

Land use change and agricultural development in Santa Cruz, Bolivia

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Using data collected

in the field, interviews, socio-economic information and satellite remote sensing imagery integrated in a GIS, the authors analyze the dynamics of agricultural frontier expansion in Santa Cruz.



Landscape mosaic in the Guarayos zone.
Photo C. Colfer.

RÉSUMÉ

CHANGEMENTS DE L'UTILISATION
DES TERRES ET DÉVELOPPEMENT
DE L'AGRICULTURE À SANTA CRUZ,
BOLIVIE

Le département de Santa Cruz, en Bolivie, appartient au bassin amazonien. Il contient une grande partie des forêts boliviennes de basse altitude et est principalement couvert de forêts semi-décidues. Le développement agricole et la déforestation n'y suivent pas une trajectoire similaire à celle des autres pays tropicaux de la région. Il se caractérise par une activité agricole productive, rentable et de haute valeur. Toutefois, le développement des fronts pionniers agricoles, qui implique des petits, moyens et grands producteurs, a conduit, depuis les deux dernières décennies, à une croissance exponentielle de la déforestation. La conversion des forêts dans cette région en fait un des « points chauds » de la déforestation à l'échelle mondiale. Cet article analyse les dynamiques d'expansion de la frontière agricole à Santa Cruz, en distinguant des zones écologiquement, socialement et économiquement très variées. L'objectif est triple : illustrer l'intensité et la localisation de la déforestation sur trois périodes de temps ; décrire les dynamiques différenciées du développement des frontières agricoles attachées aux types de producteurs et conditions géographiques ; déterminer les facteurs qui influencent l'expansion agricole dans cette région. Cette étude repose sur des données collectées sur le terrain, interviews, informations socio-économiques, et les images de télédétection satellitaire intégrées dans un Sig, afin de faciliter l'analyse des changements d'utilisation du sol.

Mots-clés : déforestation, frontière, développement de l'agriculture, colonisation, Amazone, Bolivie.

ABSTRACT

LAND USE CHANGE
AND AGRICULTURE DEVELOPMENT
IN SANTA CRUZ, BOLIVIA

The department of Santa Cruz in Bolivia makes part of the Amazon basin, and it embraces a large portion of the Bolivian lowland forest, with most of its area covered by semi-deciduous forest. The agricultural development, and hence deforestation in Santa Cruz, does not follow any similar path of other tropical countries of the region, and it is characterized by a productive, high value and profitable agricultural land use. Yet, the agricultural frontier development involving both small and medium and large-scale producers has, since the two last decades, led to an exponential process of deforestation. Forest clearing is currently localized in an area known as being one of the region's major "hot spots" of deforestation. This paper aims at analysing the dynamics of agricultural frontier expansion in Santa Cruz distinguishing different zones with varied ecological, social and economic characteristics. The three main objectives are to illustrate the magnitude and localization of deforestation in Santa Cruz in a three-fold period, to describe the differentiated dynamics of agriculture frontier development linked to diverse actors and geographical settings within the department of Santa Cruz; and to determine the factors that influence on agricultural expansion at the frontier. This study is based on informant interviews, secondary socio-economic information, and satellite remote sensing imagery integrated in a GIS to facilitate land-use change analysis.

Keywords: Amazon, Bolivia, deforestation, frontier, agriculture development, colonization.

RESUMEN

CAMBIOS EN LA UTILIZACIÓN
DE LAS TIERRAS Y DESARROLLO DE
LA AGRICULTURA EN SANTA CRUZ,
BOLIVIA

El departamento de Santa Cruz, en Bolivia, pertenece a la cuenca amazónica. Contiene una gran parte de los bosques bolivianos de baja altitud y, principalmente, está cubierto con bosques semicaducifolios. El desarrollo agrícola y la deforestación no siguen una trayectoria similar a la de los otros países tropicales de la región. Se caracterizan por una actividad agrícola productiva, rentable y de alto valor. No obstante, el desarrollo de los frentes pioneros agrícolas, que implica a pequeños, medianos y grandes productores, ha conducido, en los últimos veinte años, a un incremento exponencial de la deforestación. La transformación de los bosques en esta región la convierte en uno de los "puntos calientes" de la deforestación a escala mundial. Este artículo analiza las dinámicas de expansión de la frontera agrícola en Santa Cruz, diferenciando zonas ecológica, social y económicamente muy variadas. El objetivo es triple: mostrar la intensidad y la localización de la deforestación en tres períodos de tiempo; describir las dinámicas diferenciadas del desarrollo de las fronteras agrícolas relacionadas con los tipos de productores y las condiciones geográficas y determinar los factores que influyen en la expansión agrícola en esta región. Este estudio se basa en datos tomados sobre el terreno, entrevistas, información socioeconómica, y las imágenes de teledetección por satélite integradas en un SIG, para facilitar el análisis de los cambios de utilización del suelo.

Palabras clave: deforestación, frontera, desarrollo de la agricultura, colonización, Amazonas, Bolivia.

Introduction

The country of Bolivia comprises an area of one million square km, around 70% of which is located in areas below 500 m above sea level corresponding to the Bolivian lowlands, which share a portion of the Amazon Basin. About 80% of the country's total forest is located in the lowlands. Historically, deforestation magnitudes and rates in Bolivia remained low by international standards until the mid-1980s, equivalent to an annual rate of 0.2% of the forested area (BAKKER, 1993). Nevertheless, the deforestation rates rose significantly from the mid-1980s to the mid-1990s, reaching a rate of 0.55% (STEININGER *et al.*, 2000). This rate of deforestation is even higher than the average of the other Amazonian countries, which is close to 0.43% (FAO, 2001).

A major portion of the deforestation in the Bolivian lowlands occurred in the department of Santa Cruz, which comprises over a third of the total area of the country (37 million hectares) (Figure 1). The development of the frontier in Santa Cruz began only in the late 1950s, driven by small- and large-scale farmers

seeking mainly to supply agricultural goods to the domestic market, but since the mid-1980s agricultural producers have looked for ways to increase the exports of some commodities to the regional markets, primarily soybeans (BAUDOIN *et al.*, 1995). The expansion of the agricultural frontier, with the subsequent deforestation in Santa Cruz, has accelerated since the mid-1980s as a result of shifts in the government's macroeconomic policy and efforts to open up external markets in order to increase the contribution of agricultural exports to national revenues, as part of a strategy aimed at restructuring the country's economy on the basis of some dynamic sectors such as telecommunications, hydrocarbons and modernized mining and agriculture (PACHECO, 1998).

The agricultural frontier development and subsequent deforestation in Santa Cruz in the last four decades did not follow a similar path to that of any other tropical country of the region. It is characterized by a productive and profitable agricultural land use, related initially to cotton

and sugar production, followed over time by soybean production. This does not mean that no areas were exhausted and degraded, but that overall the agricultural frontier remains productive, with high value products traded on the international market. However, not all producers have benefited equally, and there are still some risks that make agricultural frontier development vulnerable to changes in external demand and soil depletion (BAUDOIN *et al.*, 1995).

This paper aims to analyze the dynamics of agricultural frontier expansion in Santa Cruz, distinguishing different zones with varied ecological, social and economic characteristics. The first section will analyze the magnitude and rates of deforestation in Santa Cruz, while the second will describe the land uses and rural actors in Santa Cruz. The third section will explain the differentiated dynamics of agricultural development and deforestation and the underlying factors behind them in diverse zones within the department of Santa Cruz. The final section states the main conclusions of this paper.



Mountainous landscape in the north of Santa Cruz department.
Photo C. Colfer.

Magnitudes and rates of deforestation in Santa Cruz

The department of Santa Cruz comprises around one third of the total area of the country and 51% of its forested lands (WB, 1993). By 2001 approximately 60% of total forest clearing carried out in the country took place in this department (SIA, 2001). Historically, forest clearing in Santa Cruz was limited but it has grown exponentially in the last two decades. As recently as 1950 the entire department had less than 60 000 ha of cultivated land, most of which was corn and rice. Forest clearing slowly accelerated from 1950 to the early 1980s as a result of government policies promoting import substitution of agricultural goods, mainly rice, cotton and sugarcane.

There have been numerous government policies seeking to expand the lowlands agricultural frontier since the late 1950s and the early 1980s, as part of import substitution policies dominant in the whole region. The main policies to expand the domestic supply of agricultural goods were: (i) road building to facilitate the occupation of new frontiers and connect them to the main urban consumption centers, (ii) subsidized credit targeting specific agricultural goods (i.e. rice, cotton and sugarcane), (iii) agricultural price supports to guarantee minimum profits, (iv) allocation of land through legal and semi-legal means to medium- and large-scale farmers, and (v) support for formal rural settlements to facilitate migration of the labor force to the lowlands (DANDLER, 1984). All of these policies encouraged forest clearing. The goals of the substitution program were achieved in the early 1970s, and after that time the limited size of the domestic market, coupled with commercial barriers for exporting surplus production, became the main factors constraining the expansion of the frontier (KAIMOWITZ, 1997).



Figure 1.
Bolivia and the department of Santa Cruz.



Agricultural patterns in the northern and southern expansion zone.
Landsat ETM+, 2000, band composition 5-4-3.
Source: University of Maryland, Global Land Cover Facility (GLCF).

By the mid-1980s most deforestation was localized in the areas closer to the city of Santa Cruz, the urban capital of the department of the same name, around the area labeled “integrated zone”. This area is connected to the main cities of the western part of the country (Cochabamba and La Paz), which constituted the main centers of consumption of agricultural goods besides the city of Santa Cruz (Figure 1). The frontier expansion was stimulated by an intense process of migration from the highlands to the north and northwest areas around the city of Santa Cruz, in addition to increasing investments by medium- and large-scale establishments in mechanized agriculture. Our estimations, based on INE (2003), indicate that by 1985 the total area cultivated with agricultural crops by small farmers in Santa Cruz (excluding pasture) was about 150 000 ha (mostly rice, corn and manioc), while the total area cultivated by medium- and large-scale farmers reached approximately 170 000 ha (mostly cotton, sugarcane, wheat, and soybeans).

The situation described above changed substantially after the second half of the 1980s when a program to overcome the economic crisis and to restructure the economy was implemented, based on incentives to stimulate the growth of the export sector. All subsidized credits for the agricultural sector were eliminated, settlement programs were no longer supported, and price supports for agricultural goods were suppressed. Instead, another set of policies was put in place in an attempt to promote the export sector, including measures such as the devaluation of the national currency, fiscal incentives to exports, and efforts to open up regional markets for non-traditional exports through bilateral and multilateral trade agreements (PACHECO, 1998). In the agricultural sector, these policies were accompanied by the recognition of ownership rights on forested lands suitable for developing intensive agriculture to the east of the old agricultural frontiers in the depart-

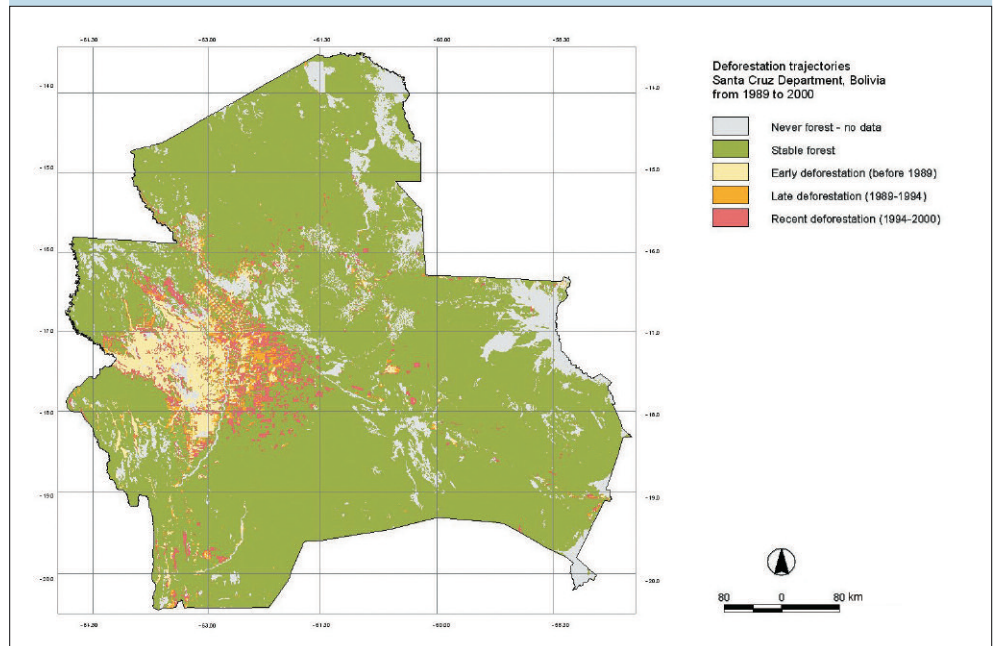


Figure 2.
Deforestation in Santa Cruz, Bolivia, from 1989 to 2000.

ment of Santa Cruz. These policies, however, favored a small group of large-scale producers, both national and foreign, which benefited from low land prices, fiscal incentives and soil fertility (BAUDOIN *et al.*, 1995) and led to explosive growth of the agricultural frontier (KAIMOWITZ *et al.*, 1999).

Based on available land cover maps (MORALES, 1993, 1996; CAMACHO *et al.*, 2001), it can be seen that the forest area in Santa Cruz originally covered about 32 542 000 ha (Table I). In the last fifteen years, deforestation rates have risen rapidly. From 1986 to 1990 CUMAT (1992) found that the Amazonian portion of Santa Cruz lost 38 000 ha of forest annually. This region covers 61% of Santa Cruz, but probably accounted for a higher percentage of forest clearing during that period. In 1989 the forested area covered approximately 30 951 000 ha. The land cover change analyses indicate that from 1989 to 1994 annual deforestation was 104 500 ha, and from 1994 to 2000 it increased to 240 780 ha (Figure 2), which indicates that forest clearing has tended to

increase exponentially over time in the department of Santa Cruz. There is nothing to suggest that it will decrease in the following years.

The cultivated area grew accordingly during that period mostly towards the eastern part of the old frontier. By 2000, while the total area cultivated by small farmers was about 200 000 ha, the area cultivated by medium and large establishments reached about 700 000 ha, with 80% of this area being given over to soybeans (INE, 2003). This indicates that important changes have occurred in the agricultural sector in the last two decades such as the increasing role of medium- and large-scale agriculture as opposed to small farmers, and the dominance of export commodities in the current agrarian economy. Furthermore, an unknown portion of deforestation is driven by pasture expansion in the eastern part of the department as a result of an increasing and unsatisfied demand for meat in the city of Santa Cruz (PACHECO, 1998). Additional studies are needed to document the dynamics of pasture expansion.



Fire and small-scale agriculture in the Guarayos region.
Photo C. Colfer.



Large scale agriculture in the expansion zone.
Photo J. Johnson.

Land use and main rural actors in Santa Cruz

We divided the department of Santa Cruz into nine zones, following a classification of DAVIES (1994). The borders of the zones were defined taking into account the type of dominant vegetation, the social process of territorial occupation and their resultant socio-economic characteristics (Figure 3 and Table II). The *Guarayos* area (zone 1) in the north is covered by dense forest, while deciduous forest is the dominant vegetation in the *Chiquitania* (zone 2), and the *Chaco* zone (zone 3) is mostly covered by dry forest. While the deciduous forest formations cover the northern and southern expansion zone (zones 4 and 5, respectively), these two areas have higher anthropogenic influence in relation to the rest of the *Chiquitania*. The northwest of the department, labeled northwest colonization and colonization in *pie de monte* (zones 6 and 7, respectively), as well as the northern expansion zone, have undergone greater pressure from small agriculture, but both differ in terms of the dominant forest formation, which is denser to the north. The western area of the department forms part of the sub-tropical valleys with low and open forest (zone 8). The last area, labeled integrated zone (zone 9), where the city of Santa Cruz is located, is where the agricultural frontier expansion was initiated.

In 2002 the department had approximately 2 million inhabitants, of which about three quarters were located in the city of Santa Cruz, the urban center with the country's highest rate of population growth. Most of the rural population is concentrated in the agricultural colonization areas to the northwest and west of the city of Santa Cruz (zones 4, 6, and 7), while the indigenous population is sparsely distributed in large areas to the north and east of the department (zones 1, 2 and 3). The zones closer to the city of Santa Cruz (zones 5 and 9) constitute

Table I.
Department of Santa Cruz, Bolivia:
land cover changes between 1989 and 2000.

Land cover change	Area (10 ³ ha)	Area of change (10 ³ ha.y ⁻¹)
Never forested	3 886.67	-
Stable forest	28 984.40	-
Early deforestation (before 1989)	1 590.97	-
Late deforestation (1989-1994)	522.50	104.5
Recent deforestation (1994-2000)	1 444.67	240.8
Total	36 429.25	-

Sources: based on outcomes from MORALES (1993, 1996) and CAMACHO *et al.* (2001).

Table II.
Department of Santa Cruz, Bolivia: description of the zones considered.

Name	Type of dominant farmer	Age of settlement	Type of settlement
1. Guarayos	Indigenous with some small farmers	Old	Spontaneous
2. Chiquitania	Medium and large ranchers, small farmers and indigenous	Mixed	Spontaneous
3. Chaco	Medium and large ranchers, and indigenous	Mostly old	Spontaneous
4. Northern expansion zone	Small farmers	Mixed	Directed and spontaneous
5. Southern expansion zone	Medium and large commercial	New	Spontaneous and directed
6. Northwest colonization zone	Small farmers	Mixed	Directed and spontaneous
7. Colonization in "pie de monte"	Small farmers	Old	Directed
8. Inter-Andean valleys	Small farmers	Old	Traditional settlers
9. Integrated zone	Medium and large commercial	Old	Spontaneous and directed

Sources: adapted from DAVIES (1994) and THIELE (1995).

the areas where a more intensive agriculture has been established, mostly by medium- and large-scale landholders (Table II). The "integrated zone" (zone 9) constituted the main agricultural frontier until the mid-1980s, and since then the "expansion zone" (zone 5) has become the most active agricultural frontier of the whole country. In addition, extensive cattle production is carried out in the *Chiquitania* and *Chaco* zones. Some protected areas have been established in the *pie de monte* area (Parque Amboro), *Chiquitania* (Noel Kempff Mercado and San Matias protected areas), and the *Chaco* zone (Kaa Iya and Otuquis) (Tables IV and V).

Over the last forty years the department has undertaken major improvements in its transportation infrastructure that have opened up new forest areas to exploitation and linked the region with the rest of the country, stimulating greater pressure on the land from the migration of poor people that originated in the western part of the country and increasing investments in land conversion for agricultural uses. Major rural economic activities include commercial farming and ranching, small-scale food production, logging, mining, and petroleum and natural gas extraction (ARRIETA *et al.*, 1990). While logging

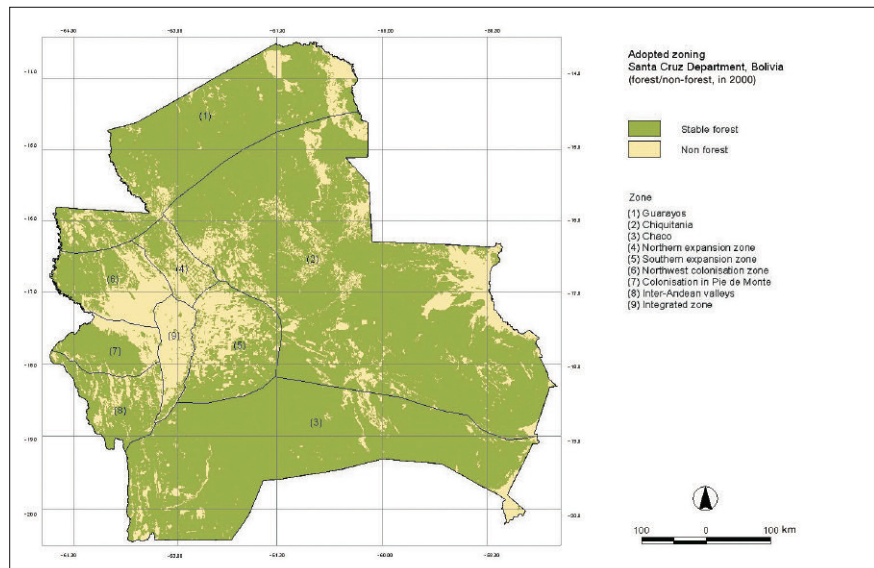


Figure 3.
Department of Santa Cruz, Bolivia: adopted zoning.

was the main economic activity in the region in the 1960s and 1970s, parallel to the development of road infrastructure, this has been followed by the development of an active agricultural sector accompanied by a growing processing industry of agricultural goods (sugar in the 1970s and soybean processing factories in the 1990s) (PACHECO, 1998). Market networks connect the region to national and international markets. These factors make Santa Cruz the main center for agricultural expansion.

The land tenure situation has changed drastically in the last twenty years (Table IV). In the 1980s, the colonization zones, both directed and spontaneous, reached 1 420 000 ha. The directed settlements were initiated in the 1960s and were intensively promoted by the state until the late 1970s, becoming the most important factor for attracting spontaneous migrants, mostly from the highlands (THIELE, 1995). In the 1990s these settlements grew very little. In contrast, community lands or areas traditionally occupied by

Table III.
Department of Santa Cruz, Bolivia: land tenure and forest use rights.

Land distribution	Area			
	1980s		1990s	
	(10 ³ ha)	(%)	(10 ³ ha)	(%)
Total department area	36 462.5	-	36 462.5	-
Individual and communal properties				
Colonization zones	1 142.1	3.14	1 142.1	3.14
Community lands	1 080.9	2.97	12 292.2	33.77
Forest use				
Protected areas	3 008.8	8.27	9,419	25.88
Forest concessions	15 238.9	41.86	3 044.2	8.36



Traditional village in the Chiquitania region.
Photo P. Pacheco.

indigenous people have been legally recognized since the early 1990s, with a current total of 12 292 000 ha. Most of these areas have been immobilized and will be titled in favor of such populations after a process of title regularization.

The areas under forest concessions declined from 15 238 000 ha to 3 044 000 ha in the period from the early 1980s to 2000 due to the implementation of new forestry regulations that disincentive forested land concentration. A large proportion of these areas is now being claimed by indigenous populations, or has been declared protected areas. The latter areas have

expanded by about 6 000 000 ha in the last twenty years due to increasing concern from the Bolivian government for biodiversity conservation, although some areas have no effective protection. The area covered by medium and large landholders and cattle ranchers is unknown, but official data mentions that about 13 000 000 ha were allocated in favor of such producers in the department of Santa Cruz (CNRA, 1995). Nevertheless, a portion of these areas has an uncertain legal status, and competing claims persist mainly between indigenous populations in the *Chiquitania* and *Guarayos* zones.

Differentiated dynamics of agricultural development

The dynamics of frontier expansion observed in Santa Cruz are quite differentiated in the zones considered. The following interpretation was supported by multinomial logistic regression models, which allow the exploration of the role of accessibility, biophysical conditions, and land tenure and zoning restrictions in the explanation of deforestation patterns. Detailed information on the modeling methodology can be found in MERTENS *et al.* (2003). Statistical parameters were estimated for three periods of time (i.e. before 1989, from 1989 to 1994 and from 1994 to 2000).

Frontier expansion is linked to the development of: (i) a peasant frontier in and around the areas settled by the government as rural settlements to the northwest and west of the city of Santa Cruz (Figure 3, zones 4, 6 and 7) and (ii) an entrepreneurial frontier in areas closer to Santa Cruz allocated to medium and large landholders and in areas of greater development of mechanized agriculture to the northeast and east of Santa Cruz (Figure 3, zones 9 and 5, respectively).

The zones surrounding the city of Santa Cruz, therefore, experienced the highest deforestation rates (Table V). In fact, proximity to the main settlements, particularly to the city of Santa Cruz, is the main factor associated with deforestation patterns. The zones mentioned above also concentrate almost all the colonization area settled by the government and do not contain any protected areas (except the Amboro National Park, which covers the southern part of zone 7). A further characteristic of the areas mentioned consists of an increasing area devoted to community lands and decreasing areas under logging concession (Table IV).

Table IV.
Land tenure and forest use rights in the zones considered (% zone area) in the early 1980s and in 2000.

Name	Colon. zone	Community lands		Protected areas		Logging concessions	
		1980s	2000	1980s	2000	1980s	2000
1. Guarayos	0.00	1.25	32.66	9.22	20.45	90.52	19.00
2. Chiquitania	0.00	4.50	17.00	2.01	23.88	53.16	11.13
3. Chaco	0.17	3.55	82.19	0.00	48.36	6.69	0.00
4. Northern expansion zone	38.55	2.44	16.81	0.00	0.00	35.58	10.19
5. Southern expansion zone	11.61	1.51	26.45	0.00	2.49	14.15	0.00
6. Northwest colonization zone	13.79	0.00	0.00	1.07	0.00	64.28	13.49
7. Colonization in "pie de monte"	12.32	0.00	0.00	54.96	55.92	4.17	0.00
8. Inter-Andean valleys	0.70	0.00	9.11	0.27	0.00	4.74	3.57
9. Integrated zone	25.97	0.00	23.13	1.91	0.00	2.49	0.00

Table V.
Department of Santa Cruz, Bolivia: land cover change by zones.

Zones	Non forest	Stable forest	Land cover		
			Before 1989 (10 ³ ha)	1989-1994 (10 ³ ha.y ⁻¹)	1994-2000 (10 ³ ha.y ⁻¹)
1. Guarayos	719.8	4 762.5	16.5	2.7 0.06	6.6 0.14
2. Chiquitania	2 211.5	12 107.2	128.7	12.5 0.10	30.6 0.25
3. Chaco	401.4	7 870.8	70.7	8.7 0.11	15.5 0.20
4. Northern expansion zone	82.7	390.3	120.4	13.8 3.53	23.6 6.05
5. Southern expansion zone	26.7	1 246.1	117.7	35.9 2.88	92.7 7.44
6. Northwest colonization zone	143.0	799.1	429.2	10.0 1.25	32.6 4.08
7. Colonization in "pie de monte"	61.1	718.6	185.6	4.3 0.60	15.2 2.12
8. Inter-Andean valleys	159.9	983.4	77.0	5.6 0.57	6.9 0.71
9. Integrated zone	80.6	106.5	445.4	11.0 10.34	17.1 16.02
Santa Cruz Department	3 886.7	28 984.4	1 591.0	104.5 0.36	240.8 0.83

First line: (area, thousand ha)
Second line: (yearly rate of deforestation)

A different dynamic is observed in the large area of the *Chiquitania* (Figure 3, zone 2) where, in addition to forest extraction, cattle production constitutes the main economic activity. In this area logging concessions were the predominant land use until the mid-1990s, and the area covered by community lands and protected areas have both grown substantially since the early 1990s (Table IV). In the same decade there was growing pressure of forest clearing for pasture expansion in relation to a growing demand from the Santa Cruz market for meat. In contrast to the trends mentioned above, there has been little pressure of forest clearing in the zones where indigenous populations are prevalent such as *Guarayos* and *Chaco* (Figure 3, zones 1 and 3 respectively).

In Bolivia, in contrast with other patterns of frontier expansion, small farmers have not been displaced by a large farm sector. Therefore, peasant settlements have persisted over time and the entrepreneurial producers have extended over areas defined by the government as suitable for intensive agricultural development (THIELE, 1995). The area occupied by small farmers is basically limited to higher rainfall areas, which are more suitable for rice production, while medium- and large-scale farmers have moved to areas more suitable for developing mechanized agriculture. Rainfall decreases sharply to the south and east moving from the Andean foothills into the dry Chaco. Statistical analyses reveal that the influence of access to roads, rainfall and soil quality declined over time, in association with migration dynamics and the major agricultural shifts experienced in Santa Cruz.

In the 1960s, when the government initiated a program of import substitution, colonists and large farmers both contributed to the expansion of the areas under production with rice and cane, therefore requiring land with the same ecological characteristics. This brought them into potential conflict, although at a



Forest clearing in the *Chiquitania* region.
Photo J. Johnson.



Large scale agriculture in the expansion zone.
Photo from: www.bolivialand.com.

time when public land was an abundant resource; some small farmers were displaced further away from the integrated zone. In the 1970s and 1980s, medium and large farmers expanded into ecological areas with lower rainfall which are less suited to slash-and-burn agriculture based on rice production. This occurred because these producers began to benefit from subsidized credit to produce cotton, a crop that demands lower rainfall. In the late 1980s and early 1990s the area under soybean, which cannot tolerate high rainfall, expanded into the southern expansion zone. (ARRIETA *et al.*, 1990; PACHECO, 1998; THIELE, 1995). The livestock sector has evolved somewhat independently due to the existence of a large zone where livestock production can easily be developed.

Table V, in accordance with the dynamics mentioned, shows that by 1989 the areas with greater pressure of forest conversion to agriculture were those occupied by both directed and spontaneous colonization. About 50 percent of forest clearing occurred in areas dominated by small farmers until late the 1980s, and they were often blamed for being the main agents of deforestation at that time. Even after taking into account soil quality, rainfall and accessibility, colonization zones underwent more deforestation, while forest concessions and protected areas experienced less deforestation. However, location in a protected area or forest concession provided less effective protection from deforestation in these periods, while location in a colonization zone ceased to be associated with higher deforestation rates.

Conclusions

This trend reverted in the following years, when both medium- and large-scale producers became the main agents responsible for deforestation, with higher rates in the new frontiers. In the period from 1989 to 1994, deforestation continued to increase in the zones dominated by small farmers, but it grew at exponential levels in the zones dominated by medium and large commercial farmers by about 45 000 ha/year.

In the period from 1994 to 2000 forest clearing continued to grow in both types of frontiers, although there was greater growth in the entrepreneurial frontier. While deforestation was about 71 000 ha/year in peasant frontiers, it was equivalent to 110 000 ha/year in areas with a large presence of medium- and large-scale farmers. The area deforested annually on average in the *Chiquitania* and *Chaco* also duplicated in the two zones.

The acceleration of deforestation has different explanations according to the type of frontier. The growth of deforestation in the peasant frontier is due to greater pressure on stand forest around the settlements rather than as a result of the expansion of the settlements over new areas. Most of the pressure comes from efforts to mechanize rice production and from the introduction of soybean during the winter season, in addition to the increasing interest of farmers to expand their livestock activities in order to improve their cash income (URIOSTE, PACHECO, 2001). In such areas deforestation patterns tend to be associated mostly with the proximity to existing agricultural lands (i.e. a *diffusion* process). In contrast, the entrepreneurial frontier grew under the influence of fiscal incentives to exports, subsidized public fees in the railroad system, the construction of new roads, and policies that made new lands available at low cost to large landholders. In addition, a decisive factor can be found in the favorable market conditions for exporting Bolivian soybeans to the Andean market (KAIMOWITZ *et al.*, 1999).

This paper shows the strong interaction existing between agricultural frontier development and deforestation in the department of Santa Cruz, while highlighting that this has depended largely on factors located at the macro-level. It also illustrates that the spatial patterns of land use change in the early stages of frontier development were greatly influenced by variables such as access to roads, rainfall and soil quality, but that the importance of such variables declined over time in association with major agricultural shifts experienced in Santa Cruz. In this light, fine tuned analysis of land-use trajectories linked to the evolution of the agricultural sector contributes largely to understanding the dynamics of agricultural frontier development when associated with the contextual factors that influence such trends.

In Santa Cruz, pressures on forest cover were low until the middle of the 1950s, and deforestation remained low to international standards over the following three decades. It was after the mid-1980s, as a result of major shifts in the macro-economic policy, that forest conversion to agricultural uses exceeded the average regional rate. Three major areas have undergone higher forest conversion in Santa Cruz: the peasant frontiers, the entrepreneurial agricultural frontier, and the livestock frontier of the *Chiquitania*. While small farmers were the main agents responsible for forest clearing before the 1980s, this trend reverted in the following years due to medium- and large-scale farmers who began to convert forest more actively to agricultural uses. The livestock sector has historically contributed little to deforestation but that trend has quickly reverted in recent years. In contrast, the zones where indigenous people are dominant have had lower rates of deforestation.

The agricultural frontier development and subsequent deforestation experienced in Santa Cruz in the last four decades has not followed a similar pattern to that found in any other

tropical country of the region. It is characterized as a profitable agricultural land use, although not all producers have benefited equally. To a large extent, the way in which the land has been allocated, the road development, and the policies targeting the agricultural sector, in addition to the fiscal incentives set up at a macro-level to benefit some specific groups of producers, have all been factors that have decisively contributed over time to defining the trajectory of land use evolution in Santa Cruz. Statistical analyses performed here suggest that trends of deforestation will not decrease in the following years and that deforestation is likely to be lower in community lands, in addition to the fact that location in a protected area or forest concession is likely to provide less effective protection from deforestation in the future.



Corn and soybean silos in Santa Cruz.
Photo K. Evans.



Large scale agriculture in the expansion zone.
Photo from: www.bolivialand.com.

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