Adoption of sustainable forest management practices in Bolivian timber concessions: a quantitative assessment

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SUMMARY

Bolivia implemented an extensive reform of their forestry sector during the 1990s. Starting five years later, we evaluated the degree of adoption of sustainable forest management practices (SFM) by timber concessionaires in Bolivia and investigated the factors influencing their adoption. Data were obtained from surveys that quantified the level of adoption of 11 SFM practices in 23 concessions. The study revealed that concessionaires adopted some practices more than others. It found that regulation plays a critical role in promoting adoption. Adoption of SFM practices was also more frequent among operators that had been in the forestry business for a longer time, had larger concessions, harvested and processed larger volumes, utilized a wider set of species, were located closer to markets, had received more technical assistance, had trained their employees, and had made other investments. The owners' perception that SFM practices contributed to ecological sustainability was also an important factor in their decision to adopt these practices.

Keywords: forest degradation, technology adoption, sustainable forest management, decision-making, Bolivia, forest regulation, tropical forests.

Adoption des pratiques de gestion forestière durable dans les concessions de bois de la Bovilie: une évalution quantitative

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La Bolivie a mis en pratique une réforme étendue dans son secteur de foresterie pendant les années 90. Cinq ans plus tard, nous avons évalué le degré d'adoption des pratiques de gestion forestière durable (SFM) par les concessionnaires de bois en Bolivie, et avons conduit une investigation des facteurs influençant l'adoption de ces pratiques. Des données furent obtenues dans des recherches qui quantifiaient le degré d'adoption des 11 mises en pratique des SFM dans 23 concessions. L'étude révéla que les concessionnaires avaient tendance à adopter certaines pratiques de préférence à d'autres. Elle découvrit que la règlementation joue un rôle critique dans la promotion de l'adoption. Il apparut également que l'adoption des SFM était plus fréquente chez les opérateurs qui étaient dans la foresterie depuis longtemps, ceux qui possédaient des concessions plus importantes, ceux qui récoltaient et raffinaient de plus grands volumes, utilisaient un éventail plus large d'espèces, se trouvaient plus proches des marchés locaux, avaient reçu davantage d'assistance technique, ceux qui avaient formé leurs employés, et avaient fait d'autres investissements. Le fait que les propriétaires aient réalisé que les pratiques SFM contribuent à la durabilité écologique est également un facteur important dans leur décision d'adopter ces pratiques.

Adopción de prácticas sostenibles de gestión forestal en las concesiones madereras bolivianas : una evaluación cuantitativa

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En Bolivia se implementó una reforma importante del sector forestal durante los años 1990. Cinco años más tarde, se empezó a evaluar el nivel de adopción de prácticas sostenibles de manejo forestal (MFS) por parte de los concesionarios madereros en Bolivia, y se investigaron los factores que influían sobre la adopción de estas prácticas. Los datos fueron proporcionados por encuestas que cuantificaron el nivel de adopción de 11 prácticas en 23 concesiones. El estudio reveló que los concesionarios adoptaban algunas prácticas más que otras, y demostró que la regulación desempeña un papel fundamental en la promoción de dicha adopción. La adopción de prácticas de MFS fue también más frecuente entre los operadores que: llevaban más tiempo en el sector de gestión forestal, poseían concesiones más grandes, cosechaban y procesaban volúmenes mayores, utilizaban un mayor número de especies, y estaban situados más cerca de los mercados, habían recibido más asistencia técnica, habían proporcionado formación profesional a sus empleados, y tenían otras inversiones. La idea de los proprietarios de que las prácticas de MFS contribuían a la sostenibilidad ecológica constituyó también un factor importante en su decisión de adoptar estas prácticas.

INTRODUCTION

The selective logging of high-value species (often amounting to timber mining), the unplanned way in which harvesting is conducted, the lack of attention to areas and species of high ecological value, and to the regeneration and growth conditions of stands after harvest, have all been associated with important economic and environmental losses. These losses have been measured in terms of lost economic rents, mining and degradation of forest resources, disruption of watershed services, social distress and conflict, loss of biodiversity, and emission of greenhouse gases (Sharma 1992, Balmford *et al.* 2002).

To reduce these negative externalities associated with timber harvesting, a set of practices known collectively as sustainable forest management (SFM) has been promoted to reduce the negative impacts of timber harvesting on other forest resources and services. From a management viewpoint, these practices aim at balancing harvest with growth, and by introducing planning and careful harvesting, at protecting and increasing the yield of desired products and services from a given forest area over time. The implementation of SFM makes timber harvesting compatible with the maintenance of a wide range of environmental values and services from forests. Tropical forests are home to more than 50% of the world's species and also store a significant portion of the world's carbon, as well as playing important roles in recycling precipitation and protecting soils from heavy rainfalls. For these reasons, the implementation of SFM in tropical forests has long been considered a high priority (e.g., Poore *et al.* 1989; Panayotou and Ashton 1992; Pearce *et al.* 1999).

To promote SFM, millions of dollars have been spent annually worldwide to improve governance, resource access, taxation, income distribution, and forest management (Rice *et al.* 2001, Chipeta and Joshi, 2001, Sheperd *et al.* 1998). Such efforts have produced mixed results. On the one hand, major institutional and policy reforms have taken place in all tropical regions (Poore and Chiew 2000). According to ITTO (2006), more than 96 million ha (27%) of tropical natural production forest currently have management plans. Of these 25 million (7.1%) were estimated to be sustainably managed and about 10 million ha were certified as well managed by 3rd party certifiers like the Forest Stewardship Council. Nonetheless both deforestation and forest degradation continue at worrisome levels (FAO 2005). UN negotiations seeking to finance Reduced Emissions from Deforestation and Forest Degradation (REDD), represent yet another effort to address this challenge. To reduce the contribution of logging to forest degradation, it is important to understand and build on the incentives and disincentives for adopting SFM practices on the part of those who manage tropical forests for timber production.

Bolivia has 59 million ha of forests that cover more than 54% of the country, including significant areas within the Amazon Basin. For decades, these forests were used as a mine for mahogany timber (*Swietenia macrophylla*) for export. By 1990, mahogany supplies had declined. This was one of the factors leading to a major forestry reform initiative that began in 1994, to which support was provided by the BOLFOR (Bolivian Sustainable Forest Management) project, funded by USAID. Extensive consultations yielded regulatory reforms, including Forestry Law 1700 of 1996, and its regulations, which were implemented in 1997. The "*Superintendencia Forestal*" Bolivian Forest Superintendency (SIF), an institution independent of the Ministries that experienced frequent turnovers, was established to oversee forestry activities (Contreras and Vargas 2002, 2006; Pacheco 2006; Snook *et al.* 2006). There were 2 Superintendents during the first 10 years after the reform, as compared to 13 Ministers of Sustainable Development (CFB 2006). By the late 1990s, Bolivia had the highest number of certified timber concessions of any country in the tropics - 2.2 million ha (Snook *et al.* 2006). For this reason, we decided to evaluate the adoption of SFM in Bolivia to better understand what factors had contributed to these changes; this study also provided a point of comparison for a broader study comparing forest management in Bolivia with forest management in the neighboring countries of Peru and Brazil[1].

Past scientific inquiries and anecdotal evidence suggest that there are numerous and complex reasons that affect the decision by forestry firms to adopt better forest practices. An earlier study in Bolivia mentions the importance of productivity and cost considerations, laws and regulations, external pressure and certification, technical assistance, and a dwindling supply of high value species (Blate *et al.* 2002). Other studies have described as impediments to adoption insufficient regulatory and market pressure, inadequate economic incentives (whether provided by the market or by governments), institutional instability (e.g., insecure rights), lack of capital and trained personnel, unsuitable equipment, fluctuations in the timber markets, ignorance and resistance to change (e.g., Putz *et al.* 2000, Karsenty 2001). A number of past studies that have inquired into this issue have focused on economic analyses comparing conventional logging with a set of practices usually referred to as "reduced impact logging" (RIL). A study that inquired into the obstacles to more widespread adoption of RIL concluded that such practices are not adopted "because of ignorance or for reasons that remain unclear" despite evidence that such practices might increase the profitability of forestry operations (Pearce *et al.* 1999).

In this paper we attempt to better understand the factors that influence the adoption of sustainable forest management. With a focus on Bolivia, we attempt to:

(i) Quantify the level of adoption of various forest management practices in different concessions;

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[1] This study is part of a research project that aims at better understanding the constraints to the adoption of better forest practices in Bolivia, Peru and Brazil. Additional information can be found in: Snook *et al.* (2006) and Sabogal *et al.* (2006a, 2006b).

(ii) Test the importance of laws and regulations in explaining why certain practices are adopted more than others, and
(iii) Identify an initial set of characteristics that differentiate adopters from non-adopters.

To begin addressing these inquiries, we selected a set of 11 practices considered to be key to achieving sustainability benefits and quantified their level of adoption by 23 timber concessionaires in the Bolivian lowlands. We decided to analyze these practices separately (rather than as a bundle, like RIL) in order to capture the fact that rarely are they all implemented, even within the same concession. We hypothesized that this selective adoption reflects the fact that different practices differ in terms of costs, benefits, complexity of adoption and treatment by the law.

The next section describes the practices and the rationale for their selection. Section 3 describes the data and provides some summary information. In section 4 we present two separate analyses. The first analysis compares the average level of adoption of different practices by the sampled concessions. Because the average rate of adoption varied among practices, this analysis seeks to explain these differences in terms of *the attributes of the various SFM practices*. A second analysis compares the behavior of the 23 concessionaires with respect to the adoption of two practices. This analysis, a comparison among concessions, emphasizes the difference in rates of adoption of SFM practices as a function of *the attributes of the concessionaires*.

Forestry practices considered

In this paper we considered a set of 11 practices that are often promoted to minimize the damage caused by harvesting operations and sustain forest productivity and other ecological services. The practices are briefly described in Table 1, along with the benefits they are intended to generate, which range from those accruing at the time of the current harvest to benefits accruing at the time of the second harvest or beyond, or to beneficiaries other than the timber producer. Numbered to reflect the timing of benefit accrual they are: (1) stock survey (census) and mapping, (2) vine cutting, (3) skid trail planning, (4) road planning, (5) directional felling, (6) delimitation of the annual harvesting unit, (7) marking and protection of seed trees, (8) establishment of permanent plots to monitor growth, (9) delimitation of the concession limits, (10) hunting control measures, and (11) conservation set-asides.

Practices 1-5 are widely known as elements of "reduced impact logging" (RIL) since they aim at reducing the amount of damage caused by timber harvesting operations. For example, liana cutting prevents trees felled during harvesting from dragging down other trees, thus reducing forest damage and the risks of accidents for workers, as does

TABLE 1 *Selected forestry practices and their contributions to sustaining forest productivity and environmental services*

	Practice	SFM objective	Other benefits
1	Stock survey and mapping of harvest trees	Tool for planning skid trails to reduce damage, protect next harvest and seed trees	Information obtained is useful for marketing and planning
2	Vine cutting	Reduce damage to residual trees; on residual trees, increase in growth and seed production	Reduction of risk to faller; reduction of damage to felled tree
3	Skid trail planning and layout	Reduce damage to soil, rivers, future harvest trees	Increased efficiency, lower skidding costs
4	Careful road design and construction	Reduce damage to site, rivers; increase efficiency	Reduced cost of transport, reduced damage to vehicles
5	Directional felling	Protection of next-harvest trees and seed trees	Reduction of risk to faller; reduction of damage to felled tree
6	Respecting the annual cutting area	Sustain annual harvests during the first cutting cycle; favor post-logging recovery	Protect volumes for second cutting cycle.
7	Leaving, protecting seed trees	Providing for regeneration	Trees left behind provide volume for next cutting cycle
8	Monitoring growth	Tool for sustaining yield by ensuring that cutting cycles provide for replacement of harvested volume	Sustaining harvest volumes for second cutting cycle and beyond
9	Protecting the forest from invasion by marking its limits	Sustaining forest cover and productive capacity	Protect future harvests
10	Controlling hunting on forest management unit	Protection of biodiversity and ecological processes underlying sustainability	Long term sustainability
11	Establishing and respecting reserve areas within forest management units	Protection of biodiversity and ecological processes underlying sustainability	Long term sustainability

directional felling. Some of these practices are implemented prior to harvesting (e.g., census of trees on the annual cutting area, vine cutting, planning of skid rails and roads). Others, like directional felling, are carried out during the harvest. The adoption of RIL practices in tropical forests has been documented to reduce damage to next-harvest trees, other residual trees, soils and water (Johns *et al.* 1996) . Studies in Brazil (Boltz *et al.* 2003, Holmes *et al.* 2002, Barreto *et al.* 1998) show that such practices can also improve the profitability of logging since they improve the efficiency with which machinery, personnel and forest resources are used. In addition to RIL practices, we included in this study practices such as monitoring tree growth, identifying and protecting seed trees and prohibiting hunting. These practices allow forest managers to define sustainable harvesting levels and rates, ensure regeneration of harvested species and maintain ecological processes important to sustainability.

Methods and data

Between the end of 2001 and the beginning of 2002 a survey was conducted of 23 concessions on the Bolivia lowlands. Since on three occasions the same owner controlled two concessions, the total number of firms was 20. They were a stratified random sample of the total population of 75 concessions nationwide. We randomly selected about 30% of the concessions in each Department: 12 in Santa Cruz (out of 35), 3 in La Paz (out of 8), 6 in Pando (out of 19), and 2 in Beni (out of 12). An additional concession, not part of our sample, was active in the Department of Tarija. Five of these concessions were certified at the time of the survey.

For each concession two interviews were conducted: one with the general manager and one with a technical person (usually a forester). From the general manager we gathered concession-level information and perceptions about the desirability of individual practices. From the forester we collected information about which practices were adopted and how they were implemented in the field. The information collected through interviews therefore encompassed concession-level data and practice-level data[2]. Table 2 describes some of the concession-level variables collected. The last column of Table 2 also reports whether the information was provided by the general manager or by the forester.

Some of the variables collected (e.g., area of concession, etc.) were verifiable, while other ones were subjective assessments of the respondent. For example, SUST and ECON represented a perception by the forest owner of the impact of a given practice on ecological sustainability and economic profitability, respectively.

The survey data was complemented with information regarding the treatment of the practice within the law and regulations governing forestry practice; and with a categorical assessment of whether the practice, if mandated by law, was easy to enforce. For example, while all eleven practices are mentioned in the forest regulations and norms, some, such as the stock survey and mapping, are clearly mandated by the law while others, such as vine cutting and directional felling, are mentioned only as recommendations[3]. We assigned a value of 0 or 1 to a variable (LEGAL) depending on whether the law mentions the practice as a recommendation or as an obligation. Practices mentioned in the law as obligations carry heavier penalties, if violated[4]. Therefore, we expected that practices with LEGAL=1 were more likely to be adopted than practices with LEGAL=0.

For those practices that are legally required, we then tested whether ease of enforcement results in more frequent adoption than for practices that are difficult to enforce. We accounted for the difficulty in enforcing compliance with a given practice via two indicators: the permanence of the signs of violation (PERM) and the ease with which violations can be detected (EASE). PERM was assigned a value of 0 (the signs of violation are short lived) or 1. PERM=0 was assigned to practices (e.g., directional felling or hunting control) that essentially require that the implementation of the practice be witnessed first hand, since on a few weeks the signs of the violation will no longer be visible. PERM=1 was assigned to practices like the stock survey, road planning, or the retention of seed trees, which can be verified months after harvesting.

EASE was assigned a value of 0 (difficult to enforce) or 1 (easy to enforce) depending on the existence of double checks that limit the need for inspection in the field. For example, the Bolivian Forest Superintendency (SIF) periodically issues permits for the harvesting and transport of logs based on information provided during the stock survey. The transport of logs is monitored relatively closely, providing an incentive to accurately carry out the stock survey and related activities (e.g., delimiting the annual harvesting unit). On the other hand, practices like vine cutting, directional felling or growth

[2] The information collected through interviews was not immediately and independently verified in the field. A field assessment took place the following year that used more rigorous definitions of SFM practices than the ones used in this paper (see also discussion section).

[3] For example, the Resolución Ministerial 62/97 (Normas Técnicas para la Elaboración de Instrumentos de Manejo Forestal) states that "la corta será acompañada de acciones concretas tendientes a maximizar la utilización de los árboles y reducir los daños por caída de los mismos. Con este fin **puede que sea** fundamental promover la ejecución de la tumba direccionada de árboles ó la corta previa de lianas en caso de que éstas ocasionen entrelazamiento de copas y el consiguiente perjuicio sobre los árboles vecinos durante el derribe." [emphasis added]. [Felling will be accompanied by specific actions tending to maximize the use of the trees and reduce the damage due to their falling. With this objective, **it may be** fundamental to promote directional felling of the trees or the prior cutting of vines in case these cause interlinking of crowns and the consequent damage of neighboring trees during felling".

[4] For example, the Decreto Supremo 24453 (Reglamento General de la Ley Forestal) states that "No se podrán considerar como faltas leves las contravenciones expresamente sancionadas de manera distinta por la Ley o el presente reglamento." [The contraventions specifically sanctioned by law or this regulation can not be considered light misdemeanors".

TABLE 2 *Description of selected explanatory variables*

Explanatory Variable	Description	Source*
HACON	Area of the concession (thousand hectares)	O
YRS	Years in the forestry business	O
VOL	Volume harvested from the concession in 2000	O
OWN	% of own production (not from third parties)	O
SELL	Equals 1 if concession sells roundwood to other forest operators; 0 otherwise	O
EXP	% of production exported	O
ASERR	Annual production of sawnwood	O
VAL_ADD	Ratio of plywood, veneer, and secondary manufacturing to sawnwood	O
KMTOT	Distance (Km) between concession and port of export	O
SCZ	Equals 1 if concession is located in the department of Santa Cruz; 0 otherwise	O
PAN	Equals 1 if concession is located in the department of Pando; 0 otherwise	O
HIGH	Equals 1 if mahogany, cedar and *roble* are easily accessible in the concession; 2 if they are accessible but far; 3 if not accessible	O
NSP	Number of species harvested	O
TEC	Number of permanent forest engineers and technicians in the concession	O
TRAIN	Employees receive periodic training	F
TA**	Equals 1 if concessionaire and workers received technical assistance to learn about practice; 0 otherwise	F
SUST**	Varies between 1 and 5 depending on the respondent's perception of the importance of the practice for ecological sustainability	O
ECON**	Varies between 1 and 5 depending on the respondent's perception of the importance of the practice for profitability	O
DROP**	Equals 1 if concessionaire would abandon the use of practice if it weren't mandated by law; 0 otherwise	O
INVEST	Equals 1 if concessionaire made investments in the concession in the past 3 years; 0 otherwise	O
INVRES	Equals 1 if concessionaire made investments in research in the past 3 years; 0 otherwise	O
INIT1	Equals 1 if the decision to adopt the practice came from the forester; 0 otherwise	F
INIT2	Equals 1 if the decision to adopt the practice came from the owner; 0 otherwise	F
OPINION	Varies between 1 and 5 depending on the perceived importance of the forester's opinion in adopting a new practice	F
CERTIF	Equals 1 if the concession is certified; 0 otherwise	O
SFSUB	Varies between 1 and 5 depending on whether the SIF is perceived as focusing on formal versus substantive issues	F
SFINSP	Number of months since last inspection by the SIF	F

* O: from interview with owner/manager; F: from interview with forester.
** Information collected for each practice.

monitoring require that SIF officers carry out frequent and careful on-site inspections. We expected that practices that are mandated by law and easier to enforce would be more widely adopted. The values of LEGAL, PERM, and EASE are summarized in Table 3.

To test the importance of LEGAL, PERM and EASE, we computed the average rates of adoption of practices for which regulations are explicit, easy to enforce, and for which signs are lasting. We then compared these values to the average adoption rates of practices that are not explicitly mandated by law, are more difficult to enforce, and whose signs do not last long. T-tests were used to see whether the differences in adoption rates between these groups were statistically significant. Practice-specific attributes such as SUST (the average perception of the contribution of the practice to ecological sustainability), ECON (the average perception of the contribution of the practice to profitability), and DROP (preference of managers to discontinue the use of the practice if it were not mandated by law) were also tested by computing Spearman rank correlation coefficients between these variables and the average adoption rates.

To inquire into why certain firms decided to adopt a certain practice while others did not, we looked at the characteristics (see Table 2) of adopters versus non-adopters. The differences in the means for the two groups (adopters and non-adopters) were tested using a t-test, assuming equal variances. All the variables listed in Table 2 were tested independently. We did not test here for the

TABLE 3 *Regulatory pressure for adoption of practice**

Practice	Practice mandated by law (Legal)	Permanence of violation signs (Perm)	Ease of enforcement (Ease)
Stock survey and mapping	1	1	1
Vine cutting	0	0	0
Skid trail planning	1	1	1
Road planning	1	1	1
Directional felling	0	0	0
Delimitation of annual harvesting unit	1	1	1
Retention of seed trees	1	1	0
Growth monitoring	1	1	0
Delimiting concession limits	1	1	0
Hunting control	1	0	0
Establish conservation areas	1	1	1

* Legal = 1 if practice is mentioned in the law as an obligation; Legal = 0 if mentioned as recommendation.
Perm = 1 if adoption of practice (or its violation) can be detected months after harvesting; Perm = 0 if otherwise.
Ease = 1 if practice is easy to enforce (e.g., linked to closely supervised monitoring); Ease = 0 if otherwise.

importance of regulation since it applies equally to adopters and non-adopters (all concessions are subjected to the same regulations). However, because enforcement may differ from area to area, we tested whether the frequency of inspections (measured by SIFINSP) differed between the two groups.

This test is not ideal to quantify the importance of explanatory variables on the adoption decision. It does not address causality nor does it account for correlation between variables and it fails to say whether a variable is still important once the influence of others is considered. To account for these, the decision to adopt a given practice would need to be modeled using, for example, a multivariate probit or logit model (Mercer 2004). This type of regression model allows one to estimate the effect of explanatory variables on a binary dependent variable. Unfortunately, the accuracy and feasibility of these models is greatly impaired when a limited number of observations is available, which is our case. A preliminary multivariate analysis was run on two practices, directional felling and monitoring forest growth, mostly as a complement to the t-tests.

RESULTS

The average size of the concessions was 200,000 ha, with a range of 18,000 – 700,000 ha and harvested 300-7000 ha/year of forest. On average, producers obtained 4400m^3/year from their concessions, from 7 species (a range of 3-21). They exported an average of 60% of their production (0-100%). Almost all the concessionaires (92%) had at least one, and up to 4, professional foresters.

The extent to which a practice was reportedly adopted is summarized in Figure 1. The overall level of adoption varied across practices from a minimum of 17% (for vine cutting) to 100% (for census, road planning, delimitation of annual harvesting unit, and retention of seed trees).

We analyzed the importance of various factors in the decision to adopt a given practice with two separate inquiries: (1) what helps explain the different levels of adoption among different practices? And (2) what helps explain the variability in adoption behavior among different concessionaires?

Variability in adoption across practices

As Figure 1 suggests, average rates of adoption among concessionaires vary by practice: concessionaires are adopting certain practices more frequently than others. What can help explain such variability? Clearly, the reason has to be sought in the attributes of the practices since all concession level variables (e.g., location, size, access to technical expertise) have the same values regardless of the practice analyzed.

Table 4 shows the average adoption rates of practices for which regulations are explicit and easy to enforce and for which signs are lasting. These values are compared with the average adoption rates of practices that are not explicitly mandated by law, are more difficult to enforce and of which the signs do not last.

FIGURE 1 *Extent of adoption by practise*

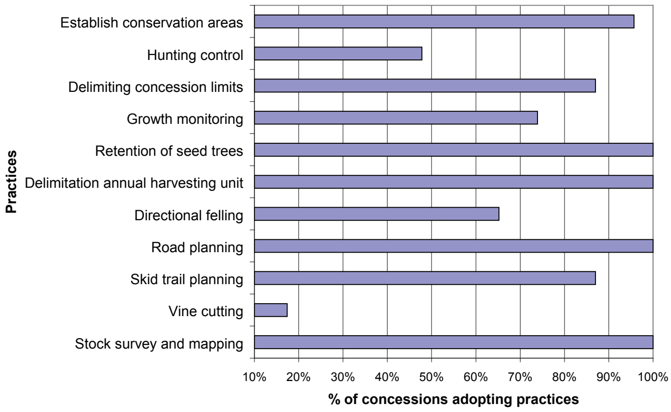

TABLE 4 *Adoption rates of practices by regulatory clarity, ease of enforcement, and permanence of signs of violation*

Variable	Average adoption rate		P-value
	Var = 0	Var = 1	
Legal	0.41 (n=2)	0.88 (n=9)	0.0077
Ease	0.77 (n=4)	0.96 (n=5)	0.0497
Perm	0.48 (n=1)	0.93 (n=8)	-

Practices that are clearly mandated by law are adopted by 88% of firms while only 41% of firms adopt practices that are only recommended. The importance of enforcement is also critical. Among the practices that are clearly mandated by law, only 77% are adopted if enforcement is difficult, compared with 96% of those practices for which the enforcement is easier. These differences are statistically significant at the 5% significance level. There is a sizable difference also between adoption rates of required practices that could be verified months after harvesting and practices for which this cannot be easily done. Practices that could be verified in the future were adopted almost twice as frequently as the practices that could not (e.g., hunting control).

Spearman rank correlation coefficients between adoption and the perceived contribution of the practice to ecological sustainability or to economic profitability had the expected positive sign but did not emerge as statistically significant.

Variability in adoption behavior across firms

Data also revealed that adoption behavior varied across firms, with certain operators adopting a given practice while others did not. To inquire into the possible reasons for this variability we looked into the characteristics of adopters versus non adopters. As mentioned above, we tested the significance of the difference between the mean variables of the two groups (adopters and non-adopters) using a t-test and assuming equal variances.

We ran these tests on two practices: directional felling and monitoring forest growth. These two practices were selected because they both had a balanced proportion of adopters versus non-adopters[5] and represented practices treated differently by the law. Directional felling is a critical element of RIL and is mentioned in Bolivian regulations only as a recommendation. Monitoring forest growth allows managers to learn how fast trees of different species are growing. As such, it is an essential piece of information to ensure sustainable harvest levels. In Bolivia, monitoring forest growth through the establishment of permanent plots is mandated by regulation. The differences between adopters and non-adopters of these two practices are reported in Table 5.

Overall, these results largely confirm the hypotheses and observations made in previous studies. Most of the signs are as expected. Adopters appear to be operators that have been in the forestry business for a longer time (YRS), have larger concessions (HACON), harvest and process larger volumes (VOL) and utilize a wider set of species (NSP). They tend to be located closer to markets (in the department of Santa Cruz as opposed to Pando), have received more technical assistance (TA), have trained their employees (TRAIN), and have made other investments in the past, either in their industry or in forest management operations (INVEST).

Adopters of directional felling have relatively higher abundance of high value species such as mahogany (*Swietenia macrophylla*), cedar (*Cedrela odorata*) and 'roble' (*Amburana cearensis*). This result was expected, as one would intuitively assume that a higher density of high value species would lead to more careful harvesting. Adopters of directional felling also perceive the practice as economically advantageous and more of them have received technical assistance (TA) as compared to their counterparts (60% v. 25%). Adopters of monitoring forest growth harvest larger volumes, produce larger amounts of sawnwood and utilize a wider set of species (8.2 instead of 4.8). These variables probably correlate with each other, since larger processing outputs make the marketing of lesser-known species (LKS) more feasible. These results suggest that a wider utilization of LKS is associated with the adoption of monitoring, since the growth and regeneration pattern of LKS is still largely unknown. Adopters also are closer to markets than non-adopters (the average concession of non-adopters is 440-510 Km further from the port than that of adopters).

A surprising result of this analysis was that adopters consider both practices (directional felling and monitoring growth) more important for sustainability (SUST) than do their counterparts. When asked whether these practices hinder or enhance ecological sustainability, both groups responded with an average mark above 3 (the middle point on a 1-5 scale) but adopters gave significantly higher scores. This information acquires even more importance when we consider that changes in forest management are usually implemented following the initiative of the owner (INIT2), not the opinion of the forester. The decision to adopt monitoring was not taken on economic grounds, since both adopters and non-adopters considered this practice to be unprofitable (the average score was less than 3 for both groups). None of the non-adopters were certified while about 30% of the adopters were (CERTIF).

Also surprising is the fact that enforcement pressure, measured in number of months since last inspection, appears to be higher for non-adopters (they have been inspected more recently). This information could be interpreted as more stringent enforcement on less well-managed concessions, or that earlier inspection bore fruits. In any event, the difference between adopters and non-adopters was not significant.

In the probit analysis, the variables that appeared to most strongly influence the adoption decision were SUST, the perception of the effect of the practice on ecological sustainability, and HIGH, the scarcity of high value trees

[5] If a practice is adopted by almost all concessions, it becomes impossible to say what makes adopters different from non-adopters.

TABLE 5 *Differences between adopters and non adopters of selected SFM practices. Variables defined in Table 2*

	Directional felling		Monitoring growth	
	Nonadopter	Adopter	Nonadopter	Adopter
HACON	78 291	82 474	76 215	83 746
YRS	15.1	25.8***	16.8	23.9*
VOL	5 601	5 785	3 324	6 616*
OWN	93.1	81.7	93.5	82.9
SELL	0.37	0.40	0.33	0.41
EXP	56.8	64.1	68.33	59.18
ASERR	3 766	3 847	2 304	4 427
VAL_ADD	0.11	0.34	0.16	0.30
KMTOT	2 029	1 590*	2 120	1 609*
SCZ	0.50	0.53	0.50	0.53
PAN	0.50	0.13**	0.33	0.23
HIGH	2.25	1.73*	1.67	2.00
NSP	6.37	7.87	4.83	8.23*
TEC	2.50	2.20	3.17	2.00**
TRAIN	0.37	0.67*	0.33	0.65*
TA	0.25	0.60*	0.40	0.59
SUST	3.86	4.47*	3.00	4.41***
ECON	3.00	4.13**	2.60	2.62
INVRES	0.25	0.47	0.17	0.47
INVEST	0.75	0.93	0.67	0.94**
INIT1	0.87	0.73	0.83	0.76
INIT2	0.12	0.60**	0.17	0.53*
OPINION	3.50	4.13*	3.67	4.00
CERTIF	0.00	0.33**	0.00	0.29*
SFSUB	3.00	2.67	3.17	2.65
SFINSP	3.12	14.87	5.33	12.71

* Different from non-adopters at the 10% significance level; ** Different from non-adopters at the 5% significance level; *** Different from non-adopters at the 1% significance level; P(T<=t) one-tail

in the concession. The SUST coefficient was positive and significant in all cases, suggesting that the manager's perceptions about the impact of the practice on ecological sustainability were quite important. The HIGH coefficient was only significant in the case of directional felling. Its negative sign in the directional felling model suggests that abundance of high value species induces increased care in felling trees. The positive sign (although not significant) in the growth monitoring model suggests that scarcity of high value trees seems to promote a heightened concern for forest growth and recovery.

In both models we included the managers' subjective perceptions on the economic impact of the practice. In both cases the coefficient was not significant, although it had the expected sign (positive perceived impact is associated with a higher probability of adoption.)

We suspect that other factors significantly influence the adoption decision. However, a larger number of observations would be needed to reveal such effects through statistical analyses. In light of the number of factors interacting in the adoption decision, it was not possible to define thresholds corresponding to the inflection point for any independent variable with regards to the decision to adopt or not.

DISCUSSION AND CONCLUSION

In this paper we assessed the level of adoption of SFM practices in Bolivia and inquired into selected factors (attributes of practices and of operators) that are associated with greater or lower levels of adoption. Differences in adoption levels across practices were linked to regulation and to the perceived profitability and sustainability impacts of the practice. Differences across operators were associated with factors such as experience, technical assistance and resource scarcity. These results confirm earlier observations (e.g., Blate *et al.* 2002, Putz *et al.* 2000). A contribution of this study was the quantification of the importance of these factors, since it detected statistically significant differences between adopters and non-adopters. For example, practices that were explicitly mandated by law were adopted more than twice as often as practices that were not explicitly mandated.

The results reported in this paper rest on two important assumptions: First that each respondent answered truthfully when asked about the practices used. The second assumption is that there was a common understanding across respondents about the meaning of each individual practice. In 2003, CIFOR conducted a field assessment of harvesting operations in a subset of 11 concessions (Snook *et al.* 2006). These field evaluations were carried out during the harvesting season and consisted in the collection of data on 53 indicators linked to the adoption rate of 14 practices. While it is not possible to make a direct comparison between the responses used in this study with the data collected by Snook *et al.* (2006) we note here that the practices reported in this survey as having been adopted by most concessions (e.g., stock survey and mapping, retention of seed trees, road planning, etc.) were also found, in the field assessment, to have been adopted by most concessions. Practices reportedly adopted less (e.g., vine cutting, growth monitoring, directional felling) were found, during field evaluations, to be rarely used. We concluded that the discrepancy in the figures between the survey and the field assessment were largely due to the more rigorous methodology employed during the field assessment (Snook et al., 2006). With the above clarification, this study provides a quantitative picture of the level of adoption of sustainable forest management practices in Bolivia. It shows that adoption of sustainable forest management practices in Bolivian concessions is high.

The analyses revealed that regulation plays a critical role in promoting the adoption of these practices. This was substantiated by the high correlation between the level of adoption of a given practice and an indicator of regulatory pressure, and by the fact that, according to the data collected, no firm was adopting the census of commercial trees until the enactment of the law 1700 in 1996. Shortly after law 1700 was passed, many firms began to conform to the new regulations, and by 1998 more than 80% of firms had embraced the practice. The analysis also revealed that, contrary to our own expectations and existing literature, managers' perceptions about the sustainability impacts of their operations potentially influence the way they operate more than economic considerations. This result warrants further scrutiny and suggests an increased role for capacity building, not only pertaining to the economic desirability of RIL and other practices, but also regarding the long term consequences of logging practices for forest productivity and sustainability.

One can conclude that Bolivia's forestry reform, notably its forest law and regulations and the oversight by the *Superintendencia Forestal*, contributed to improved forest management through the adoption of forest management practices delineated in the law, and the increased awareness on the part of timber producers of the benefits of SFM practices. In light of the increasing concern with forest degradation around the world, and recognition of its negative consequences not only for forest productivity and biodiversity conservation but also for climate change, the insights from this study support the value of investments in such reform efforts, including technical support and capacity building as components of incentive systems to improve forest management. It would also be worthwhile to carry out additional quantitative studies inquiring into the factors that affect the behavior of those who manage and use tropical forests.

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