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Post-Frontier Forest Change Adjacent to Braulio Carrillo National Park, Costa Rica

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Effective biodiversity conservation in national parks depends to a large extent on adjacent forest cover. While deforestation and forest fragmentation as a result of colonization and agriculture have been widespread in neotropical countries over the past few decades, in some places agricultural intensification, wage labor, and rural to urban migration are becoming the most important emerging trends. Changes like this have resulted in forest recovery in other places, mostly in temperate zones, but there have been few studies of this phenomenon in the tropics. This paper presents a case study from a national park buffer zone in Costa Rica. An expansion of Braulio Carrillo National Park (BCNP) in 1986 forced the closing of a frontier that had been characterized by spontaneous colonization and widespread forest-to-pasture conversion. After that time, the Sarapiquí region surrounding the northern sector of BCNP underwent a dramatic social and economic transformation. Population more than doubled, new roads created easy access to a coastal port and the capital city (San José), industrial agriculture and ecotourism enterprises expanded, and population and urbanization along major highways increased. In spite of government reforestation and forest protection programs and changes in rural people's attitudes favoring forest conservation, we find that there has been only slight detectable forest recovery in satellite imagery and that forest fragmentation continued, even in remote rural areas near BCNP with stable or shrinking population. We attribute this to the consolidation of landholdings into large cattle ranches and smaller hobby ranches, driven by an inflow of capital from urban areas and

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developed countries. This pattern has important implications for the management of this and other national park buffer zones. We suggest that strategies focused only on sustainable land use inside buffer zones are unlikely to succeed when carried out in a context of certain macro-level changes. Conservation of endangered biological resources will only be possible if we broaden our thinking about national parks and adjacent lands in the tropics to address new land ownership and use patterns that are occurring as a result of globalization, urbanization, and expanding wage labor employment.

KEY WORDS: land use and land cover change; forest transition; national park buffer zones; sustainable development; Costa Rica.

INTRODUCTION

The conversion of forests to agricultural land uses in association with the colonization of forested frontiers has historically represented one of the most significant threats to biodiversity in the neotropics (Sayer, 1991). The establishment of national parks and protected areas has been an important strategy for forest conservation, but biodiversity in many protected areas has been threatened by forest loss and fragmentation on adjacent lands (Laurence and Bierregaard, 1997; Sánchez-Azofeifa *et al.*, 2003b; Saunders *et al.*, 1991; Schelhas and Greenberg, 1996). A key strategy for addressing this limitation in the effectiveness of protected areas has been to promote sustainable, forest-based land uses on private lands adjacent to core protected areas, often in buffer zones (Sayer, 1991; Schelhas and Greenberg, 1996). Buffer zones are dual purpose and seek to protect national parks by surrounding them with vegetation that extends habitat outward and provides migration corridors for species, while at the same time providing economic benefits to local people (Sayer, 1991). Successful forest conservation on private lands and in buffer zones requires understanding the social, economic, and policy processes that determine land cover change and intervening in such a way as to promote favorable changes in forest cover.

One of the most serious issues affecting protected areas in the tropics has been deforestation of surrounding lands. Tropical deforestation has been an issue of practical and academic concern for several decades, and a well-developed literature has emerged on its causes, patterns, and measures to reverse or prevent it. Studies have generally found deforestation to be best explained by a combination of proximate causes and underlying driving forces[4] that play out in specific ways in different places (Geist and

[4]Proximate causes are immediate actions at the local level, such as agricultural and pasture expansion, wood extraction, and road expansion. Underlying driving forces are fundamental

Lambin, 2002). While population growth is an important underlying factor, a number of cross national studies agree that it is not the primary driver of deforestation at the local scale over moderate time periods of few decades (Bawa and Dayandanam, 1998; Geist and Lambin, 2002; Templeton and Scherr, 1999). Rather, social and economic institutions such as mode of production, migration patterns, land policy, and resource perceptions have been found to be important intervening variables between population and forest cover change (Lambin *et al.*, 2001; Mather, 1992; Mather and Needle, 2000).

The history of human–forest relations includes both losses and gains in forest cover. While the tropics have been subject to severe and widespread deforestation in the past few decades, forests have returned on a large scale in some regions of the world following major economic changes. Mather (2002) found that reforestation in three European countries in the nineteenth and twentieth centuries occurred after agricultural intensification, rural-to-urban migration, and changes in transportation and energy sources. Pfaff (2000) found that forests recovered in New England in the mid nineteenth to twentieth centuries as populations concentrated in urban centers along rivers due to industrialization and "export" of agricultural production to the Midwest. Rudel (2001) found that, in the mid twentieth century, changing cropping patterns, new agricultural technology, and the increasing employment opportunities in the industrializing cities depopulated the rural U.S. South and led to reforestation. Grau *et al.* (2003) found that in Puerto Rico forest cover increased from 9% to 37% of the island's area due to urban and international migration, changing agricultural economies, and industrialization.

There is some evidence of a U-shaped curve where forest cover first decreases with population growth and then increases as a result of technological and institutional innovations (Templeton and Scherr, 1999). Mather (1992) discusses a general pattern of forest cover change called the "forest transition," in which deforestation trends are replaced with reforestation following economic development and urbanization. Forest transitions can be driven by material changes such as concentration of agriculture on the lands most suited for it, technology change and agricultural intensification, changes in the demand for and production of forest products, as well as by value changes such as increasingly viewing forests as a source of recreation and non-commodity values (e.g., aesthetics and biodiversity conservation) rather than a source of timber or agricultural land (Mather, 1992, 1998; Mather and Needle, 2000; Perz *et al.*, 2005).

social processes, such as human population growth, poverty, agricultural policies, timber markets, and technological change. (Geist and Lambin 2002).

Grau *et al.* (2003) predict that the world trend is toward population stabilization and a globalized economy that promotes agricultural intensification, industrialization, and rural-to-urban migration, and suggest that a potential consequence is abandonment of marginal agricultural lands and forest recovery. Europe and North America provide the most convincing evidence that this sort of forest transition might occur, but it is unclear if tropical countries will follow similar trajectories. Puerto Rico provides a tropical example consistent with the European pattern (Grau *et al.*, 2003), but Puerto Rico has a political and economic situation that is unique in Latin America. Klooster (2003) finds evidence that forests are becoming reestablished on marginal lands in Mexico but also finds that harvesting continues to degrade remaining forests, suggesting a different type of or incomplete forest transition. Rudel *et al.* (2002) and Bilsborrow and Carr (2001) found evidence in Latin America of "hollow frontiers" in which rural population declined without forest recovery. The hollow frontier thesis is consistent with research on the political ecology of deforestation in Central America, which has shown how policies and inequities in access to resources has resulted in cycles where small-scale farmers colonize forested frontier regions and then are replaced by large cattle ranches, whereupon they move to another forested frontier where the process is repeated (Rudel *et al.*, 2002; Stonich and DeWalt, 1996). Recent research has found that in some cases the people displaced in these processes migrate to urban areas or find labor on large-scale agricultural enterprises rather than migrating to forested frontiers (Rudel *et al.*, 2002).

We still have much to learn about the conditions under which deforestation and forest recovery take place in the tropics, and what the implications are of these changes for conservation efforts. Previous studies on the links between human populations and forest cover change emphasize that complex suites of social, economic, cultural, and political variables have differing mediating roles at different places (Geist and Lambin, 2002; Perz *et al.*, 2005). Developing a body of case study literature that shows how these factors interact and produce unique outcomes in different places is needed to underpin generalized models. The present study analyzes how forest cover on private lands in a national park buffer zone in Costa Rica has changed over a 30 year period in relation to social, economic, and policy changes. This time period has seen significant social and economic changes of the sort that have been closely linked to changes in rates of deforestation and reforestation in other places. We analyze overall trends and dynamics of socioeconomic and forest cover changes, and discuss what these changes may mean for national park buffer zone management.

STUDY AREA

Costa Rica is well-known globally for its extensive park and protected area system (Evans, 1999). The Central Volcanic Cordillera Biosphere Reserve in northeast Costa Rica includes Braulio Carrillo National Park (BCNP), La Selva Biological Station (LSBS), and two areas of private landholdings designated as buffer zones (Butterfield, 1994) (Fig. 1). This reserve system conserves a rich tropical forest biodiversity, ranging from the lowland forests of La Selva Biological Station (elevation 36 m) to the top of Barva Volcano (elevation 2,906). It is notable for being one of the few places in Central America where an intact forested altitudinal gradient is formally protected, which is important for the many species that engage in seasonal altitudinal migrations (McDade and Hartshorn, 1994; Schelhas, 1991). Schelhas (1991) analyzed the external issues facing Braulio Carrillo National Park, finding that the greatest threat to the park results from the small size and narrow shape of its northern sector, which protects and connects to critical lowland habitat (of which relatively little is within the national park), and that protection of the park's resources requires maintaining forested habitats with conservation value on private lands in the buffer zone—which lies outside the park but within the biosphere reserve. Sánchez-Azofeifa *et al.* (1999, 2003a) studied the dynamics of tropical deforestation and fragmentation in the same region, finding a significant deforestation gradient that has been contributing to the isolation of the park from the nation's network of parks and biological reserves.

In this paper, we concentrate on the northern sector of the Biosphere Reserve, comprised of the narrow, forested corridor connecting the larger, original higher elevation park regions to the lowland forests of La Selva Biological Station and the buffer zones of private lands on either side of the corridor (Figs. 1 and 2). This area is bounded on the outside by two white-water rivers, the Puerto Viejo and the Sarapiquí. Paved highways parallel these rivers to the outside of the biosphere reserve, with few reliable and adequate bridges into the Reserve. The buffer zones are a formal part of the Biosphere Reserve (Butterfield, 1994), but government intervention in and management of these zones has differed only slightly from that of other private lands in the region because the biosphere reserve is a UNESCO designation and not a Costa Rican government administrative unit. The principal differences between the buffer zones and other private lands is that the buffer zones are patrolled more regularly by park rangers to enforce laws pertaining to forest clearing and hunting, and that they are priority areas for some natural forest management and reforestation efforts (particularly those of one NGO officially working with the Central Volcanic Cordillera

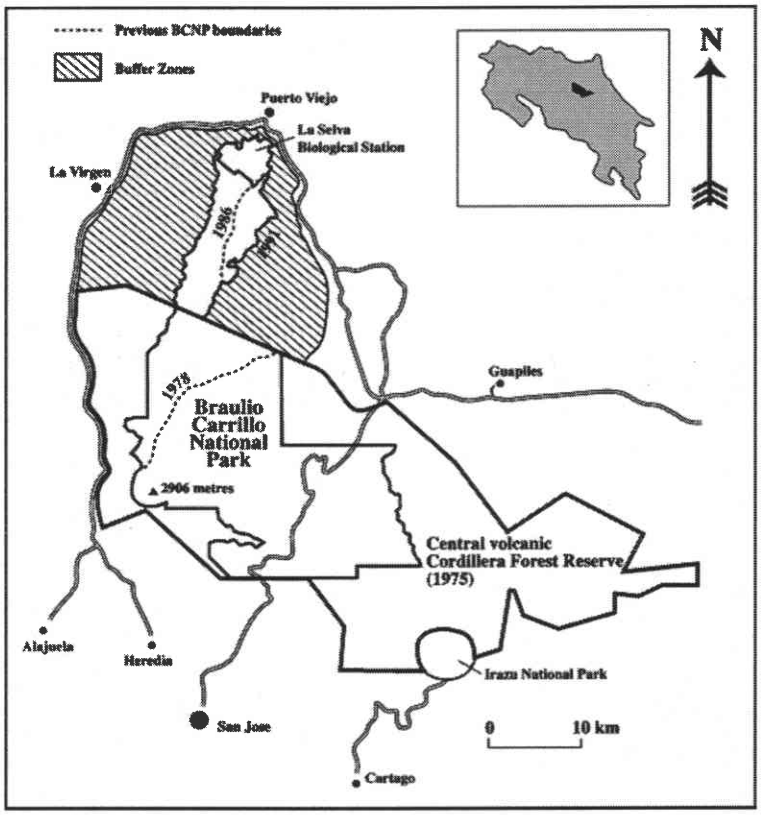

Fig. 1. Map of the Central Volcanic Cordillera Biosphere Reserve (CVCBR), showing boundary changes and dates that boundaries were expanded.

Conservation Area, which includes the biosphere reserve, and will be discussed in detail below).

Settlement

Sarapiquí, once a lightly populated trade route to the Caribbean, underwent rapid colonization and population increase in the second half of the twentieth century (Table I). Colonization was driven by multiple factors, including: (1) national population growth (Table I); (2) concentration of existing agricultural land in relatively few hands, which drove people to the frontiers in search of land (Carrière, 1990; Cruz *et al.*, 1992); and (3)

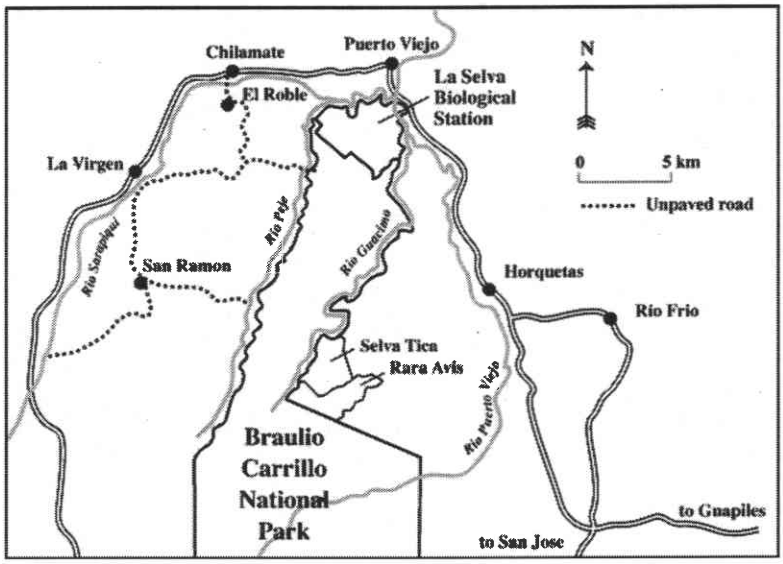

Fig. 2. Map of the Northern Sector of the CVCBR.

an economic crisis in the 1980s that led to a government policy promoting return to the land, self-sufficiency, and new land distribution projects in northern Costa Rica (Brockett, 1998). Sarapiquí was a major site of both government-sponsored and spontaneous colonization, particularly as access was facilitated by road construction and improvements through the 1980s. In the 1990s, population in Sarapiquí continued to grow rapidly (Table I). Much of this growth was in urban areas along the roads between La Virgen and Puerto Viejo (Table II), and, to a lesser extent, Puerto Viejo to Horquetas, as plantation agriculture (primarily banana and pineapple) and service sector jobs increased in this zone.

Protected Areas

The expansion of Braulio Carrillo National Park in 1986 to connect with La Selva Biological Station effectively closed the frontier of unoccupied lands in near proximity to these two protected areas (Butterfield, 1994). Homesteading of vacant public domain lands gave way to organized invasions of underused private lands, often by workers laid off from local banana plantations, and Sarapiquí became one of the nation's most active

Table I. Population of Costa Rica and Sarapiquí 1864–2000 (from Costa Rican Government Census Records)

Year	CR Population	(%) increase/year	Sarapiquí Pop	(%) inc./yr
1864	120,499	—	NA	—
1883	182,073	2.7	NA	—
1892	243,205	3.7	471	—
1927	471,524	2.7	515	.3
1950	800,875	3.0	2,169	14.0
1963	1,336,274	5.1	4,856	9.5
1973	1,871,780	4.0	12,618	15.0
1984	2,416,809	2.6	18,909	4.5
1989	Not Available	Not Available	23,511	4.9
2000	3,824,593	3.6	45,218	8.4

squatter zones in the 1980s (Brockett, 1998; Butterfield, 1994; Vandermeer and Perfecto, 1995). In 1988, the Central Volcanic Cordillera Biosphere Reserve was established under the UNESCO Man in the Biosphere Program, creating buffer zones on private lands along the narrow northern extension of BCNP that connects to LSBS (Butterfield, 1994). In 1996 the country was divided into 10 major conservation areas, each based around a major national park. Administration of each area was decentralized, with park rangers and forest guards from Costa Rican Ministry of Environment and Energy patrolling both national parks and private lands adjacent to enforce laws against forest clearing, tree felling, and hunting (Watson *et al.*, 1998). Each conservation area has an affiliated foundation to raise additional funds and develop conservation projects. For the Central Volcanic Cordillera Conservation Area, the NGO is FUNDECOR, founded in 1989 with an endowment from USAID (Escofet, 1997). FUNDECOR has developed projects in natural forest management, reforestation, carbon bonds,

Table II. Dwellings in Study Area

		San Ramon		El Roble Center	
Year	La Virgen to Chilamate	Outlying	San Ramon Center	Outlying	El Roble Center
1983	204				
1989		76	101	38	16
1996	980	79	157	31	45

Notes. La Virgen to Chilamate based on census maps. Interior areas in the study area were skipped during the 1983 census. For San Ramon and El Roble: 1989 data from maps drawn by J. Schelhas during field work. 1996 data from census maps.

and environmental service payments for forest conservation from hydroelectric developments (Escofet, 1997).

Laws and Policies

The colonization of Sarapiquí in the 1950s and 1960s took place under a series of laws and policies that were intended to promote the settlement of uninhabited public lands and productive use of private lands. These had the effect of promoting deforestation because ownership claims were generally proved by clearing the forest and planting crops or pasture (Brockett and Gottfried, 2002; Watson *et al.*, 1998). Although the Forest Law of 1969 outlawed spontaneous colonization on public lands, squatter invasions of public and private lands continued (Brockett and Gottfried, 2002; Hartshorn *et al.*, 1982). The 1969 Forest Law and its revisions (1973, 1979, and 1986) required plans and permits to cut trees and clear forest, but did little to slow deforestation due to lax enforcement (Brockett and Gottfried, 2002). During the same time period, efforts to promote reforestation increased. Beginning in the early 1970s, financial incentives for reforestation, natural forest conservation, and private protected areas have been increasingly offered (Brockett and Gottfried, 2002; Watson *et al.*, 1998). A major rewriting of the Forest Law in 1996 provided for government payments to owners of standing forest for the provision of environmental services.

Economic Change and Tourism

In the 1990s, a number of economic changes diminished pressure to clear forests. Forests were increasingly recognized as an economic asset and the value of forest land in many places surpassed that of cleared land due to forest scarcity and growing interest in investment in forest lands (Brockett and Gottfried, 2002; Schelhas, 2001). Part of this was due to the rise of ecotourism, which became a major economic activity in Costa Rica. Private forest and wildlife reserves expanded, and internationally funded forestry projects were established to promote sustainable extraction of timber, nontimber forest products, and other integrated conservation and development options (Brockett and Gottfried, 2002; Langholz *et al.*, 2000; Watson *et al.*, 1998). Forestry and forest conservation were widely promoted through Costa Rica's National Forest Financing Fund (FONAFIFO), which supports the forestry activities of small and medium producers, and by a general increase in NGOs and *campesino* groups involved in forestry and conservation (Brockett and Gottfried, 2002; Evans, 1999; Watson *et al.*, 1998).

Forest cover at the national level in Costa Rica has shown a trend toward recovery after the mid-1980s. A study by FONAFIFO found that Costa Rica's forest cover increased from 27% in 1987 to 47% in 2000, including an increase of almost 50% in forest cover in the Nicoya Peninsula, which had suffered the greatest degree of deforestation in the country (Rodriguez, 2004).

By 2001, both Costa Rica and Sarapiquí had undergone major transformations. Nationally, the traditional agricultural exports of coffee, bananas, and cattle became less important to Costa Rica's economy. Tourism surpassed bananas as the major earner of foreign exchange in 1994; nontraditional agricultural exports increased throughout the 1990s; and a computer industry developed and industrial exports increased through the 1990s (Brockett, 1998; Brockett and Gottfried, 2002; Hall, 2000). Timber prices rose enough to make forestry profitable for some landholders, and significant amounts of unsubsidized reforestation took place (Brockett and Gottfried, 2002, pp. 19–20). At the same time, large areas of pasture were abandoned in parts of Costa Rica and allowed to return to secondary forest (Kleinn *et al.*, 2002; Müller, 1998). In Sarapiquí there were two major changes: (1) a number of private nature reserves and ecotourism operations opened up, and (2) commercial banana and pineapple plantations expanded dramatically around Puerto Viejo in the early 1990s (Brockett and Gottfried, 2002; Montagnini, 1994; Vandermeer and Perfecto, 1995). The increase in investment and jobs brought about a boom in population and businesses in Puerto Viejo and the surrounding region (McDade, 1994, p. 298). Now only two hours from San Jose, Sarapiquí increased in significance as a destination for both international and national tourism, as well as a location for country homes for urban residents.

METHODS

This paper combines qualitative and quantitative social research with analysis of forest cover from satellite imagery. Data on the social aspects of landscape change were collected during two periods (ten months in 1988–89 and one and a half months in 2001) by using household surveys and ethnographic techniques. During the first period, random samples of landholders were interviewed in three communities; during the second period of field research, heavy rains, bridge outages, and impassable roads permitted only purposeful sampling in two communities.[5] The differences in methods during the two time periods did not produce fully comparable

[5]Purposeful sampling include following up on a set of case study landowners from earlier research, and selected interviews with key informants.

data sets. However, we were able to analyze changing land use and household economic patterns by using key informant interviews and time series interviews with selected households.

Two land cover information sources were used in this study. The first was derived from 1:40,000 aerial photography acquired between 1960 and 1965 by the U.S. Army to produce the first 1:50,000 topographic maps for the country. For labeling purposes we have named this data set "1960 forest cover." In addition, comprehensive remote sensing-derived data on forest cover were developed from Landsat Multispectral Scanner (1979), Landsat Thematic Mapper 5 (1986, 1996), and Landsat Enhanced Thematic Mapper (ETM+) 7 (2000). All images are from World Reference System (WRS) the path 15 row 53. Landsat images where first atmospherically corrected, georectified to 1:50,000 topographic maps and then classified as forest (canopy closure >80%), agriculture and pasture lands, clouds, and water. Deforestation was estimated for 1960–1979, 1979–86, 1986–96 and 1996–2000. All non-forest cover detected in the 1960 aerial photograph was labeled as "deforested before 1960." Forest cover maps were converted from raster to vector format using a geographic information system (GIS) and a minimum mapping unit of 3 ha was applied to all data sets. The GIS information was later ingested into Fragstats (McGarigal and Marks, 1994) to estimate the absolute number of patches for each year, the mean patch size, and the patch size standard deviation. A complete explanation of the methods used in this study can be found in Sánchez-Azofeifa *et al.* (1999) and Sánchez-Azofeifa *et al.* (2001). Figure 3 presents the forest cover and deforestation maps used in this study.

Frontier Land Use

When Sarapiquí was first colonized, agriculture was confined to alluvial floodplain soils and lands adjacent to the major travel routes. As a result of organized colonization programs and spontaneous colonization, in the 1960s and 1970s agriculture began to shift to more upland areas. Early upland colonists generally engaged in shifting agriculture to produce basic foods and generated cash by tapping wild rubber trees, and selling high value timber, and dried river fish (Butterfield, 1994; McDade and Hartshorn, 1994; Montagnini, 1994). Because of the remoteness of the region, only very high value trees were sold and most of the trees that were felled through the 1970s were burned or left to rot (Brockett and Gottfried, 2002; Schelhas, 1991). In the 1950s, rice began to be replaced by extensive cattle production as a cash crop, often for export, and by the late 1960s pasture was the predominant agricultural land use in

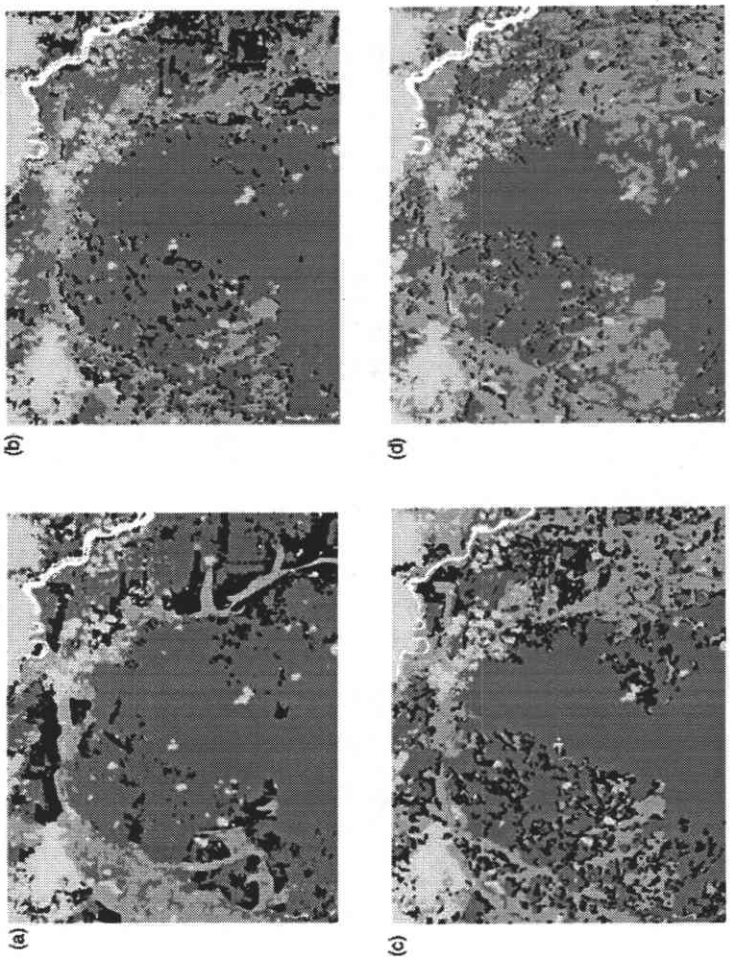

Fig. 3. Forest Cover Change in the Northern Sector of the CVCBS, (a) 1960–1979, (b) 1979–1986, (c) 1986–1996, (d) 1996–2000 (Area shown same as in Fig. 3) (Key: Black = Deforestation. Dark Gray = Forest. Intermediate Gray: Crops and Pasture. Very Light Gray: Clouds. White: Water).

Table III. General Forest Cover and Fragmentation Statistics

Year	Forest area (ha)	Percentage landscape	Number patches	Mean patch size (ha)	Patch size std. dev. (ha)
1960	53,930	75.6	403	134	2479
1979	43,161	60.5	586	74	1289
1986	42,893	60.2	405	106	1588
1996	34,573	48.5	483	72	1201
2000	32,242	45.2	1026	31	787

Sarapiquí (Montagnini, 1994). By 1979, forest cover had been reduced to about 40% of the landscape, found in 586 patches with a mean size of 74 ha. (Table III).

By the late 1980s, agriculture in the wider Sarapiquí region was dominated by cattle raising and banana plantations, augmented by smaller areas in nontraditional export crops such as citrus, black pepper, and ornamental plants (Schelhas, 1991, 1996). There were several different types of landholders in the park buffer zone, each with different agricultural systems (see Schelhas, 1996, for details). There were a number of large ranches and plantations owned by businessmen who did not reside in Sarapiquí, which were either in pasture for extensive beef cattle raising or in export agriculture (black pepper or ornamental plants). These lands generally had been acquired through purchase from the original colonists, and ranged in size from 50 to 2000 ha. Many of the cattle ranchers were investing in land rather than trying to establish productive farms, and extensive cattle operations were used to discourage squatters while producing some income to defray landholding costs. Large ranches had low stocking rates and generally employed only a few laborers. There were also large farms producing non-traditional exports that employed many people in the region, but these were mostly speculative ventures experimenting with non-traditional export crops with cash earned from enterprises in other places.

In the late 1980s, a number of the original colonists still held land and were active producers on landholdings ranging from 40 and 200 ha. Nearly all of these landholders raised dual purpose[6] cattle to produce both dairy products and meat for sale, and most also had several hectares of coffee as a supplementary cash crop. Because these landholders were often supporting relatively few people on large farms, they tended to have land extensive systems that produced enough to meet family needs with low labor

[6]Dual purpose cattle are generally a cross between zebu and Holstein cattle.

demands. Many of these farms occasionally employed day laborers to supplement family labor, but few had permanent employees.

A third major group of landholders were those with IDA (Instituto de Desarrollo Agrario) land distribution parcels, who had landholdings that ranged in size from 12 to 30 ha and generally had mixed land use systems. In the 1980s, most of these parcels were actively farmed by their legal holders, although some were illegally rented out or nearly idle. Parcel holders in the community of San Ramon engaged mostly in very intensive dual purpose cattle raising, while those in El Roble tended to grow black pepper. Parcel holders in both communities had long term plans to combine cattle, with low risk and constant returns, and intensive cash crops (black pepper, ornamental plants, or coffee) for their potential to provide high returns. Parcels were generally worked with family labor.

The final group of residents had very small farms (1 to 2 ha), house lots, or lived on rented or borrowed land. These households primarily engaged in wage labor, both as day laborers on neighboring farms and as permanent laborers on larger ranches and plantations although some had small plots of intensive crops to supplement their income. Although two of the early ecotourism ventures in Costa Rica, Rara Avis and Selva Verde, were in Sarapiquí, they provided relatively little employment for residents of the buffer zone during the 1980s (Butterfield, 1994; Evans, 1999; Schelhas, 1991). Nationally, employment in the service sector was beginning to increase at this time (Watson *et al.*, 1998), stimulating some migration out of the buffer zone in pursuit of service sector jobs in urban areas.

The abundance of trees and forests on the frontier meant that few landowners of any type placed much value on them. Forested land was considered unimproved and was of low monetary value; cleared land sold for twice the price of forested land (Schelhas, 1991). Forests were often cleared to increase land value, but also to demonstrate that land was being used, since forests were associated with underutilized land and thus were prime targets for squatter invasions. High value trees were sold or left standing for later harvest, while other trees were felled and burned or left to rot. The low value of uncleared forest land, combined with the relative abundance of wood for household use and limited markets and low prices for timber, meant that there was little incentive to conserve forests. Forest clearing continued in the early 1980s (Table IV), although abandonment of cleared land resulted in nearly as much land retuning to forest as was cleared (Table V). Reforested land linked many forest patches, decreasing the overall number of patches to 405 and increasing the mean size to 106 ha. Forest clearing and some reforestation continued from 1986–1996, increasing the number of patches to 483 and reducing the mean patch size to 72 ha.

Table IV. Forest Cover Change Statistics

Period	Total forest loss (ha)	Deforestation rate (ha/yr)	Deforestation rate (%/yr)	Change in forest islands	Change in mean patch size (ha)
1960–1979	10,769	567	1.1	183	−60
1979–1986	268	38	0.6	−181	32
1986–1996	8,319	832	19.4	78	−34
1996–2000	2,332	583	6.7	543	−40

In spite of the rapid deforestation, interviews in the late 1980s revealed an incipient interest in forest conservation among many landholders. While they often took pains to point out that forests provided no food or economic returns, during farm walks and discussions about future land use possibilities many landowners noted the importance of streamside forests for watershed protection and a few expressed interest in reforestation with fast growing timber trees. In practice, most landholders had left some forest along streams and on very steep slopes for watershed protection, and many retained woodlots to meet future subsistence needs for timber or fuelwood.

Post-Frontier Land Use

In 2001, the number of dwellings had increased rapidly along the paved road between La Virgen and Chilamate and in the centers of San Ramon and El Roble, where access to the developing urban corridor was good, while the number of dwellings in rural areas had stayed the same or decreased (Table II). Land use in the BCNP buffer zones reflected the continuing processes of: (1) accumulation of land into large absentee-held ranches and plantations, (2) smallholder experimentation with intensive cash crop production, and (3) increasing wage labor. These processes operated simultaneously to produce new patterns of landownership and land use. Virtually all the original colonists' ranches had been divided among heirs or sold, mostly to absentee landowners. Some were aggregated into

Table V. Changes in Forest and Nonforest Land Cover in Hectares by Time Period

Time period	Remained forested	Deforested	Reforested	Remained deforested
1960–1979	Not Available	10,769	Not Available	Not Available
1979–1986	36,047	7,122	6,846	11,943
1986–1996	32,079	11,267	2496	16,116
1996–2000	32,226	2,308	15	27,383

large ranches, while others were used as hobby farms or weekend retreats for urban-based small businessmen.

Many of the remaining IDA parcels had been converted to intensive perennial crops (black pepper in El Roble and ornamental plants in San Ramon). However, in only about one-third of these cases was the parcel holder the producer. After more than a decade of market fluctuations, many parcel holders had lost their enthusiasm for intensive cropping and were renting their planted parcels to landless individuals who farmed them instead of engaging in wage labor. Renter turnover on these parcels was often frequent. In San Ramon, the large ornamental plant farm that previously had employed the majority of community members closed, and all ornamental plant production moved onto small landholdings. Wage labor continued to be important, as many of the small ornamental plant producers were hired wage laborers. Cattle continued to be an attractive land use choice, although declining milk and cheese prices had led most dual-purpose producers to switch to beef production. Various forms of migration were also becoming important. A number of residents in the area were commuting to La Virgen or Puerto Viejo for white-collar jobs (e.g., teaching, businesses, and government jobs), and many residents left for employment in the cities of the Central Valley of Costa Rica or the United States.

Attitudes toward forests had changed dramatically by 2001. Landowners and community members often brought up forest conservation as one of the first topics during open-ended interviews, and several landowners asked for help in finding a buyer for tracts of forest lands. Forests were no longer seen as an undesirable obstacle to economic development, and landowners of all sizes and types had reforestation plots or had allowed portions of their land to remain in or return to forest. Reforestation, with native and nonnative species, and conservation of standing primary and secondary forest, were common even in land reform settlements, and often supported by government forestry incentive programs[7] administered by FUNDECOR and other local development associations. A number of landowners had also reforested small areas without the use of government incentives. Forest clearing slowed, and landowners often retained forests in the belief that it would enable them to sell the land for a higher price or otherwise economically benefit more than they would from cleared land, which was abundant and of low productivity.

[7]Government forestry incentives included the National Forestry Finance Fund (FONAFIFO); subsidized plantations development and forest management activities through income tax deductions, transferable bonds, municipal forest funds, and a forest development fund; credits from carbon sequestration deals; and payments for protection and supply of environmental services (Watson *et al.*, 1998).

Forest cover statistics from satellite images show that the large block of continuous forest protected by the national park had suffered little or no clearing, but that some forest clearing continued in the buffer zone (Fig. 3d and Tables III & IV). Forest clearing continued to fragment remaining forests, resulting in a total number of forest patches of 1026 and a mean patch size of 31 in 2000 Little forest regrowth (only 15 ha) was detected between 1996 and 2000 (Table V). We caution that it is difficult to distinguish young forest from pasture, and some reforested or afforested lands may appear as cleared land in our statistics. However, the lack of forest recovery, along with the continued fragmentation of remaining forests, reflects the observation during field research that lands in the buffer zone continued to be consolidated into large cattle ranches and that small-scale logging and clearing in remaining forest patches continued.

SOCIOECONOMIC AND FOREST CHANGE

Human activities and forest cover in Sarapiquí have changed over time. From the 1950s to the mid-1980s, Sarapiquí was a colonizing frontier where forest was being rapidly converted to agriculture and pasture. Flux in landholding and ownership is one of the most notable characteristics of this period, as illustrated by the many colonization schemes, squatter invasions, land purchases, and government land distribution schemes. As is common on frontiers (Moran, 1988), the isolated and inaccessible land in Sarapiquí was valued more for its potential sale value than for agricultural and forestry production. This period was largely a land grab, with the frontier pushing rapidly outward. Forests were cleared because: (1) the abundance of trees and poor roads meant that they had little cash value, (2) because cleared ("improved') land sold for higher prices than forest ("unimproved") land, and (3) because a series of laws gave favorable treatment to land in agriculture or pasture. Cattle pasture was the most attractive land use because it was viable in remote areas, provided relatively good returns to labor, and was a low cost way to demonstrate productive use of land (Schelhas, 1996).

Many of the people who came to the frontier were poor and landless and had dreams of becoming successful farmers. However they were faced with a challenging task to establish productive farms in Sarapiquí due to the combined difficulties of poor soil, a harsh climate, and isolation from labor and product markets. People of greater means also came in search of investment opportunities, and when farm families had economic difficulties there was nearly always a willing buyer close at hand. Some families sold their land to get out from under their debts in spite of their aspirations

to be successful farmers, while others who did not share or gave up these aspirations and specialized in claiming and clearing land for sale. The frontier was closed with the expansion of Braulio Carrillo National Park, from 1982–86. The few large farms in the buffer zone that employed wage laborers absorbed most of the labor that had been formerly employed in forest clearing. The success of dual purpose cattle producers and the widespread experimentation with intensive export crops suitable for the Sarapiquí climate suggested that farm families could develop sustainable farm systems for small to mid-sized landholdings (Schelhas, 1996).

Over time, banana and pineapple plantations outside of the buffer zone attracted wage laborers to the road corridor and towns grew to serve the colonists, plantations, and wage laborers. Road improvements meant that many parts of Sarapiquí were now less than two hours from San José, which made the area more attractive for commercial agriculture and also as a weekend retreat. Capital flowed into the region from urban areas and other countries and for tourism investment. By 2001, Sarapiquí was no longer a remote frontier region.

Political and economic factors continued to set the major trends in the region. Those with outside capital were generally better able to hold land than resident farmers, and the consolidation of lands into large absentee-owned holdings continued. Resident producers with mid-sized landholdings (30–200 ha) essentially disappeared, with their lands becoming hobby farms or part of large ranches. The promise of sustainable small (10–30 ha) landholdings (Schelhas, 1996) faded as market fluctuations drove landowning producers out of perennial cash cropping over time. The logic of cattle—low risk, low labor, easy marketing—continued, and pasture remained a significant land use. Forest clearing slowed, and some lands were reforested, as land ownership stabilized with the closing of the frontier and legal changes meant to eliminate incentives to clear forests and provide incentives for forested land uses.

Most of the economic growth in the region took place along the road corridor in the region of La Virgen, Puerto Viejo, and Horquetas. This development was stimulated by the establishment of new banana and pineapple plantations, palm heart plantations, ecotourism enterprises, and related secondary businesses. While the population along this urbanizing corridor increased rapidly, population in the buffer zone stagnated or declined. During the 1990s, the buffer zone attracted few new settlers and the people remaining in the buffer zone changed their orientation from frontier land claiming and farming to a focus on wage labor in urban areas and on plantations on the alluvial soils near them. Residence patterns changed as buffer zone residents moved into towns and settlements with good access to the urbanizing corridor. Costa Rica continued its shift from an

agricultural economy to a manufacturing economy, and there were more and better jobs available in the urban areas. Correspondingly, many landowners shifted their livelihood expectations and efforts and chose to pursue wage labor options rather than agriculture. This shift, in turn, increased the importance of securing an education for children so that they would be able to participate in the new economy, and the schools in the urban areas also attracted residents to these places. In spite of the decline of resident farmers in the interior parts of the buffer zone, deforestation has slowed but continued, forest recovery has been minimal, and fragmentation of forests has accelerated because cattle pasture has remained an important land use and logging has continued (Fig. 3 and Tables III, IV, and V). This pattern is different than that of the southern United States and Puerto Rico, but similar to that of Mexico and Ecuador (Grau *et al.*, 2003; Klooster, 2003; Rudel, 2001; Rudel *et al.*, 2002)

CONCLUSIONS

In this paper we have outlined long term changes in forest cover in Sarapiquí and showed their relationship to social, economic, political, cultural, and conservation factors by using remote sensing and ethnographic data. We found evidence that the closing of the frontier, combined with local infrastructure improvements and a shift in the national economy away from agriculture, has resulted in a shift of residence patterns and economic activity away from the forest frontier and toward the developing urban areas in the Sarapiquí region. This change is accompanied by a slowing of forest cover loss and some reforestation in the more remote, interior areas of the park buffer zones, although forest fragmentation and some forest clearing continues. Widespread reforestation, however, has been limited by the continued expansion of large cattle ranches and the forest clearing that continues around the edges of existing forest patches. These results raise three issues of conservation science and policy relevance: (1) Has a forest transition occurred in Sarapiquí? (2) Is human welfare improving? (3) What are the implications of our findings for protected area and conservation policy?

Consistent with the literature, we find little relationship between population numbers and forest cover. Intensification of agriculture on the better alluvial soils in the more accessible lowlands and related urban development along major roads have concentrated population growth along an urbanizing corridor and decreased interest in agriculture and settlement in remote interior regions thereby reducing the incentive to keep lands clear of forests for both production and land claiming. At the same time, a growth in ecotourism and implementation of government policies

more supportive of forest retention have changed the attitude of landowners to the point where forests are less likely to be seen as merely an impediment to development and are increasingly valued both in their own right and as an economic resource. A national shift to an industrial and service economy has increased the value of education and created new opportunities for urban employment, which in turn continue to draw people from rural to urban areas. In some regions of Costa Rica, forest cover has increased significantly (Klein *et al.*, 2002; Rodríguez, 2004). These changes are consistent with the forest transition theory, and Costa Rica as a nation may very well be in the process of a forest transition similar to what Puerto Rico has experienced over the past four or five decades. However, forest recovery in Sarapiquí has thus far has been prevented by the concentration of lands into large and small absentee-owned cattle ranches, producing a hollow frontier.

Our study area is smaller than the national and continental scales typical of the forest transition literature (Mather, 1992, 2002). Community and landscape level studies of forest transitions have found a number of complexities and ambiguities, and we find similar ones in our study. As in New England (Pfaff, 2000), trade has meant that food products can be imported and local production can be dedicated to activities for which the region has a comparative advantage, in this case specialty export crops. Like Rudel *et al.* (2002), we find evidence of tendencies toward both a hollow frontier and a forest transition in the park buffer zone, but in this case the hollow frontier trend is currently dominant. There is a process of consolidation of lands in the buffer zone into large cattle ranches that support few people but remain deforested. Like Browder and Godfrey (1997), we find that urban–rural connections are important. Much of the capital for land purchases and enterprise in the region comes from family members outside the region. Accessibility to urban areas of the Central Valley has led to the purchase of hobby farms and investment in all types of enterprises by outsiders. Flows of capital and ideas from outside are major factors in land use choice and change in the buffer zone. In some cases the result is forest conservation, but more commonly it is cattle ranching and other agricultural ventures.

Forest transitions in Europe, the U.S., and Puerto Rico have resulted from the choices of individual rural residents who were attracted to opportunities for higher paying jobs and better social services in urban areas. Both forest transitions and hollow frontiers involve a decline in numbers of small farmers. Positive environmental and social outcomes are only possible if those who move off farms are genuinely better off, and do not recolonize forested areas. As Costa Rica shifts from semisubsistence agricultural production to wage labor in export agriculture and industry, the distribution of income and well-being of the lower classes will be important factors in

determining overall patterns of land use. Poorer rural people often find it difficult to hold onto land which could provide them security and supplemental income when wealthier urban residents are consolidating formerly smaller farms into large ranches and purchasing hobby farms. This contributes to livelihood insecurity among the poor. It remains to be seen if recent changes produce genuine development or a greater divide between the rich and the poor. If the transition to a national industrialized economy and intensive plantation agriculture cropping systems in Sarapiquí do not provide sufficient well-paid jobs and benefits, there could be a return to the agrarian lifestyles and squatter invasions, and perhaps the government policies that promoted them, which characterized the early 1980s.

Our study area included a national park, biological reserve, and a buffer zone, and our findings have implications for protected area management and policy. The forest cover data and the social research provide clear evidence that the expansion of the park from 1982–86 stopped the advancing frontier and forest clearing. With park expansion, the development impetus in remote areas dissipated and economic activity and residence shifted away from the frontier and to more developed urbanizing areas. As a result, deforestation at the leading edge of the frontier was controlled and the deforestation process afterwards took place on forest remnants, thus reducing pressure at the park boundary. At the same time, the sustainable small and mid-sized land use systems that showed promise in the late 1980s (Schelhas, 1996) have not developed because of market fluctuations for nontraditional export crops, migration and commuting for employment, and the continued consolidation of lands into large ranches purchased with investment capital earned in other regions of Costa Rica or in other countries. Forest loss and fragmentation have continued.

However, unlike in the past, when a landless population was drawn to forested areas to acquire land and farms, landless people have more recently been drawn toward urban areas and nearby house lots. With small farms being replaced by wage labor, in this case development poles that draw people away from the protected areas might be more effective in setting up the conditions for forest recovery than sustainable land use programs for small landholders immediately adjacent to the protected areas. While successful development poles could improve the well-being of migrants, they will not by themselves promote reforestation in the buffer zone because of the development of a hollow frontier. Reforestation of the buffer zone will require specifically addressing the consolidation of lands into large cattle ranches.

Forest cover in Sarapiquí has not been recovering, even with declines in small-scale agriculture and a shift in economic focus from the forest frontier to the urban corridor outside the reserve. Resident landowners have

become much more reliant on wage labor employment away from home, which creates the possibility for reforestation, but absentee and hobby landowners have continued to rely on cattle as a major land use in spite of government reforestation and forest conservation incentive programs. Researchers, resource managers, and policy makers working in the tropics have tried to develop buffer zones that can accommodate small farmers and landless forest users, rather than buffer zones with the kinds of residents that are proliferating in Sarapiquí—land speculators, hobby farmers, commuters, families with migrant members, and landless wage laborers. Recognizing and understanding the various land cover phenomena related to urbanization and industrialization, such as forest transitions and hollow frontiers, is the first step toward developing buffer zone strategies for these situations, which may be more common in the future.

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