Article

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On the road through the Bolivian Amazon: A multi-level land governance analysis of deforestation

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ABSTRACT

Previous studies have shown that collective property rights offer higher flexibility than individual property and improve sustainable community-based forest management. Our case study, carried out in the Beni department of Bolivia, does not contradict this assertion, but shows that collective rights have been granted in areas where ecological contexts and market facilities were less favourable to intensive land use. Previous experiences suggest investigating political processes in order to understand the criteria according to which access rights were distributed. Based on remote sensing and on a multi-level land governance framework, our research confirms that land placed under collective rights, compared to individual property, is less affected by deforestation among Andean settlements. However, analysis of the historical process of land distribution in the area shows that the distribution of property rights is the result of a political process based on economic, spatial, and environmental strategies that are defined by multiple stakeholders. Collective titles were established in the more remote areas and distributed to communities with lower productive potentialities. Land rights are thus a secondary factor of forest cover change which results from diverse political compromises based on population distribution, accessibility, environmental perceptions, and expected production or extraction incomes.

Introduction

Changes in forest cover are often presented as following linear patterns of extension (Steininger et al., 2001; Woods, 2002). Other studies point out that forest cover dynamics are difficult to predict due to the multiplicity of both human and non-human driving forces, such as historical parameters, market influences, demography, policies and natural hazards (Woods, 2002). The combination of biophysical and social parameters is an important scope of recent research in sustainability science. Agricultural expansion, infrastructure extension and wood extraction are proximate causes of deforestation that are driven by economic, political and institutional factors (Geist and Lambin, 2002).

Scholars have also pointed out the necessity to link local patterns with broader scales – regional, national, and international – when studying deforestation and forest degradation (Reid et al., 2000). Growing attention from researchers to institutional theory has paved the way for stronger integration between multi-level governance structures, property rights and biophysical changes (Stanfield et al., 2002; Swaffield and Primdahl, 2006). Questions regarding the efficiency of land property categories (individual or collective) and appropriate governance structures are frequently asked and remain a great challenge on the way to understanding which conditions are favorable to forest sustainability. Consequently, the main purpose of the present article is to compare different institutional configurations, based on a case study in the Bolivian lowlands, and determine to what extent these configurations are significant in explaining deforestation compared to more physical drivers such as distance to road or population density. What are the main governance characteristics leading to forest sustainability, and how do they combine with land property right regimes?

Right-based approaches to forest sustainability

Although community-based forestry has increased considerably since the 1980s, private and government forests remain important and require adequate institutional arrangements (Agrawal et al., 2008). Property rights are considered critical to understanding mechanisms of deforestation, but scholars remain undecided on whether they should be individual or collective (Agrawal, 2007; Gibson et al., 2000). Comparison of land cover changes for different management regimes in Nepal shows that community forests contain the highest proportion of stable forest area, while degradation

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remains considerable in all areas (Nagendra et al., 2008). Contrary to inhabited reserves that tend to be located away from areas of high deforestation, indigenous lands stay closer to frontier expansion and are more likely preserved from deforestation despites high rates along their boundaries (Nepstad et al., 2006). In the Brazilian Amazon, the average probability of deforestation has been shown to be 7–11 times higher outside than inside indigenous land and protected areas (Ricketts et al., 2010). Do these cases suggest that deforestation is determined by ethnic factors? A comparative study of Q'eqchí and Ladino settlers on the remote agricultural frontier of northern Petén, Guatemala, denied this option, showing that the two ethnic groups shared the same productive characteristics and had almost the same impact on land cover change. However, both groups had adopted considerably more destructive agricultural practices in the settlement area than the practices they had used in their area of origin (Carr, 2004). This evidence points to settlement processes as a particular circumstance promoting deforestation, and is in line with findings from different areas of Bolivia. However, the study does not offer a clear understanding of the role played by property rights within settlements (Killeen et al., 2007, 2008).

Land use models from the Brazilian Amazon show that agents have greater incentives to degrade soil quality under a private property regime than under a common property regime (Beaumont and Walker, 1996). Land inequalities generated by the liberal laws passed in the 1980s in some Latin American countries have led to a pattern of land concentration in pastoral areas, forcing small landowners and the landless to increase pressure on forested areas (Anderson, 1990). Market-based land reform was presented as more efficient for land distribution (Deininger, 2003), but brought with it a strictly productivity-oriented concept of land, with severe ecological consequences. The necessity of clearing forests to guarantee tenure rights and credit access is a property-based problem that determines deforestation (Angelsen, 1999; Fearnside, 2001).

In some cases, however communal ownership can be subject to high levels of forest degradation as well. This is the case when local institutions are inappropriate (Perez-Verdin et al., 2009). Some interdisciplinary studies also failed to find consistent significant differences in vegetation structure or soils when comparing private and common property forests (Tucker, 1999). Forms of tenure or land titling are thus not always good predictors of sustainable management (Ludewigs et al., 2008).

More critical factors include whether the owners have decided to limit their levels of exploitation, and whether they are able to achieve their goals through monitoring and enforcement. These factors also depend on the ecological, socio-economic, and political contexts (Chhatre and Agrawal, 2008).

Complementarity in multi-level governance and political strategies

Land and resource sustainability are possible only when governance principles are established at diverse hierarchical levels (Anderies et al., 2004; Ostrom, 1990). Institutional theory makes a relevant distinction between operational and collective-choice levels (Agrawal and Ostrom, 2001; Schlager and Ostrom, 1992). The operational level determines the way people take direct advantage of land or resources, for example through extraction, production, or simple access. The collective-choice level is where decisions are made regarding the distribution of access to resources, with possible arrangements including management, exclusion, and alienation. An appropriate combination of collective-choice and operational levels is fundamental to adequate forest management (Agrawal, 2007). At national levels, for example, governments suffering from weak legitimacy showed limited capacity to support sustainable local forest governance systems (Fearnside, 2001; Ho, 2006; Palmer and Engel, 2007). Deforestation takes place when state control is difficult due to political instability or the absence of citizen participation. In contrast, democratic regimes generally correspond with better capacity to manage their forest resources in a sustainable way (Bhattarai and Hammig, 2001). At the local level, decentralized management and robust local institutions are determinant conditions for common forest sustainability (Agrawal and Ostrom, 2001; Bottazzi, 2009; Gibson et al., 2000).

Nevertheless, many environmental governance processes are matters of personal interests and political compromise rather than of ecological sustainability (Paavola, 2006). Institutions and ecosystems are not adaptive co-variables and multiple rationalities have to be taken in consideration during same governance processes (Bromley, 2007). The forest, as a socially perceived reality, is subject to contrasting ethical and technical representations on the part of policymakers (Hardin, 2005). Many countries base their forest policy development process on a top-down instrumental rationality rather than shaping it as a communicative and iterative process (Schanz, 2002). Historical studies carried out in the Brazilian Amazon have shown that current land use and land cover change has been strongly influenced by the successive and partly contradictory national policies, which allocated forest ecosystems to specific economic uses such as cattle ranching and soy bean production. Development of the road infrastructure, agricultural subsidies, tax reductions on national investments, and facilitated access to land and credit for settlers have been used as instruments to reshape land cover for macro-economic purposes (Walker et al., 2009).

Political strategies affect irreversibly the critical phases of forest planning, and financial interests drive non-coherent land allocation relative to ecosystem sustainability. According to Tucker et al. (2007), more abundant and productive forests with resources available for human use are important incentives for investing in strong institutions. Conversely, land units with low productivity or fragile ecosystems tend to have inadequate legal support for their forest management, regardless of whether they are private or common. In some cases, strong institutions are associated with either private or common property depending on the historical context and the economic potentialities of the forest ecosystem (Tucker et al., 2007). In other words, coherence between land regimes and forest regimes is difficult to find, especially when associated with separate legislation as it is the case in Bolivia (Contreras-Hermosilla and Vargas Ríos, 2002). Additionally, agriculture and forestry policies, which in theory should not be separated, lack connectivity at different levels of decision-making. Users are thus forced to make difficult choices between ecological and economic sustainability and short-term financial benefits.

More interdisciplinary local studies in Bolivia

In Bolivia, deforestation during the last decades progressed at a rate of around 270,000 ha per year, which is moderate in comparison to other Amazonian countries (FAO, 2010). However, differences between departments are considerable (Steininger et al., 2001). In the Bolivian lowlands, annual rates of land-cover change increased from about 400 km^2 per year in the 1960s to about 2900 km^2 per year in the recent period of 2001–2004. This marked increase is explained by three factors: (i) immigration of peasants who practice subsistence agriculture; (ii) mechanized agriculture for row crops; and (iii) pasture establishment for livestock production (Killeen et al., 2007). Like in the rest of Latin America, regional differences can also be explained by several geographical and economic factors, including road infrastructure, productive allocation of parcels, urban proximity, and expansion of commercial agriculture. Market-oriented studies of deforestation and macro-economic models have shown for other areas how rational patterns of household consumption and production affect deforestation

(Anderson, 1990; Beaumont and Walker, 1996; Fearnside, 2001).

Specifically for Bolivia it was shown that transition from the import-substitution industrialization model initiated in the 1950s to neoliberalism during the 1980s had a significant impact on deforestation, causing it to increase (Pacheco, 2006). Since the election of President Evo Morales, leader of the MAS (movement toward socialism) political party in 2005, very few decisions have been made regarding the forest regime (Pacheco et al., 2010). Most measures taken by his government have focused on land redistribution to enhance small farmers' access to land. A recent study near the city of Santa Cruz shows that Evo Morales' presidency has been accompanied by a constant increase of the deforestation rate (Redo et al., 2011). A key feature of Morales' 2006 land reform[2] is the importance given to the older legal principle of 'social and economic function of land (SEF)', first established during the 1950s revolution and formalized in the INRA law of 1996. The principle requires that owners or possessors demonstrate the concrete usefulness of the land they own in order to preserve their rights on it. Although the INRA law of 1996 (Art. II) includes 'conservation and protection of biodiversity' as a possible SEF, users and state technical services staff do not really understand its application. In practice, the SEF principle encouraged most land and forest users to accelerate forest clearance because deforestation is still considered the most evident proof of land use (Redo et al., 2011: 239).

Unfortunately, most studies aimed at explaining deforestation drivers in Bolivia remain based on macro-level regional or national data and thus face difficulties in addressing the complexity of local mechanisms and considering simultaneously biophysical as well as socio-economic data. In these studies, deforestation is mostly explained by the non-adaptation of national norms; however, there is a lack of more detailed observations in order to understand in concrete terms how these norms are embedded in the multiplicity of parameters that determine local practices. In the Bolivian context there is a need for more studies on the complex spatial, economic, and institutional parameters of land-use, land-use change and forestry (LULUCF) in order to differentiate more clearly between proxy and underlying drivers of deforestation as done in other cases (Lorena and Lambin, 2009; Ludewigs et al., 2008; Merry et al., 2002).

The study area: a historical process of land distribution

The Pilón Lajas Biosphere Reserve and Indigenous Territory (PLR) was traditionally occupied by several indigenous groups such as the Tsimane', Mosetene, Esse Ejja, and Tacana. After the collapse of the tin mine industry in the highlands, during the 1970s and 1980s, the military government implemented a large-scale land settlement program which brought in thousands of Andean Quechua and Aymara mainly from the city of Potosi. The National Institute of Colonisation (NIC), which was in charge of land administration, distributed communal lands, as well as big and small properties on both sides of the road from Yucumo to Rurrenabaque (Fig. 1), with small properties organized in so-called "colonies" – groups of 30–40 individual plots of 25 ha. Each category was supposed to fulfill a specific function and was intended for a specific type of owners. In order to secure their rights, owners had to prove that they actually used their land; this was done primarily by clearing the forest. After 2 years, the NIC could grant permanent individual or collective titles on the basis of physical proof of land use, which was simultaneously also proof of the so called "socio-economic function of the land" (SEF). This concept had been introduced during the 1953 Bolivian land reform. It states that all land owners must prove the social and economic output of their use of the land.

In 1983, the UDP (*Unión Democrática Popular*) national party succeeded the military junta and began to promote local empowerment through labor unions. The Unique Confederation of Rural Laborers of Bolivia (CSUTCB) took control of the NIC, and the local peasant union – the Federation of Agro-ecological Producers of Yucumo (FEPAY) – became the main manager of land within the settlement area. During this process, the more productive land, which had first been distributed to cooperatives and enterprises, was confiscated by the workers and progressively split up into individual properties. The plots closest to the road where the first to be converted into groups of individual properties, while more remote plots retained their communal status. In the course of the land regularization campaign launched in 1996, part of the remaining communal land was converted into groups of individual parcels – so-called "colonies" – as well. Ever since, the migrant conception of land rights has remained associated with forest clearance as a proof of "real work". In order to preserve their land titles, individuals are required to constantly prove its usefulness for social and economic development.

A small portion of the indigenous population composed of Tsimane' and Mostene who had lived in this area from time immemorial was included in the Andean settlement units. However, most of them had to move west, to more remote areas along the Quiquibey River, or east, towards the Maniqui River, where the main Tsimane' settlements were located. Over the next decade, the situation remained extremely difficult for these indigenous people. Then, a nationwide indigenous mobilization took place. In 1990, these local communities created a Regional Tsimane' and Mosetene Council (RTMC) and, with the support of several non-indigenous, primarily conservation organizations, they decided to claim collective land in the more remote areas where the Tsimane' used to hunt and fish. Two years later, in 1992, the Bolivian government declared the Pilón Lajas Biosphere Reserve and Indigenous Territory (PLR) on 400,000 ha of land located 5 km west of the road (Fig. 1). Then, with the INRA (National Institute of Agrarian Reform) land reform of 1996, all indigenous territories of Bolivia received the formal title of Communal Land of Origin (TCO), and indigenous entities were given more autonomy to manage forest resources.

Materials and methods

The aim of this study was to explain land use and land cover change characteristics by relating remote sensing mapping with a multi-level governance analysis. We tried to understand how individual and collective land categories as well as governance structures correlate with actual deforestation and how these different categories are embedded in complex historical governance systems. We decided to focus our study on a twenty-three-year period from the arrival of migrants in 1983 to the end of the neoliberal regime in 2006 because this period is significant with regard to the intent to implement productive forestry and agrarian regimes in Bolivia and has not yet been sufficiently evaluated.

The field analysis was carried out from May to July 2007 in the PLR buffer zone located in the Amazonian department of Beni. A preliminary survey was carried out first to identify the land categories of the area. Each concession area was digitized based on maps from the Bolivian National Institute of Agrarian Reform (INRA). Overlaying vector and raster data produced a comparative deforestation analysis according to the category of property rights in each settlement unit ($n = 77$) considered separately from their formal property right categories: 1 = community; 2 = small property; 3 = big property. For each settlement unit we computed its forest cover, its annual deforestation rate, its average fragmentation

[2] Law n°3545 of November 28, 2006.

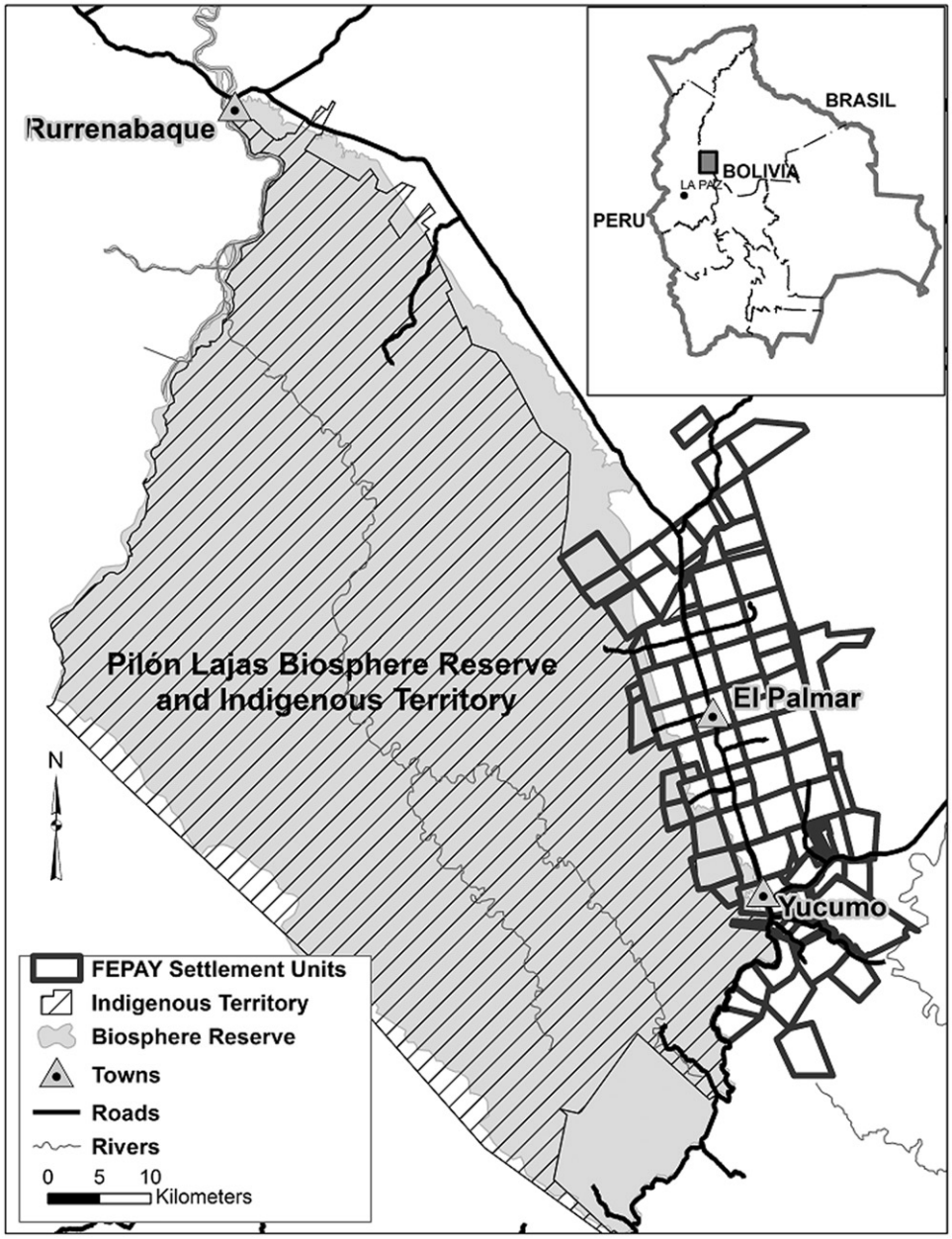

Fig. 1. Study area. The Biosphere Reserve and Indigenous Territory of Pilón Lajas is located 350 km north of La Paz in the outer limits between the western cordillera of the Andes and the plains of the Beni department. It is situated between two bio-geographical subregions: montane cloud forests (*Yungas*) and the Madeira Humid Forest. The altitude within the reserve ranges between 300 and 2000 m. The climate is characterized by an average temperature of 24.9 °C as well as by constant and high precipitation with an annual average of 2444 mm, variation range from 1500 mm to 3500 mm, and a dry period between June and July (300 mm). The study area is located in the buffer zone of the reserve, on the road between Yucumo and Rurrenabaque.

LSI, its size, its distance to road and to town, and its population density in 2001. Multi-level governance analysis combined with property rights regime analysis (Campbell et al., 2001; Schlager and Ostrom, 1992) was applied using semi-structured interviews with community members ($n = 14$), labor union members ($n = 11$), NGO representatives ($n = 8$), protected area agents ($n = 8$), colonist leaders ($n = 8$), national land administration agents ($n = 5$), and national forest administration agents ($n = 5$). Each informant was asked about his or her perceptions in three main dimensions: the history of settlement unit establishment; the units' political organization; and the land tenure modalities.

For mapping land cover we used Landsat-TM images (spatial resolution: 30 m, reference coordinates: WRS-2 Path = 001/Row = 070) taken in four different years (two TM images dated 1987-08-02 and 1993-08-02, two ETM+ images dated 2001-06-29 and 2006-08-23). The images were downloaded free of charge from the USGS website (http://glovis.usgs.gov/). For visualization purposes, several color composite images were first created for each year (RGB combinations of TM bands 4-5-3, 7-4-3, 3-2-1). An unsupervised classification (ISODATA algorithm) was then performed on the Landsat images. The 20 resulting classes were visually inspected in order to label them and to evaluate their potential reclassification into forest and non-forest categories. Spectral signatures of the original TM bands were extracted based on the unsupervised classes and were used to classify the original TM images (using the maximum likelihood classification algorithm). The resulting maps were finally aggregated into two classes (forest and non-forest). The final outputs are binary maps depicting the state of forest cover in

the entire buffer zone of the reserve for four dates between 1987 and 2006.

An analysis of fragmentation was performed on the forest/non-forest maps using the Fragstats software. An indicator called Landscape Shape Index (LSI) provides a simple measure of forest clumpiness (compactness): "LSI = 1 when the landscape consists of a single square or maximally compact (i.e., almost square) patch of the corresponding type; LSI increases without limit as the patch type becomes more disaggregated (i.e., the length of edge within the landscape of the corresponding patch type increases)" (Fragstats Manual). Patch size does not influence LSI, i.e. two forest patches with the same shape but different areas will have the same LSI value.

Results

Deforestation within the buffer zone of the Pilón Lajas Reserve

Deforestation is not perceptible in the area of the PLR outside the settlement area and can be considered as almost non-significant. However, as has been shown in previous studies, forest degradation had been significant especially during the presence of logging companies in the early 1990s, before conservationist advocacy drove them out of the forests (WCS, 2005). By contrast, the buffer zone, where the migrant settlement process has taken place, is clearly affected. From the arrival of the first migrants in 1983 until 2006, 30.8% of the studied area (62,000 ha) has been cleared (Fig. 2). The deforestation rate increased from an annual average of 1.0% during 1987–1993 to 1.5% during 1993–2001 and then decreased again during 2001–2006 (1.2%). This rate thus remains higher than the national average in Bolivia and indicates that the area is significant as a settlement zone with the purpose of intensive production (Steininger et al., 2001).

A second level of analysis presents deforestation rates relative to land categories owned by FEPAY's Andean migrants in the settlement area of the PLR (buffer zone). During the first period (1980s), Andean settlers were still few in number; most farms were located around urban centers and belonged to large-scale private owners from an earlier stage of migration, explaining the highest proportion of deforestation in this category until the mid-1990s. Since then, small properties, which are characterized by the highest annual deforestation rates, have surpassed all other categories in number and in terms of area coverage.

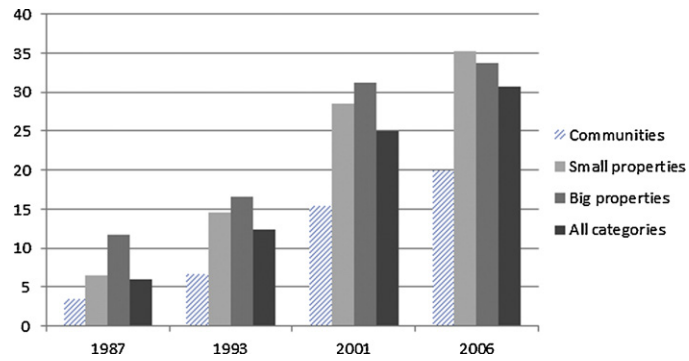

Fig. 2. Average deforested area (in % of total area) in settlement units, by type of property.

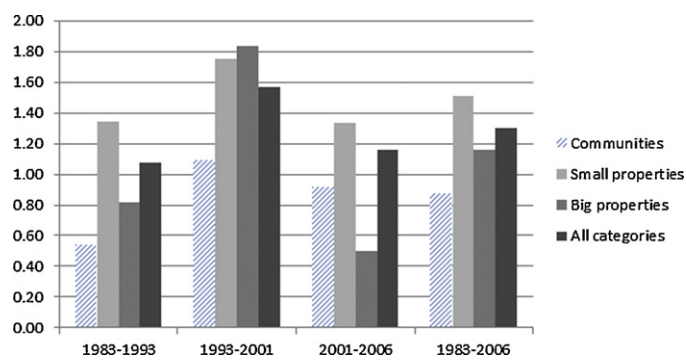

Fig. 3. Average annual deforestation rate (in % of total area) in settlement units, by period and type of property.

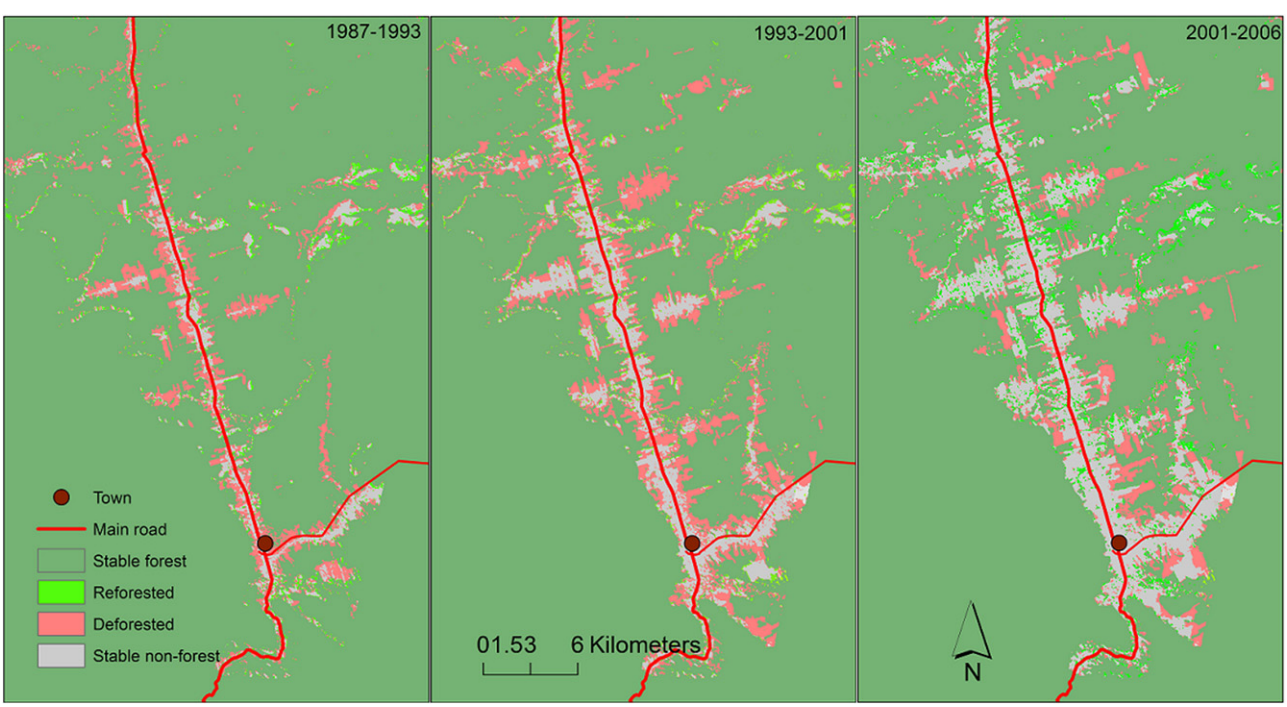

Fig. 4. Map of changes in forest cover.

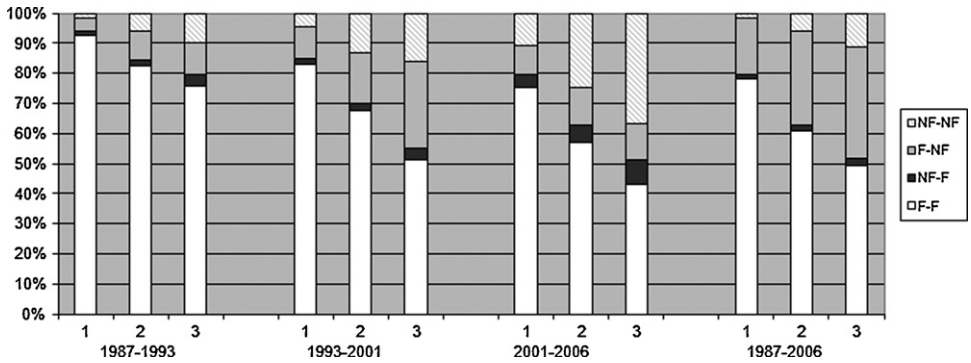

Fig. 5. Forest cover changes (in % of total area) by type of property (1 = Community; 2 = Small property; 3 = Big property; NF = Non-forest; F = Forest).

Table 1
Main variables by property types.[a]

Type	Number of settlements	Mean area (ha)	Total area (ha)	No data (ha)	Deforested by type (%)	Annual deforestation rate 87–06 (%)	Population density (pop/ha)	Mean distance to road (km)	Mean distance to town (km)
Community	20	989	19,782	2078	20.0	0.9	0.07	6.3	25.4
Small property	36	1152	41,474	1484	35.2	1.5	0.09	3.6	19.9
Big property	21	256	5370	466	33.8	1.2	0.15	4.5	11.4
All categories	77	865	66,626	4028	30.8	1.3	0.1	4.5	19.0

[a] *Number of settlements* is the total number of settlements in each category. *Mean area (ha)* is the total area (in hectares) in each category divided by the number of settlements of the given category. *Total area (ha)* is the sum of the settlements' areas in each category. *No data* represents the area outside the Landsat image. *Deforested by type (%)* is the deforested area in % of total category area. *Annual deforestation rate 87–06 (%)* is the annual deforestation rate in %. *Population density (pop/ha)* is the number of users related to settlement by hectare (owners, family members). *Mean distance to road (km)* is the mean distance from settlements' pixels to the road (Rurrenabaque-Yucumo). *Mean distance to town (km)* is the mean distance from settlements' pixels to the town (Yucumo).

As shown in Fig. 3, the ranking of average annual deforestation rates by property type (1983–2006) is as follows, from the lowest to the highest: (a) communal land (0.9%), (b) big properties (1.2%), and (c) small properties (1.5%). This means that the more land is fragmented by individual ownership, the higher the deforestation rate.

The total annual deforestation rate shows considerable differences according to the periods or phases analyzed as well as according to concession types. It decreases significantly during the period of 2001–2006, but the reforestation rate remains quite low, which explains why the proportion of stable non-forest area remains considerable (Figs. 4 and 5).

Small properties are also twice as close to the road as is communal land (Table 1). As proved by the linear regression presented in Table 2, proximity to the road is a determinant factor of deforestation. As distance to the road increases, so does the proportion of communal land and big private properties. Conversely, the more easily property units are accessible via the road, the more they are split into individual parcels. Properties with low productive characteristics (far from the road and with high slope gradient) are held under communal titles as strategic "forest reserves" that are gradually transformed and split into individual titles whenever land regularization offers an opportunity. The more land gains market and productive value, the more users try to convert it into individual titles. Land architecture is thus also important for understanding differences between individual and common property land on forest resource appropriation (Turner, 2010). As expected, fragmentation increases with time (Fig. 6) and is clearly higher in small properties than in other categories. Communalization of certain forms of production such as grazing or rice cultivation among settlement members contributes to the concentration of patches of deforestation on communal lands and big properties.

When considering all property types simultaneously, population density is almost not statistically significant as an explanation for variations in deforestation. Big properties have the highest population density. This is certainly due to the wage laborers living there and the relatively limited area allowed for units in this category (mean = 256 ha) in the studied area. Intensification of agricultural practices with the use of pesticides and mechanization on large farms could have been considered as well to explain lower deforestation rates, but we lacked the necessary empirical data. When running the regression excluding big properties, the correlation between population density and def/ha became statistically significant (sig = 0.042) and reasonably correlated (Beta = 0.203; R(zero-order) = 0.397). These results show that "colonies" (settlements with a number of small properties) are the most common form of land titling. They are mostly located close to the road and account for the largest part of the area's population. Each of the previous criteria explain the highest rate of deforestation on small properties.

Table 2
Linear regression showing the effects of population density, distance to road, distance to town, and property type on deforestation. The dependent variable (def/ha) is the total area deforested between 1987 and 2006 per hectare in each settlement (the regression is significant at 0.05).

	B	Std. error	Beta	*t*	Sig.	Corr. zero-order	Corr. partial	Corr. part
(Constant)	0.607	0.092		6.617	0			
Pop. density (inh./ha)	0.635	0.353	0.147	1.799	0.076	0.258	0.207	0.14
Dist. to road (km)	−0.027	0.007	−0.319	−3.91	0.01	−0.478	−0.419	−0.305
Dist. to town (km)	−0.011	0.002	−0.532	−6.05	0	−0.66	−0.581	−0.473
Type	0.019	0.032	0.054	0.601	0.55	0.387	0.071	0.047

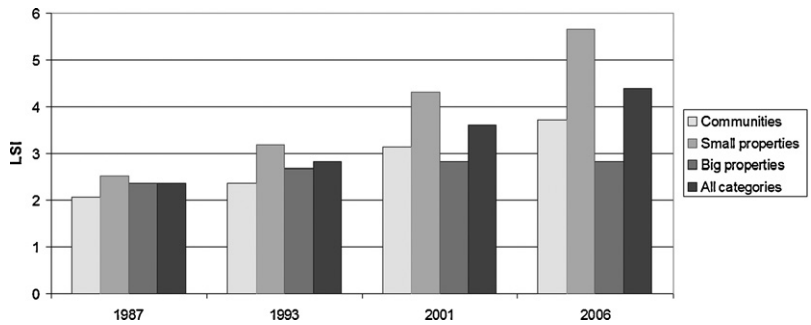

Fig. 6. Average Landscape Shape Index (LSI) of settlement units, by type of property.

Multi-level governance and land categories

State services level

Since the implementation of the PLR in 1992, as well as of the TCO in 1996 in the same area, the PLR has two legal authorities. On the one hand, the local reserve administration (LRA) based in the locality of Rurrenabaque reports directly to the National Protected Area Service as a decentralized state structure. On the other hand, approximately the same area was placed under the responsibility of the RTMC. Initially, the main task of the RTMC was to defend the indigenous communities' interests during the long process of land regularization and to facilitate the implementation of public infrastructure by the municipalities (Bottazzi, 2008, 2009). The RTMC is a decentralized structure but still remains dependent on the LRA through a co-management compromise. This situation of double legitimacy was a source of many conflicts during the first year of implementation and remains complicated even in the present due to the differences in direct interests between the LRA and the RTMC. The RTMC's primary function is to protect the land rights of indigenous communities against external pressure rather than to manage forest resources. This organization is therefore more of a service provider for communities than a public authority, and it is characterized by a complete absence of regulations and sanctions, which leads to an incapacity to monitor forest use in the PLR (Table 3).

On the part of the state, PLR forest is managed by two organizations: the LRA and the Forest Department. In the first, decisions are made with regard to conservation, and development plans are updated every four years by mandated experts in a relatively participatory process involving the local communities. A protection corps composed of 15 indigenous and non-indigenous persons is in charge of monitoring and signaling illegal activities within the reserve. The Forest Department's local units are also mandated to monitor forest activities in the protected areas, which are restricted to basic extraction needs. Cattle rearing and agriculture are not strictly limited. In cases of inappropriate use of the protected area, extracted products are confiscated and fees are imposed. Since the implementation of the PLR in 1992, large logging companies ceased their activities and were completely removed from the area; however, small-scale illegal logging still occurs and remains an important form of use for the indigenous populations.

Decentralization level

Forest management has been decentralized throughout Bolivia since the INRA law came into force in 1996 (Pacheco, 2002). Forest municipal units are supposed to supervise the distribution of forest clearing patents to local owners outside the national forest concession and the TCO. Such a patent authorizes its owner to make commercial use of trees extracted on private parcels. However, this rule is not applied given that the transaction costs for each stakeholder to reach the town and complete the formal process are too high in comparison with the low risk of being caught and subsequently charged with illegal activity. Moreover, most valuable timber easily finds access to illegal markets and can be sold without any authorization. Decentralized forest management is thus very weak in buffer area of the PLR.

Moreover, in the Andean settlement area, the Forest Department and Protected Areas Administration have completely lost their legitimacy. The settlers' federation, FEPAY, exerted pressure for local settlement units to be completely released from any kind of forest control during violent conflicts in 2003. In principle, FEPAY plays roughly the same role for settlers as the Indigenous Council does for Tsimane' and Mosetene. It aims to defend their property rights against external agents rather than to help define norms regarding natural resource management. The difference is made at the level of the peasant union, where some norms on resource extraction can be defined. Control of land distribution remains strong on the part of the union authorities, especially regarding the obligation for owners to be present during meetings, to participate in collective work and to prove that they actually use their land as defined in the agrarian law. Decisions are voted on by a

Table 3
Relation between land categories and multi-level governance structures.

	TCO/protected area	Communal land	Big property	Small property
Forest department	Strict control Sustainable forest management		Requires a patent to extract timber product	
Local reserve administr.	Strict conservation Difficult monitoring			
Municipality			Unsuccessful control of forest clearance, patents and taxes collection	
Settler federation		No regulation of forest extraction but defence of individual rights to land use		
Indigenous council	External exclusion Weak control			
Syndicate		Collective arrangements on resource use	No limitation on resource withdrawal	
Local units (household, community, enterprise, cooperatives)	Access and withdrawal rights for resources, inalienability, non-sizeability and non-mortgageability		Alienation	Non-sizeability but possibility to sell and mortgage informally

majority, and political responsibilities (*cargos*) rotate among all owners according to a regular cycle. If an owner's behavior is considered unacceptable by the other members of union, he can be removed and his land given to another user, even if the owner has an individual title certified by the Bolivian State. During these reunions, ecological rules are of little interest, and owners' practices are largely based on individual strategies to maximize economic income.

Local users level

Modalities of resource distribution are agreed directly between users, especially on communal land and on middle properties, where the absence of boundaries between individual agents leads to more complex arrangements. On individual parcels (colonies and big properties), no limitations on resource withdrawal are imposed as each user is a single land owner and boundaries are clearly defined. Production schemes follow a linear process which starts with rice, followed by semi-permanent crops – mainly cassava and plantains – and finally fodder for cattle-rearing, which leads to permanent non-forest land cover. On communal parcels, cattle are concentrated in a collective herd and crops are produced from slash-and-burn agriculture, while the common forest is managed by collective rules. During the last decade, users received small credits based on their land titles. Most of the credits were invested in cattle-rearing, and the parcels became a store of financial resources rather than a productive space. Absence of ecological norms on forested land, fragmentation of properties, and the development of cattle-rearing on very fragile soil are the main factors contributing to deforestation in the settlement area.

Discussion

Micro-economic drivers (at the household level) are certainly direct drivers of resource use and land cover change, but need to be related to multi-level governance, which explains how many categories of land use have been distributed and how those categories are controlled by several political entities (Agrawal, 2007; Ostrom, 1990). Land governance in the area does not follow a top-down model but rather an adaptive or polycentric model that allows multiple stakeholders to influence land allocation depending on their sectoral interests (Termeer et al., 2010). The land regime and land distribution is the result of mainly Andean settlers' influence on national and regional policies. It is obvious that the inherent characteristics of individual property rights pave the way for an extreme fragmentation of this space, which entails a linear evolution of deforestation under the pressure of cattle-rearing (Beaumont and Walker, 1996). On individual parcels, each user directly affects himself in the case of overexploitation, but the possibility to sell or rent his parcel for pastoral use is not an incentive to limit overexploitation (Anderson, 1990). Resource withdrawal rights on collective land make each user accountable for an overuse of resources and prevent the land from being split. Users are obliged to define collective norms to limit over-extraction and to try to prevent the complete depletion of forest resources. Inalienability, non-sizeability, and non-mortgageability of common property are supplementary incentives to claim conversion of collective land into individual plots for individual interests. This increases the impact level of human activity especially in the context of extreme splitting of agricultural sectors and market-based individual strategies.

As demonstrated by means of remote sensing analysis, collective land appropriation corresponds to a lower rate of deforestation in most situations we observed in the buffer zone of the PLR. However, this difference is not the exclusive product of a formal land tenure commodity. Local institutions are strongly influenced by macroeconomic and political drivers and simply confirm already existing modalities of resource access. The more an area of land is close to market opportunities, the more users try to secure this monetary value by means of private property titles. Consequently, it is not the formal land title that determines the degree of deforestation, but rather the relationship between owners and the spatial constraints that are then "endorsed" by legal categories perceived as being adequate for this relationship.

Like in Brazil and in Guatemala, cattle ranching accounts for the greatest part of clearing activities; however, institutional factors are preconditions for these activities, such as the fact that clearing is required to establish land claims or get access to credit (Carr, 2005, 2008; Fearnside, 2001, 2005; Killeen et al., 2008). The presence of large-scale livestock production despite its low productivity is a convincing indicator of the fact that land is owned mainly for speculative purposes. Cattle production is maintained because it requires a fairly low labor input and is thus well suited to complement the speculative nature of land acquisition (Carrero and Fearnside, 2011; Kaimowitz and Faminow, 2002). Lot turnover in colonization settlements involves the same mechanism for lot consolidation and increases deforestation and frontier expansion (Ludewigs et al., 2008, p. 1350). Forest clearance as a requirement for securing land rights has been a widespread practice in the Latin American tropical forests since the arrival of the first upland migrants in the 1980s. In Bolivia, the so called "socio-economic function of the land" has been a legal prerequisite (laws of 1953, 1996 and 2006) intended to lead to a more equitable land distribution based on observable work on land. This norm led to a socially-based conception of land legitimacy that does not include any considerations of environmental sustainability.

Population density is another factor directly associated with the land regime. The higher the population density, the more suitable an individual property right system is to reduce transaction costs between users. In addition, a very low level of population density in indigenous and communal areas explains the higher population pressure on individual land (Anderson, 1990; Beaumont and Walker, 1996) as it is the case in the settlement area. Road proximity is a productive potentiality that determines the type of property selected by migrants to optimize the relationship between the number of users concerned and the productive parcel. The closer parcels are to the road, the more single private properties (colonies) have been selected by stakeholders to secure their land rights.

Our case study shows clear discrepancies between land categories in terms of multi-level governance. Because of the high political capacity of the migrant federation (FEPAY), most formal state service structures are not concerned with monitoring forest use in the colonization area. Accordingly, forest use control takes place in the most remote areas where indigenous (Tsimane' and Mosetene) communities have been titled with large areas of land. This entails an institutional segmentation between land categories and state control capacity. In our case, the stronger the local institutions are, the less sustainable the forest management is: strong local institutions associated with illegal timber market mechanisms are sufficiently powerful to completely thwart the establishment of an important part of the forest regime in the buffer zone of the PLR. The strongest institutions are potentially the most suitable to facilitate sustainable forest management (Tucker et al., 2007) but cannot guarantee the sustainability of the forest ecosystem if political entities do not impose explicit limitations on resource use. Migrant peasant unions are organized in very strong institutions and are certainly located in the more productive areas, yet their management does not lead to a greater sustainability. Property rights themselves are thus not sufficient explanations for understanding deforestation; the main driver is always the users' willingness to limit or modify their production for the benefit of further use, regardless of whether the property regime is individual or collective. As shown

by Tucker et al. (2007), patterns of land use, and sustainability needs to be placed in the context of the long-term historical processes that establish complex relationships between humans and ecosystems.

Conclusions

A multi-level land governance analysis offers a powerful overview of the main rationalities determining local institutions and their links to sustainability. In our case, it shows that the distribution of property rights is not a direct driver of land degradation, but is the result of a political choice based on contrasting productivist and conservationist expectations. Here, the political activism for land rights shapes the construction of "environmental subjects" (Agrawal, 2005). On the one hand, Andean settlement and land reform policies have been established on the basis of a productivity-oriented conception of land legitimacy, where land distribution depends on the presumed productive capacity of socio-economic units. On the other hand, indigenous collective land titling and protected areas have been based on a strict conservationist policy, whereas the forest and protected areas department is hardly maintaining its monitoring capacities. These dichotomies lead to a strong "institutional segmentation" (Bottazzi, 2008, 2009) along ethnical boundaries as well as to a clear discrepancy between land and resource institutions (Contreras-Hermosilla and Vargas Ríos, 2002). This segmentation is clearly reflected in land cover change, which is shaped by the spatial limits of differentiated administrative responsibilities. A more integrated concept of sustainability with regard to economic activities would require a redefinition of the Bolivian land and resource regimes. To illustrate this proposition, the important principle of "socio-economic function of the land" could be changed to a "socio-ecological function of the land" including sustainability principles as fundamental mechanisms of land legitimacy. This change would create incentives for direct users to find sustainable alternatives. Criteria for evaluating land and forest use need to be redefined on the basis of growing economic opportunities that have begun to be developed in the Bolivian Amazon in recent years, such as ecotourism, non-timber forest products, or agroforestry.

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