Land-Use Change in Chiquitanía (Santa Cruz, Bolivia): indigenous lands, private property, and the failure of governance on the agricultural frontier

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Abstract

A 40-year history of land-use change in two municipalities in Santa Cruz (Bolivia) shows how deforestation and savanna conversion has increased as the region has become incorporated into the national economy. Deforestation was greater than savanna conversion in both relative and absolute terms; land-use change was more prevalent in areas with greater road access and which closer to urban markets and local population centers. Private landholders converted more than 125,500 ha compared to only 4,800 ha by indigenous communities; deforestation was minimal in both forest concessions and indigenous forest reserves. Regulatory and legal reforms enacted in the mid 1990s had no impact on slowing deforestation on lands zoned for forest management or protected as ecological easements. A spike in the rates of land-use change coincided with a governmental program to resolve overlapping land titles; evidence that such programs constitute a perverse incentive to deforest land so as to establish evidence ownership. Forest royalties resulting from land-use change went largely uncollected, representing annual losses in excess of $250,000 to local government and regulatory authorities. National economic growth was shown to impact land-use change and the only periods were the rate of land-use change actually decreased coincided with severe economic recession in Bolivia.

Keywords: land-use change, deforestation, indigenous lands, tropical forest, governance, land-use zoning, land tenure, economic growth

Introduction

Chiquitanía is located in the Department of Santa Cruz in eastern lowland Bolivia and is situated across the divide separating the Amazon and River Plate drainage systems. Jesuit missionaries first colonized the area approximately 300 years ago and, although the region has a long history of human habitation, it contains a well-preserved mosaic of savanna and forest landscapes. Forest habitats are composed of a closed canopy deciduous forest, which are dominated by extremely hard-wooded species with a large potential economic value in international timber markets (Killeen et al 1998, Mostacedo et al 2000, Jardim et al 2002). However, the forests and savannas of Chiquitania are coming under increasing threat from land-use change due, in part, to regional integration initiatives in the energy and transport sectors (PRIME 2000). Recently recognized as a unique ecoregion, the Chiquitano Dry Forest, has become the focus of conservation initiatives because it is one of the best-preserved dry forest ecosystems in the world (Olsen et al 2000; Ibisch et al 2003).

The Department of Santa Cruz has experienced some of the greatest rates of land-use change in all of Latin America. The region subjected to greatest deforestation is the fertile alluvial plain situated to the east of the Andes where the cultivation of soy and other crops has expanded exponentially since the early 1990s (Pacheco 1998, Steininger et al 2000a, 200b, Mertens et al.

2000, Kaimowitz et al 2000). Chiquitania is situated on the Brazilian Shield immediately east of the alluvial plain and is characterized by a radically different landscape that offers neither the edaphic nor topographic conditions necessary for mechanized agriculture. Nonetheless, it will experience an increasing proportion of future land-use change over the next several decades, because arable land on the alluvial plain is limited in the North due to poor drainage and by an arid climate in the South (Cochrane et al 2005). In contrast, the rolling hills of Chiquitania offer an attractive investment opportunity for cattle ranching operations, which can be profitable and sustainable over both the medium- and long-term (Kaimowitz et al 2004; Margolis 2003). Improved transport infrastructure in the region and the eradication of hoof and mouth disease has made cattle raising operations much more profitable (PRIME 2001; Vides et al. 200x).

Although future land-use change in Chiquitania is inevitable, the extent and rate of change will be influenced by the ability of the Bolivian state to limit deforestation on fragile lands and to promote the sustainable use of forest resources. Recent governments have implemented a series of political, economic and regulatory reforms that have been supported by multilateral institutions as part of a systematic effort to promote sustainable development and participatory democracy.

Land-Use Planning: Starting in 1990, the World Bank and the German government sponsored a 5-year project to evaluate and map the renewable natural resources of Santa Cruz as part of a integrated initiative to promote mechanized agriculture, commodity exports and improve economic growth (Baudoin, et al. 1997). The natural resource component developed a series of studies that were used to formulate a spatially explicit set of recommendations on land-use that were based soil capacity, prior use, social demands, and environmental factors (PLUS 1996). These recommendations were eventually adopted as a Ministerial Resolution that created a regulatory framework to govern land use and land-use change. One of the primary purposes of the PLUS was the conservation of the forests of the Santa Cruz.

Other regulations stipulate that landholdings should also be managed according to "best-use" and require landowners to create a land-use plan for individual properties. Known as *Plan de Ordenamiento Predial* or POP in the Bolivian lexicon (CITATION), these property-scale land-use plans must be approved as part of the land-titling process and landholders must present them to the by the Agrarian and Forest Superintendents when applying for a permit to deforest land for agricultural purposes (see next two paragraphs). A POP should follow the recommendations of the PLUS (1996) as well as also take into account additional regulations stipulated by the Forest Law of 1996.

***Land-Use Tenure*:** Lowland Bolivia has been plagued by a variety of administrative deficiencies and governmental corruption that has led to overlapping land titles that impede investment in natural resource dependent production models. As part of reforms of the 90s, the National Institute for Agrarian Reform (INRA, according to its Spanish acronym) organized a land-title review program to evaluate and resolve conflicting land claims. The INRA reform established procedures for validating existing titles, which also provide a mechanism for abrogating fraudulent land claims. A major goal of the land reform process is to ensure the ancestral rights of indigenous groups and indigenous groups now hold or claim approximately 25% of the Bolivian lowlands (CITATION – CPTI Atlas). To establishing or validate ownership, private landholders must demonstrate that their properties have an economic and social function, which is typically documented by the presence of crops, livestock, infrastructure, and/or a forest management plan. Land-holdings that do not demonstrate an economic and social function in compliance with regulatory guidelines are recovered by the state for distribution to other citizens, indigenous groups or as municipal reserves dedicated to forest management.

Forest Conservation and Management: The forest sector in Bolivia underwent significant reform in the mid 1990s, which included a reduction in the size of forest concessions, a redefinition of potential markets, and the adoption of more efficient management practices, as well as the nature of government oversight and modifications in the system used to calculate timber royalties. Among the features of the new forest law of 1996, was the recognition of "ecological easements" where forest cover is to be strictly protected on steep slopes and along watercourses (BOLFOR 199X). In addition, private landholders are encouraged to protect a portion of their property in its natural forest state, a provision that allows many landholders to retain portions of their estates that would otherwise revert to the state as part of the INRA review process. The law also establishes a specific royalty payment for land-use change and requires a permit that is based on the land-use plan prescribed by the agrarian reform law (see previous paragraph). The forest law establishes roles for different state agencies in the regulation of forest management; the Forest Superintendent was charged with oversight of the private sector, including the collection and distribution of royalty revenues. The national government is responsible for developing regulatory and economic policy, while municipal governments are afforded a role in the local application of both development and oversight (see below).

Governmental Decentralization: The 1990s witnessed the transfer of some administrative authority from national to municipal governments. Under the Popular Participation Law of 1993, municipal governments were guaranteed revenues from the national budget; municipal budgets are calculated based the proportion of the national population resident in that municipality. In exchange, municipalities were charged with maintaining key state assets, such as schools and hospitals, as well as management of natural resources not specifically regulated by an existing legal framework. The forest law of 1996 recognized the regulatory role of the municipalities by mandating the creation of municipal forest technical units and creating a concessionary mechanism to ensure that local inhabitants also have access to forest resources. Municipalities receive a portion of the timber royalties paid to the state to subsidize their forest management activities.

Geographic Setting of the Study Area

This study documents the history of land-use change in the San Javier and Concepción municipalities prior to and following the regulatory and governmental reforms of the 1990s. Our objective is to evaluate the efficacy of those reforms, as well as to better describe the nature of land-use change in the region in the context of the different social and economic actors, as well as the influence of external factors related to the national or regional economy. These two municipalities are currently at the front edge of the deforestation frontier and are exposed to most of the economic and social forces that drive deforestation in the Bolivia lowland. They can be viewed as case studies for all of Chiquitania and what has transpired here will also occur elsewhere.

The two municipalities are situated on the western edge of the Precambrian (Brazilian) Shield where exposed granite and metamorphic rocks have weathered to create a rolling landscape dominated by hills and low mountain ranges that range from 300 to 1000 m in elevation. Soils are variable ranging from infertile red oxisols developed on old tertiary sediments to superficial soils that are both young and relatively fertile (Killeen et al 1990; Cochrane et al 2003). The climate is markedly seasonal with a long (5 month) dry season that coincides with the Austral winter; mean annual precipitation varies from 900 to 1200 mm along a latitudinal gradient from North to South, but the region experiences significant interannual variation in precipitation with values ranging from 2000 to 500 mm per year (Killeen et al 1990; 1998). Just a few dozen kilometers to the north is a humid (semi-evergreen) forest that corresponds to the southern most

distribution of most Amazonian species. The original vegetation cover reflected the edaphic variability of the region, with a mosaic of Cerrado savannas, deciduous forest and localized wetlands. Fire is an important disturbance factor and has played a long an important role in maintaining the forest – savanna mosaic (Penard et al 199X)

The area is sparsely populated by Chiquitano indigenous communities and Creoles of mixed racial parentage (Gott 199X). Traditional land-use over two centuries has been based on cattle ranching on native grasslands, subsistence agriculture, and forest exploitations. Land-use started to change in the 1970s with the construction of a dairy plant in San Javier and the introduction of cultivated forages and the adoption of improved animal management technologies, as well as a gradual improvement of the transportation infrastructure that links Chiquitania to the urban markets of Bolivia (Killeen 1990, CITATION).

Materials and Methods

The land-use change analysis was based on a direct interpretation of cloud-free Landsat (MSS, TM, ETM) imagery obtained for the region (path 233, row 072) for eight sequential dates (1975, 1986, 1989, 1992, 1994, 1996, 1998, 2000, 2002 and 2004). All images were co-registered to topographic maps obtained from National Geospatial Intelligence Agency (formerly known as NIMA). The road network was obtained from the Military Geographic Institute of Bolivia; secondary roads were added to the cartographic database via a direct visual interpretation of satellite images. Land-use change was identified either by a visual interpretation and manual digitization (1986 through 1996) or by an unsupervised classification using the Isodata module of the Leica-ERDAS Imagine (®) software package (1975, 1998, 2000, 2002 and 2004). The earliest image (1975) was used to create a savanna – forest mask in order to identify all later land-use change as either deforestation or savanna conversion (Figure 1). Historical land-use change prior to 1975 was inferred by the spatial distribution and geometry of deforestation patches; mean annual rates of land-use change was tabulated based on time epochs that ranged from 11 to 2 year intervals (Figure 2a).

A geographic information system (GIS) was used to analyze the impact of socio-economic phenomena and policy initiatives on rates of land-use change. A multi-temporal land-use change map was used in conjunction with thematic polygons that were circumscribed for the two municipalities (Figure 2) and was also quantified for a circle with a radius of 25 km around each of three major villages. The year 1996 was identified as a watershed year, since that is when the legal and regulatory reforms were formally implemented.

Land-use change was evaluated for four different types of land tenure, including:

1) Indigenous territories (Original Community Reserve or TCO in the Bolivian lexicon); TCOs typically exist as large forest reserves in remote areas;
2) Indigenous communities, typically existing as small communal land-holdings near population centers;
3) Private properties, largely for cattle ranching but also including some land-holdings dedicated to timber exploitation; most are relatively close to population centers or on either a primary or secondary road;
4) Commercial timber concessions held by private companies on public lands under long-term contracts; concessions are also usually in remote areas.

Information on land tenure was obtained from the National Institute for Agrarian Reform (INRA), which reviewed land titles in San Javier and Concepción between the years 1998 and 2001. The process known in Bolivia as “sanitizing land-titles” included the formal recognition and titling of

communal agricultural lands for each small village, as well as the delimitation of larger indigenous forest reserves (TCOs). This process also recognized and validated previously existing private land holdings that now exist as in-holdings within TCO reserves. The resulting land-title map that was compiled by private consulting firms under contract by INRA (Figure 2b).

The effectiveness of the land-use zoning regulations was evaluated by comparing the rate of deforestation and savanna conversion in two broad categories established by the PLUS (1996). The PLUS has a total of 16 ategories of which 5 are present in the study area: 1) agriculture + cattle ranching, 2) cattle ranching + forest management, 3) cattle ranching + conservation, 4) forest management + regulated cattle ranching, 5) protected area. These classes were combined into two categories for purposes of the analysis: A) primarily cattle ranching (= 1 + 2 + 3) and B) primarily forest management (= 4 + 5) (see Figure 2c). We also evaluate the efficacy of the forest law to protect ecological easements by comparing deforestation in these areas both prior to and following the enactment of the forest law. Easements were identified by creating a buffer around all rivers, streams, lakes, and marshes according to their dimensions (20 m, 100 m, 200 ml see Figure 2d).

The degree of compliance with regulations regarding the payment of deforestation royalties was evaluated by comparing the area deforested for each private land holding for each 2-year period between 1996 and 2002. Land-holdings with less than 10-ha of total clearance are excluded from the totals, as the Forest Law exempts this amount to exempt subsistence farmers from royalty pavements. The land-use study was used to calculate potential royalty payments, which were calculated based on the value of the wood in the forest at the time of clearing, and is calculated the sum of three values: 1) a value established as 15 times the value of the minimum royalty payment for forest concessions ($1 ha^{-1} = $15 ha^{-1}), 2) a value fixed at 15% of the value of the wood present in the forest ($10 per m^3 timber *x* 15 m^3 ha^{-1} x 15% = $22.5), and 3) 15% of the price paid by the purchaser of the wood. The first two values are paid by the landowner when seeking the land-clearing permit and are included in this study, while the third value is paid by the purchaser of the word when applying for certificates necessary to transporting and commercializing timber and are not included in this study. The mean volume of harvestable logs of commercial species in the forest (15 m^3) were obtained from existing forest inventories (Dauber et al. 199X) and the estimate price of logs in Concepción ($10 m^3) were obtained by consultation with knowledgeable individuals at the Forest Superintendent in Santa Cruz Bolivia.

Results

Land use change in the two municipalities showed a variable rate over time reflecting the general advance of the agricultural frontier in the Department of Santa Cruz over the last several decades. Over the approximately 30 year period of the study, there were notable fluctuations in the rate of change, particularly in the early 1990s and between the years 2000 and 2002 when land-use change fell dramatically to near historical pre-development levels.

Land-use change in the study area includes both deforestation and savanna conversion for both crops and pasture (Figure 3a). Most of the area is unsuited for mechanized agriculture and subsistence farmers of the Chiquitano indigenous have deforested a relatively small area for crops, while land-use change on private landholdings is overwhelmingly for pasture establishment (Figure 3b). It is more difficult to detect savanna conversion from the interpretation of satellite images because of the structural and spectral similarities of native and cultivated grassland even though savanna conversion includes removing the woody stratum. Consequently, levels of savanna conversion are probably underestimated. Nonetheless, deforestation is much more common than savanna conversion due to the inherently more fertile

soils on forested landscapes, which ranchers preferentially choose to convert as it is more productive as cattle pasture.

Land tenure in the two municipalities is a mixture of private and indigenous community land-holdings. Indigenous lands comprise XX% of the total land surface; a consequence of the newly established forest reserves with traditional agricultural land-holdings representing less than XX% of the total area. Private properties represent about 50% of the land in the two municipalities with the remainder being incorporated into the private forest concessions on public lands (Table 1). The overwhelming majority of land clearing has occurred on private properties, which are almost uniformly dedicated to cattle ranching (Figure 3b; Table 1). A much smaller amount of deforestation can be attributed to the indigenous farmers who have practiced subsistence agriculture in the region for centuries. The distribution of land-use change within private land holdings is not uniformly distributed among properties. There are relatively low rates of change in small land-holdings with medium sized properties showing the greatest rates of change. The largest land-holdings showed relatively low rates of change. These trends were true for both savanna conversion and deforestation (Figure 4a and 4b).

Table 1. Land Cover by Social and Economic Actor

	Total Area	Forest	Savanna	Water	Pasture or Fallow
Indigenous forest reserve (TCO)	647,379	629,675	15,697	22	1,986
Indigenous agricultural land holdings	131,365	102,131	15,338	15	13,880
Private forest concession on public lands	72,689	71,549	1,095	0	44
Private land holdings	775,758	490,127	158,779	1,215	125,636
Undefined (probably private properties)	119,624	94,997	15,325	192	9,111
Urban Area	3,896	330	662	132	2,772

Land-use change was evaluated in terms of equal area for three different villages that were sequentially situated along the main trunk road that transects the region. Each village serves as a distribution center for supplies and is a local market for agricultural goods, as well as a cultural center with a church, schools and other services. Land-use change was greatest in San Javier, which is closest to the departmental capital Santa Cruz de la Sierra, the principal commercial market for beef and dairy product (Figure 5a). All three communities show similar temporal fluctuations demonstrating that the drivers of deforestation were acting in similar ways across the region. Ease of access is an important factor in influencing the decision to deforest a land. The region was stratified into three categories based on ease of access, as defined by its closeness to primary and secondary roads (Figure 5b).

Land-use and land tenure in Santa Cruz are governed by a variety of legal mechanisms that have been designed to ensure appropriate use of natural resources in the context of sustainable development (PLUS 1996). Native savanna and forest landscapes near the major highway are zoned for agriculture and cattle production, while the more remote forest landscapes were zoned for forest management with some limited regulated cattle production (Figure 2c). Deforestation occurred in areas zoned for cattle ranching and forest management both prior to and after the

implementation of the PLUS regulations. However, there was a marked increase in deforestation in lands zoned for forest management after the implementation of the PLUS regulations (Table 2).

Table 2. The impact of land-zoning regulations on the rate of deforestation.

	Historic Change	Pre PLUS (1989 - 1996)	Post PLUS (1997 - 2004)
Cattle ranching (and forestry)	2,016	2,611	3,519
Forest management (and cattle ranching)	329	758	3,488

The forestry and agrarian reform laws of 1996 provided protection to lands considered to be susceptible to erosion or which provided essential ecological services adjacent to wetlands and along stream corridors. Land holders undergoing the land-title review process are required to present authorities a land-use plan that demonstrates that their properties and the land-use on them conform to these regulations. Table 3 provides a summary of deforestation totals for each of the different land-tenure categories present in the study area and Table 4 shows how rates of change have increased in ecological easements after the implementation of the forest law in 1996.

Table 3. Land-use and land-use change on environmental easements.

	Forest	Savanna	Wetland	LUC	Defores-tation	%	Savana Conve r-sion	%
Indigenous forest reserve (TCO)	21,503	194	44	138	138	0.6	0	0
Indigenous agricultural land holdings	4,245	257	10	778	676	14	14	5
Private forest concession on public lands	1,782	13	-	-	-	0	-	0
Private land holdings	25,701	5,099	986	9,026	7,947	24	1,080	17
Undefined (probably private properties)	318	121	3	105	91	22	68	36
Urban Area	41	50	92	200	132	76	73	59

Table 4. Mean Annual Rate of deforestation on land designated as an environmental easement before and after the 1996/97 administrative and legal reforms.

	Historic	1992 - 1996	1997 - 2004
Indigenous Reserve	1	3	9
Community Lands	22	21	25
Forest Concession	-	-	-
Private Property	181	197	303
Unknown	3	2	1
Urban Area	11	2	1

The forest law also establishes regulations to compensate the state for the exploitation or destruction of forest timber as the result of land-clearing activities. Table 5 shows the potential revenues documented in the study area since the implementation of the forest law in 1996.

Table 5. Potential revenues from deforestation royalties on private properties.

	Total Deforestation since 1997	Annual Deforestation Rate 1997	Total Potential Revenues	Potential Annual Revenues
Concepción	25,375	3,964	888,111	138,747
San Javier	25,319	3,043	886,177	106,505

Discussion

Socioeconomic group and size of land-holdings have influenced the rate of land-use change. Governmental efforts to diminish the rate of change or to restrict it to the most appropriate soils have been unsuccessful, as have efforts to collect timber royalties owed as a result of deforestation. Land titling programs have promoted deforestation within private properties but successfully set aside large areas of forest as indigenous landholdings, a social group with historically low rates of land-use change. The most observable impact on land-use change is ease of access and the distance to the regional markets for beef and dairy products.

Land-Use and Land-Use Change in the Context of Land Tenure

Indigenous subsistence farmers have been clearing land at relatively low rates of change for centuries, yet their impact on the landscape has been minimal with less than 1% of the total area deforested. Even though the population of indigenous communities has increased over the past three decades, increasing from xxxxx to xxxxx between 1980 and 2000, the rate of change has remained relatively constant (Figure 1). The older indigenous land-holdings are small in area and are located relatively close to the two the villages of Concepción and San Javier; as a consequence, there is more deforestation on those land-holdings with between 70 to 90% of the original forest cover converted to agricultural land or second growth forest. These traditional community land-holdings are surrounded by private properties; a historical legacy of the co-dependence that existed between indigenous communities and cattle ranches. Even today, ranches depend on indigenous communities for most labor needs. In recent decades, community farmland has been established in remote areas and is an organized effort to secure land for an expanding population (Figure 2b). Deforestation in these more remote land-holdings ranges from 0 to 7%. Under current rates of land-use change (~ 500 ha yr^{-1}), communal agricultural land will become completely deforested in approximately 200 years.

The recently established indigenous forest reserves (TCOs) are essentially devoid of deforestation and the small amount of land-use change documented for those areas is most likely occurring on private properties that have yet be reviewed by the land reform institute INRA (Figure 3b and Table 1). Indigenous communities have uniformly expressed a goal of managing forest reserves via some form of sustainable forest management. However, it is unclear whether the current low levels of land-use change are the result of management practices, or a function of the difficult access to these remote areas; It is more likely the latter, but the relatively low rate of change on other traditional lands provides room for optimism that indigenous communities will be good stewards of forest lands.

Land-use change on private land varies depending on the size of the property (Figure 4). The smallest properties experience land-use change in essentially the same proportions as indigenous agricultural land-holdings and are probably owned by lower income families that practice both subsistence farming and cattle ranching on a very small scale. The rate of land-use change

increased for medium sized land-holdings with the largest values documented for properties between 1000 and 5000 hectares. These are land-holdings owned by middle class families from the local villages and/or urban investors resident in the city of Santa Cruz. The largest private land-holdings had surprisingly low rates of land-use change, which reflected the decision of those property owners to elect forest management as a production model (see below).

Land-use Change in the Context of Government Regulations

The peak in land-use change occurred in the temporal epoch between 1998 and 2000 coinciding with a period when the National Institute for Agrarian Reform (INRA) was verifying the legitimacy of land-titles in the region. This process was based on an evaluation of the economic productivity of individual properties; if a property was deemed not to be productive, some or all of that land holding was reverted to the state. In Chiquitania, the most popular production model on private properties is cattle ranching and titles are validated by counting the number of head of cattle (2 head of cattle justify 5 hectares), the amount of pasture, fencing, water impoundments, and other infrastructure. Consequently, many property owners who held moderately large land-holdings were motivated to deforest land, or face the possibility of loosing it in the title review process.

Research and extension services have also promoted land-use change. Traditional cattle ranches depended on native grasses and were characterized by low stocking rates, but technology gradually adopted since the 1970s has improved productivity by the use of cultivated forage species, modern animal husbandry practices, disease control, and genetically improved livestock. Ironically, one of the expressed objectives of the extension programs has been to decrease deforestation by improving productivity, thus lessening the need for pasture expansion (Citation XXXX; Killeen 1990). However, the evolution of the current cattle production model has had the opposite impact, as it has fostered an expansion of cultivated grasses, which grow better on forest soils, thus fostering increased deforestation. Originally, most land-use change was largely the due to deforestation, but eventually, grasses adapted to savanna soils were introduced and savanna conversion has also become more prevalent (Figure 2a).

The PLUS, INRA and forest law were all designed to promote forest management; however, only 15 private properties, ranging in size from 200 to 8000 hectares, have formally chosen the timber production model. The largest private property in the two municipalities adopted the forest management production model and has shown no deforestation, which explains, in part, the low land-use change levels for the largest size class of private land-holding (Figure 3). Nonetheless, deforestation was documented for 5 smaller land-holdings with forest management models, including one 6000-hectare property that had cleared more than 50% of its total area for pasture establishment. These properties apparently have adopted a mixed forest management - cattle raising production model.

The process of creating a management plan acceptable to the Forest Superintendent requires a significant investment in forest inventories and consulting fees, as well as a long-term commitment to pay timber royalties. In contrast, cattle ranchers also sell logs into the same timber market without investing in forest inventories or management plans and, thus far, have avoided paying forest royalties due from land-use change. Only five properties applied for land-clearing permits between 1997 and 2004, producing a mere $5000 in royalties; a value that represents less than 1% of potential revenues (Table 5). Apparently, the combination of cumbersome regulations and the failure of the Forest Superintendent to collect deforestation royalties has created a perverse incentive that subsidizes cattle ranching operations and rewards tax evasion, while penalizing private land-holders, indigenous communities, and timber

concessionaires that formally choose the forest management model, that commits them to invest in management plans and pay royalties on the volume of timber harvested.
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Likewise, the role of government in managing land-use change via land zoning regulations has been ineffective. Landholders have largely ignored the regulations recommended by the PLUS and deforestation on lands identified as best managed for timber production actually increased after the implementation of the regulations. The PLUS is both a technical document based on the potential of soil and climate, but also incorporates the demands of societal groups seeking access to natural resources. In Chiquitania, forest use and cattle ranching have traditionally been part of a single, family enterprise and the PLUS explicitly recognized this traditional land-use when recognizing the two categories: cattle ranching + forest management and forest management + regulated cattle ranching. In part, the two different zones reflect the relative abundance of forest, with the first category being limited to landscapes with mosaic of savannas and forest. However, the later category is limited to landscapes with virtually 100% forest cover and, originally, the technicians who developed the PLUS intended this category to be simply "forest management." Pressure from livestock producers caused this category to be extended to include the term "regulated cattle ranching." The term "regulated" was not defined and, essentially, allows landholders to determine the preferred land-use. Regardless of intent, enforcement is lax and there has been no effort made on the part of either national or local governmental authorities to restrict land-use or limit land-use change in any zoning category. Similarly, there was no impact on deforestation on easements and deforestation rates actually increased on these lands following the enactment of the 1996 Forest Law (Figure 4). Apparently, the elaboration of the land-use plans for individual properties (known as POPs in the Bolivian lexicon) is little more than a bureaucratic formality that is required as part of the land-titling process.

Municipalities are charged under the Popular Participation and Forest Laws for monitoring forest exploitation within their political circumscription; to subsidize this activity, they receive a 25% co-participation of the forest royalties collected by the Forest Superintendent. The only municipalities that have organized a Forest Operations Office are those with forest concession on public lands that pay timber royalties. Concepción has such an office while San Javier does not (check validity of this statement). The two municipalities have annual budgets of less than $250,000 and they do not have the resources to finance the monitoring of land use change (check validity of this statement). Much to the contrary, any additional moneys would improve the ability of these municipalities to provide essential services to their inhabitants. The Forest Superintendent would also benefit from a more effective collection of forest royalties; the annual budget between 1999 and 2002 varied between $3 and 3.5 Million dollars. The area documented in this study represents less than 5% of the forested area in Bolivia and represents only about 5% of the total deforestation in Bolivia which has been estimated at approximately 200,000 ha yr^{-1}. Conservative estimates of the revenue lost to the state by the failure of the Forest Superintendent

and municipal governments to collect deforestation timber royalties has been estimated at $3.5 million annually between 1997 and 2001 (VMRNMA 2005).

Land-use Change in the Context of Market Forces

In the 1960s, the departmental capital of Santa Cruz de la Sierra was a large town of 70,000 inhabitants that was connected to provincial villages via rudimentary roads that radiated out from the city like the spokes on a wheel. Santa Cruz was connected in the 1970s with provincial towns via a trunk road; improvements to the trunk road and the creation of secondary roads in the study area that led to a increase in the number of cattle ranching operations, which in turn fostered the creation of cattle ranches and promoted deforestation (Figure 3, 4 & 5). The most important investment was the sequential paving of the main highway between 1993 and 1998; which led to a reduction in travel time between Santa Cruz and Concepción from 15 to 6 hours. Other investments in infrastructure also impacted the area. A cheese factory was built in San Javier in the 1974 led to an increase in dairy farms that are highly dependent on cultivated grasses. More recently, the development of a regional energy grid in the late 1990s has led to a reduction in the cost of electricity, thus contributing to the profitability of ranches with access to the grid.

The importance of market forces are evidenced by the high deforestation rates on private properties when compared to indigenous lands. Cattle ranches are almost entirely dependent on the national market for selling their production, while indigenous communities, as subsistence agriculturalists, are largely isolated from that market. Consequently, the growth in deforestation rates over three decades was overwhelmingly a phenomenon of private property. Indigenous lands, either communal agricultural holdings or large forest reserves, show relatively low and constant rates of land-use change over three decades. As subsistence farmers, indigenous communities are largely immune to market forces

The importance of private capital is also evidenced by the fluctuation in deforestation rates on private properties. There were two periods with that showed a decrease in the rate of land use change, one between 1989 and 1992 and another between 2000 and 2002. Both of these periods coincide with contractions of the Bolivian national economy, showing the link between land-use change and economic growth within the country. The reduction in land-use change is the consequence of a restriction of capital flows from urban centers to rural areas. Bolivia has few investment options; there is essentially no stock market and the bond market is likewise limited in scope and options. Interest on saving accounts and certificates of deposits in banks are unattractive and private capital lent via informal mechanisms is both poorly secured and extremely risky. Real estate is considered to be the most secure of all investments and rural properties constitute a major portion of the real estate investment market. Cattle ranches preserve capital, while enjoying moderate rates of return on the investment, both in land and livestock. Investment in cattle ranches is a major form of savings in Bolivia and Chiquitania is a major recipient of this investment capital.

The link between land-use change and national economic growth cannot be understated. Much of the economic growth in Bolivia is the result of an expanding agricultural sector that is integrated in value-added production chain that spans the economy from the importation of equipment and supplies, to post harvest processing, commercialization, and transportation. This export-oriented production is generating wealth and the lack of secure and contributes to deforestation, as individuals seek safe havens for their savings. Conservation and development strategists argue correctly that sustainable development must reduce poverty and that poverty reduction must be based on economic growth. As populations expand and economies develop, most of that future

growth will be centered in urban centers. A lack of modern financial institutions and secure savings options, will contribute, if not accelerate, the expansion of the agricultural frontier,

Future Scenarios

The economic drivers of land-use change are the result of economic growth and regional integration initiatives promoted by local, national and regional institutions. There is no indication that these development phenomena will change in the near future. The rate of land-use change will show periodic fluctuations, as it has in the past, but the long-term trend is upward. Like other areas in the Amazon, the decision to deforest land rather than manage and conserve forest is related to short-term benefits that accrue to the individual versus vs. long-term economic benefits that benefit society (Margulis, 2003).

Under current rates of land-use change all of the forest within private properties will be deforested within xx years. However, land-use change may experience significant increases in the near future. However, this study primarily documents land-use change caused by a very specific social actor – Bolivian citizens native to the Department of Santa Cruz. Cruceños, as they are called, are relatively conservative in their approach to land-use and their investments are often constrained by access to capital. However, there are two other social actors that could change the dynamic of land-use change in Chiquitania. Brazilian investors have been purchasing properties in the municipalities along the international border. The Brazilian livestock model is technologically sophisticated and economically competitive (Margulis, 2003) and an increase in Brazilian immigrants or investors will increase the rate of land-use change.

Another social group in Bolivia that is responsible for extensive land-use change are peasant colonists who have migrated to the lowlands from the Andean highlands (Theile, 1995; Pacheco, 1998). In contrast to the native Chiquitanos, who are subsistence agriculturalists, Andean migrants grow food for their own consumption as well as crops, such as maize, rice and manioc with commercial value. The emphasis on crops with a market value results in a land-use change rate that is an order of magnitude, on a per family basis, larger when compared to Chiquitano communities (VMMARR, 2005). Andean colonists are present in the study area having settled along a secondary road along the eastern boundary of the Concepción municipality (Figure 1). Andean colonists at the national level are well organized and increasingly vocal in their demands for access to land (El Deber, 24 May 2005). Colonists have forcibly occupied private properties, forest concessions, and protected areas in other areas of Bolivia and the government is actively seeking to identify public lands for distribution to this sector of Bolivian society. Because land-tenure has been largely resolved in San Javier and Conception, these municipalities may not be subject to the colonization phenomena, but this social group will almost establish new settlements in some region within Chiquitania.

Whether by internal growth or by immigration from Brazil or the Andes, the rate of land-use change will continue to increase over the next two decades. If the increases occur at a rate similer to the 1990s, the forests within private properties will be exhausted in approximately xx years.

In spite of the inevitability of increasing rates of land-use change, many property owners will choose to retain a proportion of each property as native forest habitat. The forest law provides a mechanism to create private reserves and XX properties have already protected a total of xxxx ha (CITATION, Citation from Rumiz). However, this represents less than 1% of the surface area of the original forest cover and even if all property owners take full advantage of this provision, the amount would be increased to only xxx ha, or xx%. The only other option available for conserving forest is to adopt timber exploitation as a production model or, more likely, a mixed

model that includes both livestock and timber exploitation. Unfortunately, the current management model being promoted by development agencies and approved by the Forest Superintendent, contemplates a 20-year timber harvest cycle (CITATION BOLFOR publication). The native species of the Chiquitano forest are characterized by very slow growth rates and intensive exploitation over one or two 20-year cycles would lead to forest impoverishment (Dauber et al 2002). Once valuable timber resources are exterminated from the forest, these landscapes would then be prime candidates for conversion to pasture (Rice & Gullison 199X).

Perhaps the best hope for forest conservation is the conservation of the extensive forest landscapes being incorporated into the indigenous reserves known as TCOs (Table1), particularly in light of their historical low levels of land-use change. Although they have managed to acquire legal tenure, indigenous organizations it remains to be demonstrated they have the capacity to protect reserves from squatters. Many TCOs are adopting a timber management model and are adopting the management plans with 20-year harvest cycles promoted by development agencies and state authorities (CITATION ConBIO); the sustainability of this model and its eventual impact on land-use change would be similar to those already discussed for private properties.

Fortunately, there exist both time and circumstance to develop alternative production models that more effectively conserve natural forest and savanna habitats. It is evident that a reliance on regulatory mechanisms will not work on the agricultural frontier of Bolivia and that solutions must be based on economic incentives to be effective. One possibility would be to favor a modified version of the traditional production model that combines cattle ranching with low intensity timber exploitation. Essentially, landowners view timber as a type of "piggy bank," which is tapped for emergencies, important events or necessary investments in infrastructure, but not as income. Incentives could be provided in the form of land-tiling preferences, tax incentives, free technical assistance, or an exemption from royalty payments. However, to be effective land set aside for timber production should be explicitly mapped and wood volumes linked to annual growth rates (Dauber et al 200X).

Similarly, a less intensive timber exploitation model must be developed for indigenous reserves and forest concessions. Indigenous organizations would be well advised to explore non-timber exploitation based management options, including tourism and the potential benefits from ecological services, as degraded forest will be much more susceptible to deforestation. Economic constraints probably limit the ability of private companies to modify their production models on forest concessions, but partnerships between indigenous communities and private companies with concessions could lengthen harvest cycles and reduce the intensity of timber exploitation to the benefit of both indigenous communities and companies. Bolivian society would benefit by conserving a greater portion of the original forest patrimony that is in danger of being lost due to predominance of market forces exacerbated by poor planning and weak governance.

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