Forest Ecology and Management 258 (2009) 931–940

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Deforestation and forest restoration in Guanacaste, Costa Rica: Putting conservation policies in context

J. Calvo-Alvarado [a,*], B. McLennan [b], A. Sánchez-Azofeifa [b], T. Garvin [b]

[a] Escuela de Ingeniería Forestal, Instituto Tecnológico de Costa Rica (ITCR), Cartago, Costa Rica
[b] Earth Observation Systems Laboratory, Earth and Atmospheric Sciences Department University of Alberta Edmonton, Alberta, Canada T6G 2E3

ARTICLE INFO

Article history:
Received 24 July 2008
Received in revised form 4 October 2008
Accepted 29 October 2008

Keywords:
Tropical dry forest
Deforestation
Forest restoration
Payments of Environmental Services
Forest conservation
Sustainable development
Land-use/land-cover change
Costa Rica
Guanacaste

ABSTRACT

Traditionally Land Use Cover Change (LUCC) studies have focused on processes of negative land-cover change, primarily deforestation, partially because examples of positive land-cover change were not common. During the last two decades an outstanding tropical dry forest restoration process had taken place in the province of Guanacaste, Costa Rica, which has given us a unique opportunity to study how and why tropical dry forest regrowth occurs. The purpose of this paper is to undertake a retrospective analysis of the social dynamics of forest deforestation and restoration in Guanacaste from 1960 to 2005. Hence we investigate how structural drivers shape patterns of forest-cover change and examine how the role that Costa Rica's conservation policies had played in promoting forest restoration. Our study combined analyses of socioeconomic data and satellite images of forest cover. We showed that forest regrowth observed in Guanacaste after the 1980s was the result of multiple socioeconomic factors. Our results indicate that the degree of incentive provided by conservation policies such as Payment for Environmental Services are not enough to ensure that Guanacaste's forest will be protected against the potentially negative impacts of future socioeconomic changes. The findings from our analysis can assist decision-makers and managers in other regions to understand how social, economic and political dynamics impact the effectiveness of forest conservation efforts.

1. Introduction

Tropical dry forests (TDF) are one of the most vulnerable and threatened ecosystems on the planet (Bawa and Seidler, 1998). Their fertile soils and mild climates make them highly suitable for agriculture and livestock (Murphy and Lugo, 1995; Ewel, 1999; Piperno and Pearsall, 2000). Consequently, they have suffered extensive deforestation as land was cleared to make way for land colonization (Janzen, 1988; Quesada and Stoner, 2004). This pattern of degradation is nowhere more evident than in Central America and Panama. In this region, the rate of deforestation of TDF is significantly higher than global rates. According to figures taken from the Terrestrial Ecoregions Base Global Dataset, Central American TDF covers only 1.7% of its estimated original extent, whereas 34.9% of the estimated original extent of TDF remains globally. Furthermore, only 0.5% of Central America's TDF are protected by some type of conservation units, compared to 4.9% globally (Olson et al., 2001).

More promising, however, are recent studies that show TDF is recovering in some areas (Abizaid and Coomes, 2004; Arroyo-Mora et al., 2005a,b; Tucker et al., 2005). In the Costa Rican province of Guanacaste, for example, TDF have been recuperating at a significant rate (Arroyo-Mora et al., 2005a,b). Guanacaste's forests were heavily eliminated between 1950 and 1980 under the pressure of a rapidly expanding beef industry and land colonization policies. By 2005, however, regenerating secondary forests (regrowth) helped expand the total forest cover to 47.9% of the province (Sánchez-Azofeifa et al., 2006). This is a significant reversal of the dominant pattern of TDF deforestation observed in other countries of Central and South American (Miles et al., 2006).

The recovery of secondary forest in Guanacaste is not an isolated incident. Empirical studies also show that humid secondary forests are recovering in other zones of Costa Rica (Kull et al., 2007); in El Salvador (Hecht and Saatchi, 2007), Panama (Sloan, 2008); and more broadly across Latin America and the Caribbean, for example Mexico (Klooster, 2003), Puerto Rico (Grau et al., 2003), Ecuador (Farley, 2007), Brazil (Baptista and Rudel, 2006; Baptista, 2008) and Argentina (Izquierdo et al., 2008). Some of the processes found in these studies to contribute to this forest recovery include: past land-use patterns, economic globalization, urbanization, population change, government economic policies

* Corresponding author. Tel.: +506 2550 2279; fax: +506 2591 4182.
E-mail address: jucalvo@itcr.ac.cr (J. Calvo-Alvarado).

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doi:10.1016/j.foreco.2008.10.035

and environmental policies, diversification of wage labor, and agricultural transformation.

The causes of forest recovery in Guanacaste have not yet been systematically examined; however it has been partially attributed by policy makers and others to the implementation of national forest conservation policies in the region (Castro and Arias, 1998; MINAE, 2002). Costa Rica has had considerable success with developing and implementing forest conservation policies, and its experiences with these policies provide a valuable learning opportunity for other countries (Rojas and Aylward, 2003). The case of forest regrowth in Guanacaste provides an opportunity to assess the contribution of these policies to past forest regrowth and to the maintenance of these new forests in the future. Furthermore, examining the socioeconomic dynamics of forest recovery in Guanacaste can also increase our understanding of how forest recovery occurs in TDF ecosystems where few land-use studies have been conducted (Sánchez-Azofeifa et al., 2005a,b).

Land Use Cover Change (LUCC) research shows that we cannot understand the complete picture of forest-cover change without incorporating social research into natural science studies (Geoghegan et al., 1998; Rindfuss et al., 2004). LUCC is a complex phenomenon that involves interactions between social and natural systems (Geist and Lambin, 2001; Lambin et al., 2001, 2003). LUCC such as deforestation and forest regrowth is the result of changes in how people use land as social, economic, and political drivers are changing. These drivers include large-scale, structural dynamics such as price shifts in international markets and national development policy changes. They also include small-scale, proximate dynamics such as changes in the local labor market and the lifecycle of rural families. Furthermore, these dynamics interact across scale and over time. This complexity makes unraveling the causal relationships between social processes and LUCC a difficult goal to realize. Lambin et al. (2003) show that at the time scale of about a decade, the key process driving regional LUCC is farmer's responses to socioeconomic change. Examining structural changes in Guanacaste's society and economy therefore provides insight into the large-scale factors driving deforestation and forest restoration in that region.

The purpose of this paper is to undertake a retrospective analysis of the social dynamics of forest deforestation and restoration in Guanacaste from 1960 to 2005. It has two central goals: first, to investigate how structural drivers shape patterns of forest-cover change; and second, to examine the role that Costa Rica's conservation policies played in promoting forest restoration. The findings from our analysis can assist decision-makers and managers in other TDF regions to understand how social, economic and political dynamics impact the effectiveness of forest conservation efforts.

2. Methodology

2.1. The study area

Guanacaste is located in northwest Costa Rica (see Fig. 1). It is 10.140 km^2 in area and for this study is divided into two main geographical zones: the Nicoya Peninsula (3.935 km^2) and the Tempisque Northeast basin (6.206 km^2). The Nicoya Peninsula is characterized by a mix of tropical dry and moist ecological zones according to the Holdrige Life Zone Classification System (Holdridge, 1967; Bolaños and Watson, 1993). A great proportion of the Nicoya Peninsula has steep terrain and thin or infertile soils that are mostly classified as unsuitable for agriculture (Arroyo-Mora et al., 2005a,b). Before human settlement it was heavily forested with both dry and moist tropical forests. In contrast, the Tempisque Northeast basin is a flat, alluvial lowland area, sloping up to the foothills of the Guanacaste Volcanic Cordillera. It is predominantly a tropical dry zone (Holdridge, 1967), and it has more fertile soils than the Nicoya Peninsula (Arroyo-Mora et al.,

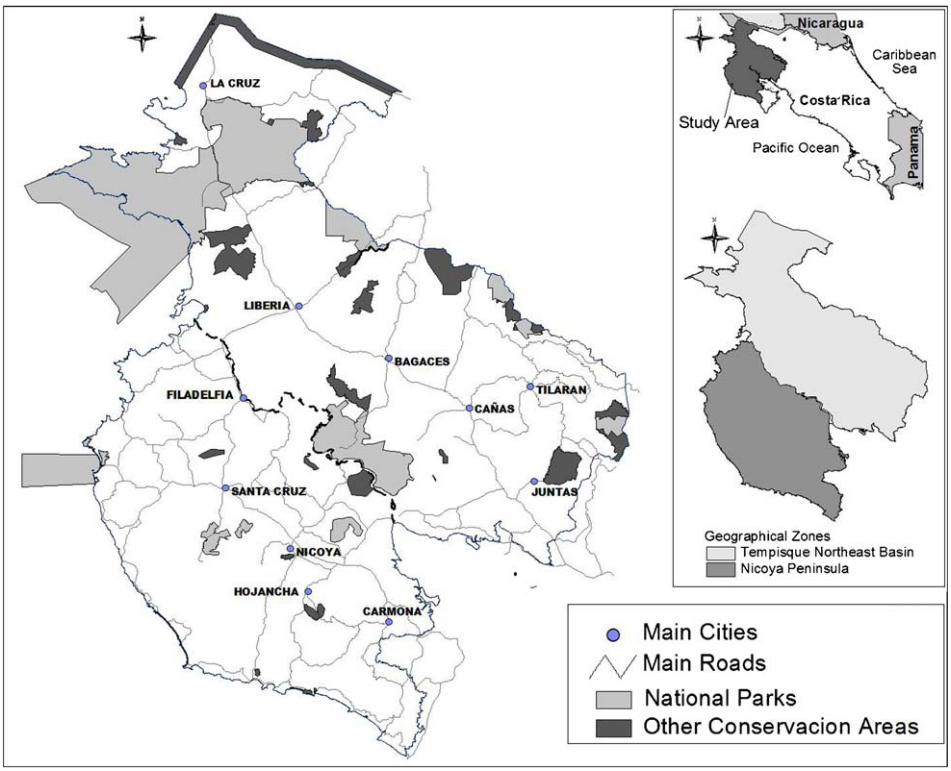

Fig. 1. Map of Guanacaste region, protected areas and location of Nicoya Peninsula and Northeast zones.

2005a,b). Its original, pre-settlement land-cover was a mix of natural savannah and tropical dry forests (Boucher et al., 1983).

2.2. Methods

Our study used two data collection methods. GIS analysis of remote sensing images provided information about the pattern of deforestation and forest regrowth. A literature review and compilation of socioeconomic data revealed structural dynamics that shaped the socioeconomic context of forest conservation. We combined the results in a discussion of the role of conservation policies in promoting forest regrowth. This discussion is positioned within current LUCC research.

2.2.1. GIS analysis

We analyzed forest-cover change in the Guanacaste province using GIS analysis of remote sensing images and cartographic pages. We compiled forest-cover maps for this province for the years 1960, 1979, 1986, and 2005. For the purposes of this study, forest was defined as at least 80% forest canopy cover, and included both natural primary and secondary forest. As remote sensing images were not available for 1960, we prepared the map for this year by digitizing cartographic pages based on aerial photographs. Maps for subsequent years were prepared from LANDSAT MSS images. Arroyo-Mora et al. (2005a) prepared the 1979 image by reclassifying an image used previously by Sader and Joyce (1988). Methodological problems in determining the extent of tropical dry forest using remote sensing (Kalacska et al., 2004; Sánchez-Azofeifa, 2000; Sánchez-Azofeifa et al., 2005a,b), were overcome by using new, more accurate classification techniques (Arroyo-Mora et al., 2005a). In particular, we used images taken at the end of the wet season. At this time, deciduous tropical dry forests still have full leaf cover but skies are also relatively clear, enabling good image quality. The 1986 and 2005 images were prepared by extracting information for the Guanacaste province from previous national studies by CCT-CIEDES-CI (1998) and Sánchez-Azofeifa et al. (2006). These studies used the same methodology as Arroyo-Mora et al. (2005a), and therefore the maps for these years produced comparable results. Also important to mention is that in the 2005 forest-cover study (Sánchez-Azofeifa et al., 2006) a GIS data base was prepared to remove any possibilities to misclassify in the 2005 forest-cover map 100,500 ha of forest plantation, 112,000 of coffee plantations and 8500 ha of fruit plantations as forest cover.

2.2.2. Literature review and compilation of socioeconomic data

In order to understand the socioeconomic context of land-use change over time in Guanacaste we conducted a thorough literature review and compiled descriptive socioeconomic data. Documents included in the literature review were in both English and Spanish and covered a range of relevant topics such as national and regional history, geography, government policy in agriculture and forest use, as well as agricultural land use. It incorporated scholarly articles in peer reviewed journals, dissertations, government reports and data, as well as a limited number of non-government organization reports. Socioeconomic data that reveals the extent of socioeconomic change in Guanacaste was obtained from a number of sources. The data included in Table 3 was extracted from the national census for 1950, 1963, 1973, 1984 and 2000. It was accessed via a public database (REDATAM) of the National Institute of Statistics and Census (INEC) (available online at http://www.inec.go.cr/). Data obtained in this way included: total reported population in the province, percentage of population living in an area classified as urban or semi-urban, percentage of workers employed in agriculture (the primary sector), percentage of households with electric lighting, and percentage of households that used wood or coal for cooking. All variables are classified according to the definitions in the national census for each year. The data was tabulated by year to show change in these variables over time. Additional data was obtained from: the Costa Rican Institute of Tourism (national tourist visitations and spending, no. hotels), the National Forestry Financing Fund (FONAFIFO) (PSA contracts in Guanacaste), the Costa Rican Chamber of Cattle Farmers (CORFOGA) and the Ministry of Agriculture (national beef prices and exports).

3. Results

3.1. Land-use history

Prior to Spanish conquest, the Guanacaste region was populated by dispersed settlements of indigenous Chorotega and Nicaraos peoples that used only the most fertile lands for subsistence farming (Flores, 1982). The first Spanish colonists arrived in Guanacaste in the early 1500s (Hall, 1984).[1] They found the natural savannahs and dry climate of the Northeast to be suitable for raising European Creole cattle (Edelman, 1985). By the 1800s, a small population of colonists had established an extensive system of large haciendas (Edelman, 1985).[2] In contrast, the thinner soils and steep terrain of the Nicoya Peninsula were not suitable for large-scale farming. Colonial settlement was restricted to small properties administered by Franciscan missionaries for subsistence farming by indigenous and *mestizo* communities (Hall, 1984). These early patterns of land tenure continue to underpin land distribution in Guanacaste today (Peters, 2001).

Land use in Guanacaste steadily intensified from the mid-1800s to the 1950s. As the national population grew, there was an increasing demand for beef and timber products out of the region (Hall, 1984). From the 1930s onwards, economic pressures and population growth pushed landless peasants from the central highland region of Costa Rica into Guanacaste in search of land for subsistence farming (Cruz et al., 1992; Gregersen, 1994). Land colonization policies and the expansion of the road network facilitated this process of migration (Hall et al., 2000; Watson et al., 1998). As the Northeast was already covered by well-established haciendas, most of these migrants headed to the relatively unpopulated Nicoya Peninsula (Cruz et al., 1992).

The rate of timber extraction also increased during this period. High value timber was harvested in Guanacaste to meet both national and export needs. Official records show that Costa Rica exported a steady supply of mahogany to the United Stated from 1908 to 1960 (Lamb, 1966). Most of this timber came from Guanacaste, which was the only region in the country where mahogany was endemic (Bolaños and Navarro, 1999; Calvo-Alvarado et al., 2000).

From the 1950s onwards, land use in Guanacaste intensified significantly as the beef industry expanded. A dramatic rise in international beef prices due to the opening of beef exports to the United States drove a major expansion of beef industries right across Central and South America (Kaimowitz, 1996). In Costa Rica, the expansion of the beef industry was further facilitated by government subsidies that were provided with the support of the World Bank and United States AID (Kaimowitz, 1996; Sánchez-Azofeifa, 2000; Quesada and Stoner, 2004).

[1] The Guanacaste region was a part of the Spanish colony of Nicaragua. It did not become a province of Costa Rica until 1824, three years after Costa Rica's independence from Spain.

[2] Haciendas were large farms (>5000 ha) assigned by the Spanish crown to colonists.

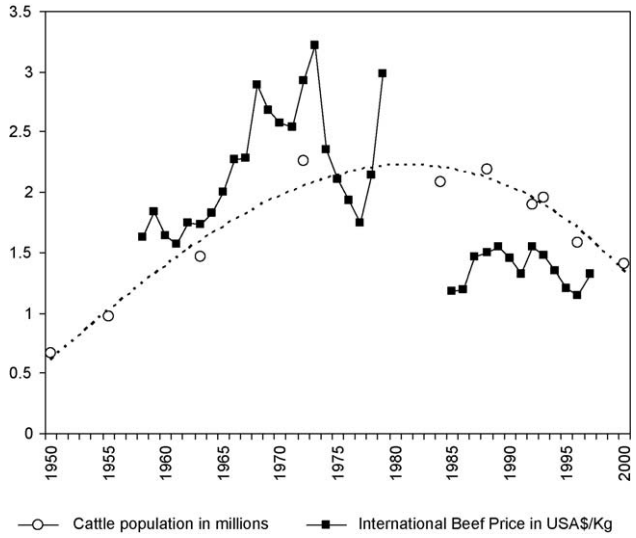

Fig. 2. Cattle population trend in Costa Rica in relation to international beef price (Sources: Montenegro and Abarca, 1998; Ibraham et al., 2000).

The extent to which the beef industry expanded in Costa Rica is reflected in official figures for the size of the national cattle herd. As shown in Fig. 2, the national cattle herd more than doubled in size between 1950 and its peak in 1972. Guanacaste contained a large percentage of this cattle herd. Some accounts estimate that in 1972 40% of all the cattle in Costa Rica were located in Guanacaste (Boucher et al., 1983; Ibraham et al., 2000).

The rise of the beef industry was the single most influential driver of deforestation in Guanacaste. Prior to the 1960s, deforestation was sustained but gradual. Indigenous populations had little impact on forest cover, as their agricultural activates were restricted to small, dispersed areas (Boucher et al., 1983; Solórzano et al., 1991). The extensive haciendas of the Spanish colonists also had minimal impact on forest cover, as their Creole cattle were wide ranging and largely restricted to areas of natural savannah (Edelman, 1985). The rate of deforestation began to increase in the 1930s with the influx of landless peasants, the introduction of land colonization polices that encouraged land clearing, and the expansion of the road network (Hall, 1984; Augelli, 1987; Watson et al., 1998; MINAE, 2002). However, it was not until the rise of the beef industry in the 1950s that deforestation rates radically escalated (Solórzano et al., 1991; Kaimowitz, 1996; Watson et al., 1998).

The rapid clearing of forest for pasture expansion eliminated most of Guanacaste's forest by the 1970s. In the Nicoya Peninsula, forests were converted to pasture as farms expanded in size (Gregersen, 1994). Land used for subsistence agriculture was also converted to pasture as the thin soils became degraded and unable to sustain crop production (Gregersen, 1994). In the Northeast, deforestation intensified on the already existing haciendas as new farming techniques enabled farmers to increase the size of cattle herds. New techniques included, fencing, the expansion of fire resistant exotic grasses such as *Jaragua* (*Hyparrhenia rufa*), and the introduction of Brahman cattle breed that had a much higher output than the European Creole cattle (Hall, 1984; Edelman, 1985; Jiménez and González, 2001; Peters, 2001). The new fire resistant grasses also led to the widespread use of fire as a method for establishing and 'cleaning' pasture. Fire proved to be a very efficient method for expanding and maintaining pastures in Guanacaste's dry climate (Parsons, 1983).

Cattle farming was not the only land use in Guanacaste during the 1950s and 1960s, but other land uses had relatively little impact on deforestation rates compared to cattle. Timber harvesting was mostly a byproduct of clearing land for pasture (Quesada-Mateo, 1990; Harrison, 1991; Solórzano et al., 1991). Large-scale agriculture, particularly sugar cane and cotton, also expanded in alluvial lowland areas in the 1960s but crops were largely planted on former pasture lands rather than on cleared forest areas (Mateo et al., 2001).

The strong relationship between an expanding beef industry and high rates of deforestation, described by Myers (1981) as the "Hamburger Connection", was not restricted to Guanacaste during this period. The rise of the international beef market led to the deforestation of large tracts of forests right across Central and South America. As a result of this, Central American beef exports rose from $9 million in 1961 to $290 million in 1979 (Kaimowitz, 1996). However, international beef prices were low between 1975 and 1977, rose for a few years, and then started falling again after 1980 (Fig. 2). Beginning in the mid-1980s the Costa Rican government also withdrew its support for the industry (Watson et al., 1998). The decline in the international beef price had two main explanations: (a) the European Economic Community went from being a net beef importer to becoming a net exporter and (b) per capita beef consumption in the US fell after 1977 as consumers became more health conscious and real incomes stagnated (Kaimowitz, 1996). As a consequence, by the mid-1990s, the national cattle herd had decreased in number to its 1960s levels (Fig. 2).

3.2. National conservation policies in Guanacaste

A large body of literature already describes the development of conservation policies in Costa Rica (see for example Watson et al., 1998; Evans, 1999; De Camino et al., 2000; Brockett and Gottfried, 2002). Costa Rica created a regulatory and institutional framework for forest conservation and management through a series of policy and legal changes over four decades. In 1969, the first Forest Law in the country regulated forest use on public land and established a national parks system. In the 1980s, Costa Rica adopted the concept of sustainable development (Calvo-Alvarado, 1990). It created an Environment Department and introduced subsidies for reforestation and forest management on private land. In the 1990s, it introduced a National System of Conservation Areas called SINAC to decentralize forest management and conservation. A Forest Law passed in 1996 introduced a permit system to restrict timber extraction and forest-cover change on private land, and a program of Payments for Environmental Services, known as PSA.

Hence with this law the prohibition of forest clearing and the PSA became the primary mechanisms for promoting forest[3] conservation on private land in Costa Rica. PSA as such warrants further explanation (Chomitz et al., 1999; Barrantes, 2000; Rojas and Aylward, 2003). It is administered by an autonomous government body, the National Forestry Financing Fund, known as FONAFIFO. FONAFIFO pays landholders for the environmental services performed by forests on their lands. In this way, PSA provides a direct incentive to landholders to engage in conservation activities (Ferraro and Kiss, 2002). The specified environmental services are carbon sequestration, water protection, biodiversity protection, and scenic beauty. Funds for payments are sourced from a national tax on fuel consumption, private companies such as water and electricity utilities, and international sponsorship.

[3] According to this law forest is defined as any land unit of at least 2 ha that is covered by natural regenerated trees, or alternatively a natural forest that is actively managed. Trees of different ages and structure must cover at least 70% of the surface with a minimum of 70 trees per hectare with at least 15 cm of DAP.

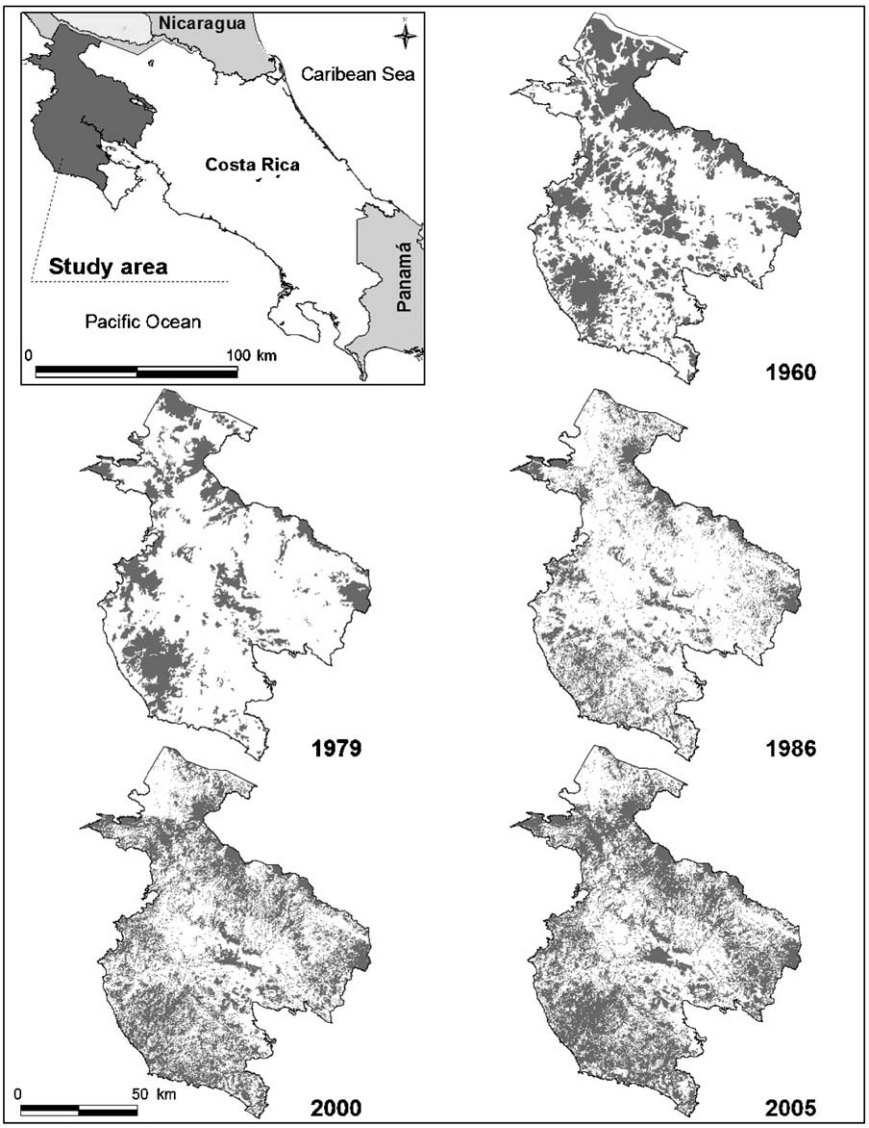

Fig. 3. Forest-cover maps for the Chorotega region, Costa Rica, from 1960 to 2005. Dark areas correspond to forest cover (Source: Arroyo-Mora et al., 2005a,b; Sánchez-Azofeifa et al., 2006).

Under PSA, landholders receive payments from FONAFIFO in exchange for forest protection, sustainable forestry and reforestation.[4] Sustainable forestry contracts cover a 15-year period, but payments are made in the first 5 years at a progressively decreasing rate in an effort to offset set-up costs. Forest protection contracts cover 5 years and payments are provided at a flat rate throughout the contract. In both cases landholders must fulfill the requirements of a forest management plan that includes fencing off protected areas, excluding cattle, and maintaining firebreaks and access trails. The total payment for sustainable forestry is substantially higher than for forest protection (sustainable forestry payments from 1997 to 2001 averaged USD $623 per hectare compared to USD $221 for forest protection; see Zbinden and Lee, 2005). Nevertheless, the PSA for sustainable forestry was suspended in 2002 and the accumulated assigned funds were insignificant in comparison to forest protection, only 5% of the total amount of PSA assigned from 1997 to 2007.

[4] Currently, PSA in Costa Rica also includes payments for agroforestry and forest regeneration but these payments are not common and are not included in this study.

The three key national conservation policies – protected areas, PSA, restrictions on timber extraction and forest clearing have all been implemented in Guanacaste. An extensive system of protected areas was established from 1970 to 1990 and covers roughly 9.6% of Guanacaste's territory (Fig. 1). The largest protected areas are the Santa Rosa National Park (495 km^2), which was the country's second national park created by presidential decree in 1972 (Evans, 1999); and the Guanacaste National Park (324 km^2), which was created by a series of land purchases from private landholders after the 1980s (Allen, 2001). Both these national parks are located in the Northeast zone. Another larger protected area on the lower Tempisque basin is Palo Verde National Park (454 km^2), created in 1978. In addition to these national parks, there are also a number of smaller national conservation units such as forest reserves and wildlife refuges scattered across the province. Land use is heavily restricted within protected areas, although some mixed land use is permitted within forest reserves and other conservation land units (Allen, 2001; Stern et al., 2001).

According to FONAFIFO's official database (FONAFIFO, 2007), between 1997 and 2002, 555 PSA contracts for forest protection

Table 1
Forest cover as a percentage of land area by province.

Province	Year				
	1960	1979	1986	2000	2005
Guanacaste	37,8	23,6	23.,1	40,4	47,0
Nicoya Peninsular	40,3	22,5	20,7	37,8	43,6
Tempisque Northeast Basin	34,1	25,6	26,9	44,8	52,6
Alajuela	62,0	44,7	26,8	26,9	26,7
Limon	79,8	72,3	71,3	67,4	68,3
Heredia	79,1	69,7	62,3	53,1	53,1
Puntarenas	57,9	40,8	35,1	43,2	46,8
San Jose	45,0	34,6	30,7	39,7	42,5
Cartago	65,8	62,4	66,8	64,3	65,0
Costa Rica	58,9	46,0	40,5	45,3	47,9

were established in Guanacaste. These contracts accounted for 51,168 ha which represent only a small fraction (10%) of the total forest cover of the province. During the same period, 276 PSA contracts for sustainable forestry were established (covering only 8742 ha), the majority of which covered land located in the Nicoya Peninsula. At the same time, there were only 78 other types of PSA contract established, including agroforestry. In total, the area covered by PSA contracts in Guanacaste is only 12% of the total natural forest cover of the province today.

3.3. GIS analysis of forest-cover change

The results of the GIS analysis of forest-cover change in the Guanacaste province indicate that major forest regrowth has occurred since the 1980s. This pattern is revealed in Fig. 3, which shows the forest-cover maps prepared for 1960, 1979, 1986, 2000 and 2005.

Tables 1 and 2 show the results of GIS analysis of forest cover. Between 1960 and 1979, forest cover fell from 37.8% to 23.6%. This represented an annual deforestation rate of −0.74% of the Guanacaste territory (−0.68% nationwide). There was a very low deforestation rate (−0.1%) between 1979 and 1986. This contrasts with national figure of 0.89% indicating that deforestation in the rest of the country continued during this period. Between 1986 and 2005 forest cover increased in Guanacaste from 23.6% to 47.0%, much greater than the %forest cover reported for 1960 (37.8%). The annual rate of regrowth was therefore +1.26%. This far exceeded the national forest regrowth rate for this period, which was only +0.39% (Table 2).

The pattern of deforestation and regrowth was slightly different in the Nicoya Peninsula and the Northeast Tempisque basin (Table 1). The rates of deforestation between 1979 and 1986 in the Nicoya Peninsula were considerably higher (a change of 40.3% to 22.5%) while the Northeast experienced slightly smaller deforestation rates (from 34.1% to 25.6%). From 1986 to 2005, the Northeast Tempisque basin had a higher rate of forest regrowth than the Nicoya region. Additional analysis showed that by 2005 only 20% of the total forest cover was protected in conservation units. Furthermore, of the total forest regrowth that took place from 1986 to 2005, only 10% occurred in conservation units, meaning that 90% of the regrowth has been taking place on private lands.

Table 3
Indicators of socioeconomic transition in Guanacaste province, 1950–2000.

	1950	1963	1973	1984	2000
Population (1000s)	77	88	143	195	264
%Urban population	13.6	15.0	23.9	26.6	41.9
%Rural population	86.4	85.0	76.1	73.4	58.1
%Houses with electricity	10	16	31	64	93
%Kitchens with wood/coal combustion	76	95	81	69	28
%Agricultural employment	80	–	58	50	9

3.4. Structural dynamics

The two structural dynamics that are central to our study have already been described above: they are (i) the collapse of the beef industry and (ii) the introduction of conservation policies. Socioeconomic data from 1950 to 2000, shown in Table 3, reveal that other important structural dynamics were also occurring before and during the period of forest regrowth. A major transition occurred in the socioeconomic conditions in Guanacaste between 1950 and 2000. It was marked by a sustained growth in population, increasing urbanization, a sharp drop in agricultural employment, rising health and education standards, and the expansion of the electricity grid. During this transition, the economy shifted from an almost exclusive focus on agriculture and cattle raising to a much stronger focus on the services sector, in particular tourism.

The structure of society in Guanacaste changed markedly between 1950 and 2000. In 1950, Guanacaste had a population of 77,000, 86% of which was classified as rural. In addition, the agricultural sector employed 80% of the province's workers. Only 10% of houses had electricity, and 76% of households used charcoal or wood for cooking. By 2000, the population in Guanacaste had more than tripled to 264,000. Only 58% of this population was classified as rural (although in absolute figures the rural population had risen since the 1950s). The drop in the percentage of workers employed in the agricultural sector was tremendous, falling to 9%. By this time, 93% of households had electricity, and only 28% used charcoal or wood for cooking.

Table 2
Change in forest cover (ha) and deforestation rate (percentage) by province.

Province	Temporal period					
	1960–1979		1979–1986		1986–2005	
	Change	Rate of change (%)	Change	Rate of change (%)	Change	Rate of change (%)
Guanacaste	−144,113.47	−0.74	−5,819.51	−0.10	244,137.42	1.26
Alajuela	−168,333.64	−0.91	−174,828.80	−2.98	−1,077.64	−0.01
Limon	−68,939.51	−0.40	−9,361.90	−0.17	−27,361.38	−0.16
Heredia	−25,083.54	−0.50	−19,552.34	−1.22	−24,468.15	−0.48
Puntarenas	−192,449.90	−0.90	−63,748.62	−0.95	130,834.01	0.61
San Jose	−51,674.79	−0.55	−19,423.14	−0.65	58,721.31	0.62
Cartago	−10,597.98	−0.18	13,646.07	0.74	−5,572.61	−0.09
National	−661,192.83	−0.68	−272831.9	−0.89	375,212.96	0.39

The collapse of the beef industry was partly responsible for this socioeconomic shift in Guanacaste. It decreased the economic opportunities in rural areas, compelling people to seek out alternative employment in urban areas. The conversion of some of the largest haciendas to national park may have also been a factor in the reduction of rural labor. However, the socioeconomic shift cannot be explained without also considering the significant impact of tourism. The rapid growth of the tourism industry in Guanacaste provided the majority of the alternative employment opportunities in the region, as well as driving up the price of land. The growth of tourism altered the shape of the Costa Rican economy as a whole (Weaver, 1999). According to the records of the Institute of Tourism (ICT, 2004), international visitors to Costa Rica increased by an average of 16,000 people a year between 1966 and 1983. After 1986, this figure jumped to an annual increase of 60,000 visitors per year. By 2005, the number of tourist to visit Costa Rica had reached 1.7 million (Cordero and Paus, 2008). This was an extraordinary number of international visitors in a country with a national population under 4 million at the time. In 2005, tourists spent US$1,600 millions in Costa Rica, making tourism the most important source of national income and employment.

The beaches of Guanacaste received a large portion of these international visitors. In 2000, 24% of Costa Rica's hotels were located in Guanacaste (ICT, 2004). It was the most visited area in the country outside of the capital of San José. Tourism received an added boost in the region when the Daniel Oduber International Airport was built outside the provincial capital of Liberia in 1993. Since that time, international visitors entering Guanacaste directly through this airport have steadily increased (CATURGUA, 2007).

4. Discussion

We consider that the forest regrowth observed on remote sensing images between 1986 and 2005 for Guanacaste is not due entirely to the implementation of conservation policies. The restrictions on timber extraction and the PSA program were not introduced in Guanacaste until after 1997. Most forest regrowth resulting directly from these policies would be too young to be detected as forest on the remote sensing images up to 2005. Furthermore, the 555 PSA contracts for forest protection established in Guanacaste between 1997 and 2002 accounted for only 51,168 ha which represents only a small fraction (20%) of the total forest recovered from 1979 to 2005.

LUCC research shows that the underlying driver of deforestation is landholder's responses to economic change (Lambin et al., 2001). LUCC research also shows that a wider range of structural dynamics other than just economic change define the land-use alternatives that are available to landholders (Geist and Lambin, 2001; Lambin et al., 2001). These dynamics include new government policies in related arenas, demographic shifts, and cultural transformation. They combine with economic change to create the opportunities and restrictions that landholders must negotiate when making land-use choices. In Guanacaste, conservation policies were only one of the structural dynamics that contributed to forest regrowth. Other structural changes that were not driven by the goal of forest conservation also reinforced forest regrowth and conservation. For example, the new employment opportunities in the tourism industry drew workers away from agriculture.

The experience of forest regrowth in Guanacaste is an example of what Lambin, Geist and Leper call a land-use transition (Lambin et al., 2003, p. 228). A land-use transition is a period of intensified land-use change caused by dramatic and interrelated changes in the structure of a society. The structural transformation of society fundamentally alters the economic opportunities and restrictions that exist for landholders. It creates a new set of conditions that landholders must negotiate when considering the relative costs and benefits of alternative land uses. These changes encourage landholders to alter to how they use land on a large scale.

In Guanacaste, the structure of society changed between the 1950s and 2000s with the collapse of the beef industry and the shift towards a more urbanized and service-oriented economy. This transition involved interrelated changes in a number of different sectors of society. Guanacaste became more populated but also more urbanized. Standards of living increased and tourism overtook other land uses to become the most profitable economic activity. The new social structure created new opportunities and restrictions for cattle farmers. Within this specific context, abandoning pasture to natural forest regrowth and establishing timber plantations emerged as two of the best land-use choices available to cattle farmers. Also within this specific context, conservation policies acted as extra encouragement and reinforcement for choosing these land uses. A study of the drivers of forest regrowth on the central Pacific coast of Costa Rica found that a similar set of factors lead to forest regrowth (Kull et al., 2007).

As Lambin et al. (2003) note, however, there is no reason why further land-use transitions will not occur. This is the source of doubt over the ability of current conservation policies to protect Guanacaste's secondary forests in the future. If further structural changes occur that create a new set of opportunities and restrictions for cattle farmers, their evaluations of which land uses are the best for their circumstances will also change. There is no guarantee that in a different socioeconomic context the current conservation policies will promote forest protection and reforestation. In Guanacaste, an increase in timber prices, the introduction of new agro-industries that makes marginal land more profitable again, a demand for land for real estate development, or a global economic crisis depressing tourism could provide enough incentive to landholders to convert forests once again.

Emerging evidence suggests that legal restrictions on forest-cover change and the payments made under PSA may not prevent deforestation when a strong economic incentive to clear forests is present (see also Ibarra, 2007). Along these lines, an independent study using aerial photographs from year 1997 and 2003 (Cordero, 2008) revealed very interesting results that support the suggestion that a structural change is already taking place in Guanacaste, one that is already affecting the sustainability of forest conservation. This study evaluated the forest-cover change of the Tempisque Conservation Area, which includes the entire Nicoya Peninsula (the Nicoya Peninsula represents 78% of the total area in the Tempisque Conservation Area). It found that during the study period a total of 12,664 ha (5% of the 1997 forest area) were deforested. The main cause of this forest-cover loss was pasture expansion as about 72% of the change was classified as pasture. Nevertheless Cordero (2008) also detected an increase of 5000 ha of forest regrowth (2% of the 1997 forest area), mostly on abandoned pasture lands, hence resulting in a net lost of 7600 ha of forest cover. These findings also support our hypothesis that most of the forest regrowth in Guanacaste Province took place prior 1997.

There are a number of forest-cover change pathways that have the potential to explain the deforestation detected by Cordero (2008) and that also might help anticipate future pressures on Guanacaste's secondary forest. According to information available from the Costa Rican Chamber of Cattle Farmers, there is a push to reactivate and modernize the cattle industry in Costa Rica (http://www.corfoga.org):

- The international beef price had increased to an average of $2.37 between 2002 and 2004, equivalent to an increase of 72% over the average price between 1986 and 2000 (Fig. 3).

- During the last 3 years (2005–2007) the international beef price averaged $2.8, which has moved the market back to a scenario similar to the 1970s (see Fig. 3).
- Costa Rican beef exports grew from 10,440 ton in 2000 to 17,400 ton in 2005.
- A national cattle farming reactivation program was also launched in 2007 by the government and the cattle industry, led by Guanacaste ranchers, that provides lower interest on bank loans and increased technical assistance for cattle farmers (COFORSA, 2007). Together, these movements may drive the expansion and intensification of cattle ranching in Guanacaste in the near future.

In addition to these changes to the cattle industry, a second pathway of forest-cover change could be through tourism infrastructure and real estate development. According to Cordero and Paus (2008), by 2006 foreign investment in Costa Rica amounted to US$1,410 millions, almost 3.5 times the amount reported in 1997. Of the total investment in 2006, 17% and 40% occurred in the tourism and real estate areas, respectively, collectively surpassing investment in industry, which was only 50%. In the absence of strong regional zoning and legislation to control this development, roads, houses and hotels are being constructed on marginal lands that were previously abandoned. Ironically, the locations that are most attractive to these investors are the hilly terrain with coastal views that is most marginal for cattle production and therefore were the first areas to be abandoned by farmers to forest regrowth (Kull et al., 2007).

A third pathway of land-use change that threatens Guanacaste's secondary forests in the near future is the expansion of agribusinesses and the introduction of new crops that are adapted to hilly terrain and dry conditions (Hecht and Saatchi, 2007). For example, *Ricinus comunis* L. (Castorbean) and *Jatropha Curcas* (Physic Nut) are two biofuel crops adapted to hilly conditions in Guanacaste (CATIE/IFO, 2004). There are also plans to expand irrigation schemes in the lowlands of Guanacaste (MIDEPLAN, 2008) that could also further encourage the expansion of large-scale agribusinesses. A number of biofuel crops such as sugar cane (restricted to the irrigated areas of Guanacaste) and palm oil (restricted nowadays to the humid areas of southern Costa Rica). If additional irrigated land becomes available, these crops may expand further into both the Nicoya Peninsula and the more fertile Tempisque Northeast basin.

All of these land-use change pathways have the potential to promote future forest conversion in Guanacaste. In addition, the Central American-Dominican Republic Free Trade Agreement (CAFTA) that was recently approved in Costa Rica, may also give new impetus to any of these potentially threatening developments. Equally important to consider is the impact of global economic crisis that could depress Guanacaste tourism industry, forcing a redefinition of the local economy.

These findings show that conservation policies are only one of many structural factors that influence landholder's land-use decisions. Conservation policies only change land-use decisions when they alter the relative costs and benefits of alternative land-use options in a way that favors forest conservation. As such, their success relies on the way they interact with other factors in society. Industries rise and fall, labor markets shift, and government policies in related arenas change. These changes impact the capacity of conservation policies to influence land-use decisions. This suggests that the success of conservation policies, particularly those that aim to influence land-use decisions, could be highly tenuous.

This is not to say that direct incentives like PSA are necessarily ineffective as a conservation mechanism at all. PSA has provided a certain degree of incentive for forest protection and reforestation in Guanacaste. PSA also has other benefits. Empirical studies in other regions of Costa Rica show that the PSA program can raise environmental awareness amongst landholders and can also contribute to the development of social organizations that promote sustainability (Camacho et al., 2003; Miranda et al., 2006). Additionally, the requirement under PSA forest management plans to maintain fire breaks can help to control the large threat that fire poses to Guanacaste's dry forests.

Our point is that the degree of incentive provided by PSA is not enough on its own to ensure that Guanacaste's forests will be protected against the potentially negative impacts of future socioeconomic changes. This is particularly worrying given that the threat of further socioeconomic change leading to deforestation in Guanacaste in the near future is very real. In order to better protect Guanacaste's forests, conservation managers need to implement a wider range of conservation programs on private lands rather than relying only on PSA. By doing this, they can increase the degree of influence that conservation programs as a whole have on land-use decisions, and therefore be better placed to counter strong economic incentives for deforestation.

5. Conclusions

A number of outstanding questions remain regarding the future of Guanacaste's forests; however there is sufficient evidence to raise concern over the ability of current conservation policies to protect forest from future land-use change. Relative to regional socioeconomic change, conservation policies made a small contribution to the observed forest regrowth in Guanacaste. A far greater impetus for forest recovery came from the decline of the cattle industry and the increase in economic opportunities associated with the booming tourism industry. However, the emerging developments in the regional cattle industry, land development, and agribusinesses have the potential to significantly increase the economic incentive to deforest. Evidence shows that these emerging land uses already pose potentially significant threats to secondary forests in other regions of Latin America (Hecht and Saatchi, 2007; Parés-Ramos et al., 2008; Perz and Skole, 2003).

Current conservation policies can only go so far to prevent this deforestation occurring. PSA payments were not a major factor in promoting forest recovery in Guanacaste, and current PSA payments for forest protection (an average of $320 USD, http://www.fonafifo.com) are unlikely to compete favorably with the potentially high economic return from the newly emerging land uses. The impact of timber extraction and forest-cover change restrictions is less clear and requires further investigation, but there are indications that these are also insufficient to deter further deforestation in their current form.

What are the alternatives? Harvey et al. (2008) make some recommendations for reconciling rural land use and conservation. They highlight the central need for integrated land-use planning that includes forest management and protection as well as incentives for sustainable agriculture. This includes a mix of regulation, incentives for forest protection and sustainable agriculture, education, and increased attention on the conservation of forests within agricultural landscapes. The need for more integrated landscape planning that includes both sustainable forest use and sustainable agriculture is supported by other studies of forest recovery and sustainable land use in Latin American regions (Bray and Klepeis, 2005; Carr et al., 2006; Izquierdo et al., 2008; Klooster, 2003; Mercer, 2004; Parés-Ramos et al., 2008). In addition, this range of policies needs to be targeted to the areas where they have the most potential to achieve outcomes, and to

involve stakeholders in land-use planning (Harvey et al., 2008). We would also highlight the importance of establishing legislation and zoning plans for non-agricultural land uses in rural areas, such as tourism and real estate investment.

A more integrated approach to planning multiple land uses within mixed landscapes in Guanacaste is needed. Relying too heavily on the relatively weak incentives for forest conservation provided by PSA and the potentially incomplete protection provided by the current forest-cover change restrictions, is unlikely to protect Guanacaste's valuable dry forests from the future threat of deforestation.

Acknowledgments

We thank the editor and the two anonymous reviewers for their detailed and useful comments that improved the quality of this paper. This work is part of the Research Project: TROPI-DRY (Human, Ecological and Biophysical Dimension on Tropical Dry Forest) a collaborative research network sponsored by Inter-American Institute for Global Change Research (IAI) CRN II # 021 which is supported by the US National Science Foundation (Grant GEO-0452325). Logistical support by the University of Alberta and Instituto Tecnológico de Costa Rica is acknowledged.

References

Abizaid, C., Coomes, O.T., 2004. Land use and forest fallowing dynamics in seasonally dry tropical forests of the Southern Yucatán Peninsula, Mexico. Land Use Policy 21 (1), 71–84.

Allen, W., 2001. Green Phoenix: Restoring the Tropical Forests of Guanacaste, Costa Rica. Oxford University Press, New York, 310 pp.

Arroyo-Mora, J.P., Sanchez-Azofeifa, G.A., Kalacska, M.E.R., Rivard, B., Calvo-Alvarado, J.C., Janzen, D.H., 2005a. Secondary forest detection in a neotropical dry forest landscape using landsat 7 Etm+ and Ikonos imagery. Biotropica 37 (4), 497–507.

Arroyo-Mora, J.P., Sanchez-Azofeifa, G.A., Rivard, B., Calvo-Alvarado, J.C., Janzen, D., 2005b. Dynamics in landscape structure and composition for the Chorotega region, Costa Rica from 1960 to 2000. Agricultural Ecosystems and Environment 106, 27–39.

Augelli, J.P., 1987. Costa Rica's frontier legacy. Geographical Review 77, 1–15.

Baptista, S.R., 2008. Metropolitanization and forest recovery in Southern Brazil: a multiscale analysis of the Florianópolis City-Region, Santa Catarina State, 1970 to 2005. Ecology and Society 13 (2), 5.

Baptista, S.R., Rudel, T.K., 2006. A re-emerging Atlantic forest? Urbanization, industrialization and the forest transition in Santa Catarina, Southern Brazil. Environmental Conservation 33 (03), 195–202.

Barrantes, G., 2000. Aplicación de incentivos a la conservación de la biodiversidad en Costa Rica. Ministerio del Ambiente y Energía (MINAE), Sistema de Áreas de Conservación (SINAC) e Instituto Nacional de Biodiversidad (INBio), Costa Rica, 28 pp.

Bawa, K.S., Seidler, R., 1998. Natural forest management and conservation of biodiversity in tropical forests. Conservation Biology 12, 46–55.

Bolaños, R., Navarro, C., 1999. Diagnóstico del estado de la caoba en Costa Rica. Tropical Science Centre, Central American Commission on the Environmnet and Development and PROARCA-CAPAS, San José, Costa Rica, 45 pp.

Bolaños, R., Watson, V., 1993. Mapa ecológico de Costa Rica 1:200,000: Según el sistema de zonas de vida de Holdridge. Centro Científico Tropical, San José, Costa Rica.

Boucher, D., Hansen, M., Risch, Vandermeer, D., 1983. Agriculture. In: Janzen, D.H. (Ed.), Costa Rican Natural History. University of Chicago Press, Chicago, pp. 66–73.

Bray, D.B., Klepeis, P., 2005. Deforestation, forest transitions, and institutions for sustainability in Southeastern Mexico, 1900–2000. Environment and History 11, 195–223.

Brockett, C.D., Gottfried, R.R., 2002. State policies and the preservation of forest cover: lessons from contrasting public-policy regimes in Costa Rica. Latin American Research Review 37, 7–40.

Calvo-Alvarado, J.C., Bolaños, R., Watson, V., Jiménez, H., Navarro, C., Guillén, J., Mendieta, M., Rosado, M., Lopez, Argüelles, A., Rivera, H., 2000. Evaluation of the conservation state of Mahogany in Mesoamérica. In: General Overview, Tropical Science Centre, Central American Commission on the Environment and Development and PROARCA-CAPAS, San José, Costa Rica, 31 pp.

Calvo-Alvarado, J.C., 1990. The Costa Rican national conservation strategy for sustainable development: exploring the possibilities. Environmental Conservation 17, 355–358.

Camacho, M.A., Reyes, V., Miranda, M., Segura, O., 2003. Gestión local y participación en torno al pago por servicios ambientales: Estudios de caso en Costa Rica. Centro Internacional de Política Económica Para el Desarrollo Sostenible (CINPE), San José, Costa Rica, 147 pp.

Carr, D., Barbieri, A., Pan, W., Iranavi, H., 2006. Agricultural change and limits to deforestation in Central America. In: Brouwer, F., McCarl, B. (Eds.), Agricultural and Climate Beyond 2005. A New Perpective on Future Land Use Patterns. Environment and Policy Series Book. Springer, (chapter 6), pp. 91–107.

Castro, R., Arias, G., 1998. Costa Rica: Toward the Sustainability of its Forest Resources. Technical report. Fondo Nacional de Financiamiento Forestal (FONAFIFO), San José, Costa Rica, 23 pp.

CATIE/IFO, 2004. In: Cordero, J., Doshier, D. (Eds.), Arboles de Centro América. Centro Agronómico de Investigación y Enseñanza y Instituto Forestal de Oxford, Costa Rica, 1100 pp.

CATURGUA, 2007. Liberia Airport, Guanacaste Costa Rica: Summary of International Commercial Passengers. Cámara de Turismo Guanacasteca, Costa Rica.

CCT-CIEDES-CI, 1998. Estudio de cobertura forestal actual (1996/97) y de cambio de cobertura para el período entre 1986/87 y 1996/97 para Costa Rica. Fondo Nacional de Financiamiento Forestal (FONAFIFO), San José, Costa Rica, 50 pp.

Chomitz, K.M., Brenes, E., Constantino, L., 1999. Financing environmental services: the Costa Rican experience and its implication. The Science of the Total Environment 240, 157–169.

Cordero, R., 2008. Cambio de la cobertura foresta de la tierra para el Area de Conservación Tempisque, período 1998–2003. In: Tesis de grado. Escuela de Ingeniería Forestal, Instituto Tecnológico de Costa Rica, Cartago, Costa Rica, pp. 75.

Cordero, J., Paus, E., 2008. Foreign Investment and Economic Development in Costa Rica: The Unrealized Potential. Working group on Development and Environment in the Americas Discussion Paper Number 13. Tufts' Global Development and Environment Institute. Medford, Massachusetts, USA, 27 p.

Cruz, M.C., Meyer, C.A., Reppeto, R., Woodward, R., 1992. Population Growth, Poverty, and Environmental Stress: Frontier Migration in the Philippines and Costa Rica. World Resources Institute, Washington, DC, USA, 105 p.

COFORSA, 2007. Plan Estratégico para el desarrollo de la agrocadena de la ganadería bovina de carne en la Región Chorotega. Federación de Cámaras de Ganaderos de Guanacaste and Ministerio de Agricultura y Ganadería Región Chorotega. Costa Rica, 72 pp.

De Camino, R., Segura, O., Arias, G., Pérez, I., 2000. Costa Rica: Forest Strategy and the Evolution of Land Use. World Bank, Washington, D.C., USA, 171 pp.

Edelman, M., 1985. Extensive land use and the logic of the latifundio: a case study in Guanacaste Province, Costa Rica. Human Ecology 13, 153–185.

Evans, S., 1999. The Green Republic: A Conservation History of Costa Rica. University of Texas Press, Austin, Texas, USA, 355 pp.

Ewel, J., 1999. Natural systems as models for the design of sustainable systems of land use. Agroforestry Systems 45, 1–21.

Farley, K.A., 2007. Grasslands to tree plantations: forest transition in the Andes of Ecuador. Annals of the Association of American Geographers 97 (4), 755–771.

Ferraro, P.J., Kiss, A., 2002. Direct payments to conserve biodiversity. Science 298, 1718–1719.

Flores, E., 1982. Geografía de Costa Rica. Editorial Universidad Estatal a Distancia, San José, Costa Rica, 473 pp.

FONAFIFO, 2007. Administración de Proyectos SIAP: Consultas PSA mapas. Fondo Nacional de Financiamiento Forestal, Costa Rica.

Geist, H.J, Lambin, E.F., 2001. What drives tropical deforestation? A meta-analysis of proximate and underlying causes of deforestation based on subnational case study evidence. LUCC Report Series. International Human Dimensions Programme on Global Environmental Change (IHDP), International Geosphere–Biosphere Programme (IGBP), Louvain, Belgium, 116 pp.

Geoghegan, J.M., Pritchard Jr., L., Ogneva-Himmelberger, Y., Chowdhury, R.R., Sanderson, S., Turner II., B.L., 1998. ''Socializing the pixel'' and ''pixelizing the social''. In land-use and land-cover change. In: Liverman, D., Moran, E.R., Rindfuss, R.R., Stern, P.C. (Eds.), Land-Use and Land-Cover Change. In People and Pixels: Linking Remote Sensing and Social Science. National Academy Press, Washington, pp. 51–69.

Grau, H.R., Aide, T.M., Zimmerman, J.K., Thomlinson, J.R., Helmer, E., Zou, X., 2003. The ecological consequences of socioeconomic and land-use changes in post-agriculture Puerto Rico. BioScience 53 (12), 1159–1168.

Gregersen, K., 1994. Campesinos y el desarrollo forestal: El caso de la región Chorotega en Costa Rica. Anuario de estudios centroamericanos 20 (1), 115–132.

Hall, C., 1984. Costa Rica una interpretación geografía con perspectiva histórica. Editorial Costa Rica, San José, Costa Rica, 466 pp.

Hall, C., Leon, C., Leclerc, G., 2000. Quantifying Sustainable Development: The Future of Tropical Economies. Academic Press, San Diego, 710 pp.

Harrison, S., 1991. Population growth, land use and deforestation in Costa Rica, 1950–1984. Interciencia 16, 83–93.

Harvey, C.A., Komar, O., Chazdon, R., Ferguson, B.G., Finegan, B., Griffith, D.M., Martínez-Ramos, M., Morales, H., Nigh, R., Soto-Pinto, L., Van Breugel, M., Wishnie, M., 2008. Integrating agricultural landscapes with biodiversity conservation in the Mesoamerican hotspot. Conservation Biology 22 (1), 8–15.

Hecht, S.B., Saatchi, S.S., 2007. Globalization and forest resurgence: changes in forest cover in El Salvador. BioScience 57 (8), 663–672.

Holdridge, L.R., 1967. Life Zone Ecology. Tropical Science Center, San Jose, Costa Rica, 149 pp.

Ibraham, M., Abarca, S., Flores, O., 2000. Geographical synthesis of data on Costa Rican pastures and their potential for improvement. In: Hall, C., Leon, C., Leclerc, G. (Eds.), Quantifying Sustainable Development: The Future of Tropical Economies. Academic Press, San Diego, pp. 423–446.

Ibarra, E., 2007. The profitability of forest protection versus logging and the role of payments for environmental services (PES) in the Reserva Forestal Golfo Dulce, Costa Rica. Forest Policy and Economics 10 (1–2), 7–13.
ICT, 2004. Instituto Costarricense de Turismo Estadísticas del Sector Turismo. Departamento de Estadísticas, Costa Rica.
Izquierdo, A.E., De Angelo, C.D., Aide, T.M., 2008. Thirty years of human demography and land-use change in the Atlantic forest of Misiones, Argentina: an evaluation of the forest transition model. Ecology and Society 13 (2), 3.
Janzen, D.H., 1988. Tropical dry forests: the most endangered major tropical ecosystem. In: Wilson, E.O. (Ed.), Biodiversity. National Academy Press, Washington, D.C., pp. 130–137.
Jiménez, J., González, E., 2001. La cuenca del Río Tempisque: Perspectivas para un manejo integrado. Organización para Estudios Tropicales, San José, Costa Rica, 136 pp.
Kaimowitz, D., 1996. Livestock and Deforestation – Central America in the 1980s and 1990s: A Policy Perspective. Center for International Forestry Research, Jakarta, Indonesia, 87 pp.
Kalacska, M., Sanchez-Azofeifa, G.A., Calvo-Alvarado, J.C., Quesada, M., Rivard, B., Janzen, D.H., 2004. Species composition, similarity and diversity in three successional stages of a seasonally dry tropical forest. Forest Ecology and Management 200, 227–247.
Klooster, D., 2003. Forest transitions in Mexico: institutions and forests in a globalized countryside. The Professional Geographer 55 (2), 227–237.
Kull, C.A., Ibrahim, C.K., Meredith, T.C., 2007. Tropical forest transitions and globalization: neo-liberalism, migration, tourism, and international conservation agendas. Society and Natural Resources 20, 723–737.
Lamb, F.B., 1966. Mahogany of Tropical America: Its Ecology and Management. University of Michigan Press, Ann Arbor, MI, USA, 200 p.
Lambin, E.F., Geist, H.J., Lepers, F., 2003. Dynamics of land-use and land-cover change in tropical regions. Annual Review Environment and Resources 28, 205–241.
Lambin, E.F., Turner, I.I., Geist, B.L., Agbola, H.J., Angelsen, S.B., Bruce, A., Coomes, J.W., Dirzo, O.T., Fischer, R., Folke, C., 2001. The causes of land-use and land-cover change: moving beyond the myths. Global Environmental Change 11, 261–269.
Mateo, J., Jiménez, J., González, E., 2001. Características generales de la cuenca del Río Tempisque. In: Jiménez, J., González, E. (Eds.), La cuenca del Río Tempisque: perspectivas para un manejo integrado. Organización para Estudios Tropicales, San José, Costa Rica, pp. 32–72.
Mercer, D.E., 2004. Adoption of agroforestry innovations in the tropics: a review. Agroforestry Systems 61–62, 311–328.
MIDEPLAN, 2008. Plan de acción para la Provincia de Guanacaste, 2009–2010. Ministerio de Planificación Nacional y Política Económica, San Jose, Costa Rica, 13 pp.
Miles, L., Newton, A.C., DeFries, R.S., Ravilious, C., May, I., Blyth, S., Kapos, V., Gordon, J., 2006. A global overview of the conservation status of tropical dry forests. Journal of Biogeography 33 (3), 491–505.
MINAE, 2002. El éxito forestal de Costa Rica: en cinco casos. Ministerio del Ambiente y Energía, San José, Costa Rica, 60 pp.
Miranda, M., Dieperink, C., Glasbergen, P., 2006. Costa Rican environmental service payments: the use of a financial instrument in participatory forest management. Environmental Management 38, 562–571.
Montenegro, J., Abarca, S., 1998. La ganadería en Costa Rica: Tendencias y proyecciones, 1984–2005. Ministerio de Agricultura y Ganadería, San José, Costa Rica, 63 pp.
Murphy, P.G., Lugo, A.E., 1995. Dry forest of Central America and the Caribbean. In: Bullock, S.H., Mooney, H.A., Medina, E. (Eds.), Seasonally Dry Tropical Forest. Cambridge University Press, Cambridge, UK, pp. 9–34.
Myers, N., 1981. The hamburger connection: how Central America's forests became North America's hamburgers. Ambio 10, 3–8.
Olson, D.M., Dinerstein, E., Wikramanayake, E.D., Burgess, N.D., Powell, G.V.N., Underwood, E.C., D'amico, J.A., Itoua, I., Strand, H.E., Morrison, J.C., Loucks, C.J., Allnutt, T.F., Ricketts, T.H., Kura, Y., Lamoreux, J.F., Wettengel, W.W., Hedao, P., Kassem, K.R., 2001. Terrestrial ecoregions of the world: a new map of life on earth. BioScience 51, 933–938.
Parés-Ramos, I.K., Gould, W.A., Aide, T.M., 2008. Agricultural abandonment, suburban growth, and forest expansion in Puerto Rico between 1991 and 2000. Ecology and Society 13 (2), 1.
Parsons, J., 1983. Beef cattle. In: Janzen, D.H. (Ed.), Costa Rica: Natural History. The University of Chicargo Press, Chicago, pp. 77–79.
Perz, S.G., Skole, D.L., 2003. Secondary forest expansion in the Brazilian Amazon and the refinement of forest transition theory. Society & Natural Resources 16 (4), 277–294.
Peters, G., 2001. La cuenca del Tempisque: Una perspectiva histórica. In: Jiménez, J., González, E. (Eds.), La cuenca del Río Tempisque: Perspectivas para un manejo integrado. Organización para Estudios Tropicales, San José, Costa Rica, p. 136.
Piperno, D.R., Pearsall, D.M., 2000. Origins and Agriculture in the Neotropics. Academic Press, San Diego, CA, 400 pp.
Quesada, M., Stoner, K.E., 2004. Threats to the conservation of tropical dry forest in Costa Rica. In: Frankie, G.W., Mata, A., Vinson, S.B. (Eds.), Biodiversity Conservation in Costa Rica Learning the Lessons in a Seasonal Dry Forest. University of California Press, Berkeley, pp. 266–280.
Quesada-Mateo (Eds.), 1990. Estrategia de conservación para el desarrollo sostenible de Costa Rica. Ministerio de Recursos Naturales, Energía y Minas, San José, Costa Rica, 163 pp.
Rindfuss, R.R., Walsh, S.J., Turner II, B.L., Fox, J., Mishra, V., 2004. Developing a science of land change: challenges and methodological issues. Proceedings of the National Academy of Sciences, USA 101, 13976–13981.
Rojas, M., Aylward, B., 2003. What Are We Learning from Experiences with Markets for Environmental Services in Costa Rica? A review and Critique of the Literature. International Institute for Environment and Development, London, 109 pp.
Sader, S.A., Joyce, A.T., 1988. Deforestation rates and trends in Costa Rica, 1940 to 1983. Biotropica 20, 11–19.
Sánchez-Azofeifa, A.G., Calvo-Alvarado, J.C., Chong, M.M., Castillo, M., Jiménez, W., 2006. Estudio de cambios de cobertura forestal de Costa Rica 2000–2005. Alberta University, Instituto Tecnológico de Costa Rica, San José, Costa Rica, 37 pp.
Sánchez-Azofeifa, A.G., Kalacska, M., Quesada, M., Calvo-Alvarado, J.C., Nassar, J.M., Rodriguez, J.P., 2005a. Need for integrated research for a sustainable future in tropical dry forests. Conservation Biology 19, 285–286.
Sánchez-Azofeifa, G.A., Quesada, M., Rodriguez, J.P., Nassar, J.M., Stoner, K.E., Castillo, A., Garvin, T., Zent, E.L., Calvo-Alvarado, J.C., Kalacska, M.E.R., Fajardo, L., Gamon, J.A., Cuevas-Reyes, P., 2005b. Research priorities for neotropical dry forests. Biotropica 37, 477–485.
Sánchez-Azofeifa, A.G., 2000. Land use and cover change in Costa Rica: a geographical perspective. In: Hall, C.A.S., Hall, C.A.S., Perez, C.L., Leclerc, G. (Eds.), Quantifying Sustainable Development the Future of Tropical Economies. Academic Press, San Diego, pp. 473–501.
Sloan, S., 2008. Reforestation amidst deforestation: simultaneity and succession. Global Environmental Change 18 (3), 425–441.
Solórzano, R., de Camino, R., Woodward, R., Tosi, J., Watson, V., Vasquez, A., Villalobos, C., Jiménez, J., Repetto, J., Cruz, W., 1991. Accounts Overdue: Natural Resource Depreciation in Costa Rica. World Resources Institute, Washington, D.C., 110 pp.
Stern, M., Quesada, M., Stoner, K., 2001. Changes in composition and structure of a tropical dry forest following intermittent cattle grazing. Revista Biología Tropical 50 (3–4), 1021–1034.
Tucker, C.M., Munroe, D.K., Nagendra, H., Southworth, J., 2005. Comparative spatial analyses of forest conservation and change in Honduras and Guatemala. Conservation and Society 3 (1), 174.
Watson, V., Cervantes, S., Castro, C., Mora, L., Solis, M., Porras, I.T., Cornejo, B., 1998. Making space for better forestry: Costa Rica study. In: Policy that Works for Forests and People, IIED, Junaforca, Centro Científico Tropical, San José, Costa Rica, 110 pp.
Weaver, D.B., 1999. Magnitude of ecotourism in Costa Rica and Kenya. Annals of Tourism Research 26, 792–816.
Zbinden, S., Lee, D.R., 2005. Paying for environmental services: an analysis of participation in Costa Rica's PSA program: institutional arrangements for rural poverty reduction and resource conservation. World Development 33, 255–272.