gaining windfall profits. Thus, fees could be revised upwards in accordance with current market prices and adjusted spatially, with areas closer to milling centers paying higher fees than those farther away.

If the historical growth rate of processing capacity remains steady at 10% for the next 20 years and optimal stumpage fees were implemented, total forest revenues could increase from the current \approx US \$1 million/yr (MEF, 2011) to an average of US\$23.4 \pm 1.4 million/yr, in the case where timber is harvested, processed on-site, and transported as lumber (SAW-scenario), and of US\$14.2 \pm 2.7 million/yr for the case of roundwood (LOG-scenario). These harvest levels can be met in Madre de Dios without harvesting in protected areas, indigenous reserves, and ecotourism and conservation concessions. Nonetheless, a 20-year cutting cycle might not be an ecologically sustainable forest management (Dauber et al., 2005; Putz et al., 2008; Silva et al., 1995) and further analyses are still required to define a suitable cutting cycle.

The fact that Brazil-nut concessions appear to be competing with timber concessions to provide commercial timber to markets should be taken into account when revising fees. A harvest cap of 5 m³/ha inside Brazil-nut concessions would be necessary to mitigate the impact of timber harvesting without incurring the opportunity costs of not harvesting inside Brazil-nut concessions. At the same time, this harvest cap may contribute to reduced competition between Brazil-nut and timber concessions. Furthermore, no harvest cap inside Brazilnut concessions could potentially impose a threat to maintaining forest cover within timber concessions, since national authorities could perceive them as low-value, and decide to convert these forests to other land uses such as oil-palm plantations (CNR, 2011). Thus, the harvest cap seems to be a good policy choice to reconcile timber harvesting and Brazil-nut collection, which is an important source of income for urban and rural populations of Madre de Dios (Nunes et al., 2012).

Taking the example of Madre de Dios, the Peruvian government should consider allowing on-site processing since it would be more profitable than harvesting roundwood only. It is possible that the use of chainsaws to process lumber has less of an ecological impact than the use of heavy machinery, despite lower processing yields, and it's possible that on-site processing techniques will improve with time as more advanced machinery becomes available. Furthermore, a complete enforcement of the ban on using chainsaws may have a significant impact on local incomes.

Our estimates provide a means to anticipate the economic consequences from revising the current forest fee policy in Madre de Dios. Larger revenues provided by higher stumpage fees, which should be revised and adjusted regularly in accordance with market prices, could encourage improved management and monitoring that would reduce illegal logging and deforestation threats, and would complement a suite of forest-friendly economic activities that includes Brazil-nut collection (Nunes et al., 2012), ecotourism, and conservation concessions in Madre de Dios (Kirkby et al., 2010, 2011).

Acknowledgements

We thank the Gordon and Betty Moore Foundation and the Conselho Nacional de Desenvolvimento Científico e Tecnológico-CNPQ for funding. We also acknowledge the Rufford Small Grants for Conservation for funding the initial work in Madre de Dios of one of us (RG) and the Administración Técnica Forestal y de Fauna Silvestre – Ministerio de Agricultura del Perú at Tahuamanu and Tambopata-Manu, Maderacre SAC, Chris Kirkby, Elsa Mendoza, Felipe Nunes, Manuel Vía, Carlos Vinicio and Germán Zumaeta for providing databases, and Leticia Hissa and Aline Oliveira for preparing the figures.

Appendix A. Supplementary Data

Supplementary data to this article can be found online at doi:10. 1016/j.ecolecon.2012.02.024.

References

- Amacher, G.S., Brazee, R.J., Witvliet, M., 2001. Royalty systems, government revenues, and forest condition: an application from Malaysia. Land Economics 77, 300.
- Balmford, A., 2003. Global variation in terrestrial conservation costs, conservation benefits, and unmet conservation needs. Proceedings of the National Academy of Sciences 100, 1046–1050.
- Bonifaz, J.L., Urrunaga, R., 2008. Beneficios económicos de la carretera Interoceánica. Centro de Investigación de la Universidad del Pacífico, Lima.
- Chirinos, C., Ruiz, M., 2003. Informe final del estudio: desarrollo e implementación de lineamientos de control de la extracción ilegal para un manejo forestal sostenible en el Perú. ITTO, Ciudad de Panamá.
- CMT, 2009. (Caja Municipal de Tacna). http://www.cmactacna.com.pe/transparencia/ TIP01-02-11%20-%20Tasas%20de%20Interes%20Pasivas%20-%20MN%20y%20ME%20-%20Vig%2009NOV11.pdf2009 accessed 10.2.2012.
- CNR, 2011. MINAG permite que Grupo Romero reanude operaciones en San Martín. http://lamula.pe/barra/cnr.org.pe/52011 accessed 20.07.2011.
- Cossío-Solano, R.E., Guariguata, M.R., Menton, M., Capella, J.L., Rios, L., Peña, P., 2011. El aprovechamiento de madera en las concesiones castañeras (*Bertholletia excelsa*) en Madre de Dios, Perú, Documento de trabajo. CIFOR, Bogor, Indonesia.
- Curran, L.M., 2004. Lowland forest loss in protected areas of Indonesian Borneo. Science 303, 1000–1003.
- Dauber, E., Fredericksen, T.S., Peña, M., 2005. Sustainability of timber harvesting in Bolivian tropical forests. Forest Ecology and Management 214, 294–304.
- FAO, 2011. Global Forest Resources Assessment 2011. Food and Agriculture Organization of the United Nations, Rome.
- Galarza, E., La Serna, K., 2005. Las concesiones forestales en el Perú: cómo hacerlas sostenibles? in: La política forestal en la Amazonía Andina. Estudio de caso: Bolivia, Ecuador y Perú. Consorcio de Investigación Económica y Social, Lima.
- García, A., 2007. El síndrome del perro del hortelano. El Comercio, Main section p.A4, 28 October, Lima.
- Gray, J.A., 2002. Forest concession policies and revenue systems: country experience and policy changes for sustainable tropical forestry, World Bank Technical Papers 255. World Bank, Washington DC.
- 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.
- Gutierrez-Velez, V.H., MacDicken, K., 2008. Quantifying the direct social and governmental costs of illegal logging in the Bolivian, Brazilian, and Peruvian Amazon. Forest Policy and Economics 10, 248–256.
- Hidalgo, J., 2003. Estado de la situación forestal en el Perú, Mesa especial. Seminario Permanente de Investigación Agraria (SEPIA), Lima.
- Hidalgo, J., Chirinos, C., 2005. Manual de normas legales sobre tala ilegal. IRG, USAID, CMLTI, INRENA, SPDA, Lima.
- INRENA, 1996. Guía explicativa del Mapa Forestal 1995. Instituto Nacional de Recursos Naturales. Dirección General Forestal, Lima.
- Kirkby, C.A., Giudice-Granados, R., Day, B., Turner, K., Velarde-Andrade, L.M., Dueñas-Dueñas, A., Lara-Rivas, J.C., Yu, D.W., 2010. The market triumph of ecotourism: an economic investigation of the private and social benefits of competing land uses in the Peruvian Amazon. PLoSONE 5, e13015.
- Kirkby, C.A., Giudice, R., Day, B., Turner, K., Soares-Filho, B.S., Rodrigues, H., Yu, D.W., 2011. Closing the ecotourism-conservation loop in the Peruvian Amazon. Environmental Conservation 38, 6–17.

- Lentini, M., Pereira, D., Calentano, D., Pereira, R., 2005. Fatos florestais da Amazônia. Instituto do Homem e Meio Ambiente da Amazônia, Belém.
- León, D., Mego, P. 2007. El Cluster forestal en Madre de Dios: Obstáculos y oportunidades para su crecimiento y competitividad [Master's thesis]. Lima: Universidad del Pacífico.
- Maltamo, M., Eerikainen, K., Pitkanen, J., Hyyppa, J., Vehmas, M., 2004. Estimation of timber volume and stem density based on scanning laser altimetry and expected tree size distribution functions. Remote Sensing of Environment 90, 319–330.
- MEF, 2011. Consulta de transferencias de recursos Gob. Regionales. http://ofi.mef.gob. pe/transferencias/gr/default.aspx. accessed 25.07.2011.
- Merry, F., Soares-Filho, B., Nepstad, D., Amacher, G., Rodrigues, H., 2009. Balancing conservation and economic sustainability: the future of the Amazon timber industry. Environmental Management 44, 395–407.
- MINAG, 2010. Perú forestal en números 2009. Ministerio de Agricultura, Lima, Perú.
- MINAG, 2011. Estadística forestal. http://www.minag.gob.pe/dgffs/index.php?option= com_content&view=article&id=58<emid=1792011 accessed 10.04.2011.
- Nepstad, D.C., Verssimo, A., Alencar, A., Nobre, C., Lima, E., Lefebvre, P., Schlesinger, P., Potter, C., Moutinho, P., Mendoza, E., Cochrane, M., Brooks, V., 1999. Large-scale impoverishment of Amazonian forests by logging and fire. Nature 398, 505–508.
- Nunes, F., Soares-Filho, B.S., Giudice, R., Rodrigues, H., Bowman, M., Silvestrini, R., Mendoza, E., 2012. Economic benefits of Forest conservation: assessing the potential rents from Brazil nut concessions in Madre de Dios, Peru, to channel REDD + investments. Environmental Conservation: FirstView, pp. 1–12.
- Oliveira, P.J.C., Asner, G.P., Knapp, D.E., Almeyda, A., Galván-Gildemeister, R., Keene, S., Raybin, R.F., Smith, R.C., 2007. Land-use allocation protects the Peruvian Amazon. Science 317, 1233–1236.
- Peña, P., 2010. La castaña y la shiringa en Madre de Dios: análisis del marco legal y propuestas participativas para su mejora. SPDA, Lima.
- Phillips, O., Gentry, A.H., Reynel, C., Wilkin, P., Galvez-Durand, B.C., 1994. Quantitative ethnobotany and Amazonian conservation. Conservation Biology 8, 225–248.
- Putz, F.E., Blate, G.M., 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.
- Putzel, L., Padoch, C., Pinedo-Vasquez, M., 2008. The Chinese timber trade and logging of Peruvian Amazonia. Conservation Biology 22, 1659–1661.
- Robinson, W.D., Robinson, S.K., 1999. Effects of selective logging on forest bird populations in a fragmented landscape. Conservation Biology 13, 58–66.
- Sears, R.R., Pinedo-Vasquez, M., 2011. Forest policy reform and the organization of logging in Peruvian Amazonia. Development and Change 42, 609–631.
- Silva, J.N., de Carvalho, J.O., Lopes, J., de Almeida, B.F., Costa, D.H., de Oliveira, L.C., Vanclay, J.K., Skovsgaard, J.P., 1995. Growth and yield of a tropical rain forest in the Brazilian Amazon 13 years after logging. Forest Ecology and Management 71, 267–274.
- Smith, J., Colan, V., Sabogal, C., Snook, L., 2006. Why policy reforms fail to improve logging practices: the role of governance and norms in Peru. Forest Policy and Economics 8, 458–469.
- Soares-Filho, B.S., Nepstad, D., Curran, L., Cerqueira, G., Garcia, R., Ramos, C., Voll, E., McDonald, A., Lefebvre, P., Schlesinger, P., 2006. Modelling conservation in the Amazon basin. Nature 440, 520–523.
- Soares-Filho, B.S., Rodrigues, H., Costa, W., 2009. Modeling environmental dynamics with Dinamica EGO. http://www.csr.ufmg.br/dinamica/. accessed 21.03.2010.
- Soares-Filho, B.S., Moutinho, P., Nepstad, D., Anderson, A., Rodrigues, H., Garcia, R., Dietzsch, L., Merry, F., Bowman, M., Hissa, L., Silvestrini, R., Maretti, C., 2010. Role of Brazilian Amazon protected areas in climate change mitigation. Proceedings of the National Academy of Sciences of the United States of America 107 (24), 10821–10826.
- Stone, S., 1998. Using a geographic information system for applied policy analysis: the case of logging in the Eastern Amazon. Ecological Economics 27, 43–61.
- Suárez de Freitas, G., 2009. Situación actual del sector forestal en el Perú. Revista Tecnológica y Sociedad. Soluciones Prácticas ITDG, pp. 17–26.
- Trujillo, C., 2008. Fortalecimiento de la cadena productiva de la madera proveniente de concesiones forestales y otros bosques bajo manejo forestal. http://www.cnf.org. pe/. accessed 15.05.2010.
- Vincent, J.R., 1992. The tropical timber trade and sustainable development. Science 256, 1651–1655.
- Whiteman, A., 2005. A review of the forest revenue system and taxation of the forestry sector in Fiji. Forest Finance Working Paper, FAO, Rome.
- Young, C.E.F., 2005. Financial mechanisms for conservation in Brazil. Conservation Biology 19, 756–761.