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Protected Areas and Conservation of Biodiversity in the Tropics

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Abstract: *We compared deforestation rates and the extent of fragmentation inside and outside protected areas in the Sarapiquí region of Costa Rica. We determined deforestation rates using remotely sensed images with supervised classification. We georeferenced the processed images and then transformed them to vector format for final mapping and parameter quantification. The deforestation rate in protected areas was low and declined sharply from 0.56% annually between 1976 and 1986 to 0.16% from 1991 to 1995. Outside the protected areas, the rate decreased from 3.6% in 1976–1986 to 2.8% in 1986–1991, but it increased again to 3.2% in 1991–1995. Fragmentation outside the protected areas increased considerably: the number of patches increased from 537 in 1976 to 1231 in 1996, while during the same period the average size of patches decreased from 0.95 to 0.25 km^2. Forest landscapes in the Sarapiquí region are likely to lose considerable biodiversity because of the past forest loss and fragmentation even without further increases in deforestation and fragmentation.*

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Resumen: *En este estudio comparamos las tasas de deforestación y la extensión de la deforestación y fragmentación de ecosistemas fuera y adentro de un area protegida en una región tropical. Tasas de deforestación fueron determinadas por medio de una clasificación supervisada de imágenes de satelite Landsat TM y MSS. Las imágenes fueron geo-codificadas, analizadas y los resultados fueron transformados a una formato vectorial con el fin de generar los mapas finales y la obtención de diferentes parametros de comparasión. En la región de Sarapiquí, Costa Rica, la tasa de deforestación en las áreas protegidas es considerada baja y con una pronunciada reducción en la misma. La tasa de deforestación en la región del Parque Nacional Braulio Carrillo, se redujó de 0.56% anual entre 1976–1986 a 0.16% anual para el periodo 1991–1996. Fuera de las áreas protegidas, la tasa de deforestación se redujó de 3.6% anual entre 1976–1986 a 2.8% anual entre 1986 y 1991. La misma se incrementó a 3.1% anual entre 1991 y 1996. En forma adicional, la fragmentación fuera de las áreas protegidas se ha incrementado considerablemente, el numero de islas boscosas se incrementó de 537 islas en 1976 a 1231 islas en 1996, durante el mismo periodo de tiempo el tamaño promedio de las islas se redujó de 0.95 km^2 a 0.25 km^2. Se concluye que el paisaje boscoso de la region de Sarapiquí sufrirá mayor perdida de su biodiversidad esto a pesar de que los procesos de deforestación y fragmentación sean reducidos.*

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Introduction

Continuing deforestation in the tropics remains a pressing environmental challenge (Brown & Pearce 1994). The creation of protected areas is a key strategy to combat deforestation and to curtail losses of biodiversity (Primack 1993; Hunter 1994; Heywood 1995; Meffe & Carroll 1997). Decades after the establishment of thousands of protected areas covering millions of hectares, however, there has been no consistent assessment of differences in deforestation rates inside and outside protected areas and of the role of protected areas in conserving biodiversity. Both inside and outside protected areas, moreover, emphasis has been on the loss or gain of forests, not on landscape changes such as forest fragmentation and isolation. Consequently, there is no quantitative information on the extent of fragmentation and concomitant losses of biodiversity for any tropical landscape. The emphasis on tropical deforestation (deforestation rates or total forest loss) has also distracted focus from such relevant issues as spatial and temporal variation in deforestation rates, which can reveal the dynamics of socioeconomic forces and policies leading to deforestation.

We report for the first time contemporary rates of deforestation and forest fragmentation and their consequences on the conservation of biodiversity inside and outside protected areas in a selected region in the Atlantic lowlands of Costa Rica. In particular we examine the effectiveness of protected areas in conserving forests. We show that although deforestation in protected areas has virtually stopped, forest loss and extensive landscape changes outside protected areas continue unabated, leading to substantial losses of biodiversity. Our measurements of deforestation and landscape changes allow us to pinpoint causes of deforestation in the region and to propose possible solutions to the deforestation crisis in Costa Rica.

Study Area and Methods

The Sarapiquí region in Costa Rica is of special importance because the La Selva Biological Field Station of the Organization for Tropical Studies is located in the area and has acted as a magnet and a global center for research in tropical biology (McDade et al. 1994). Moreover, the region remains heavily forested and constitutes to be an important reservoir of biodiversity (McDade et al. 1994). Yet there have been remarkably few studies on the impacts of deforestation and fragmentation on areas surrounding La Selva (Sánchez-Azofeifa & Quesada-Mateo 1995; Chase et al. 1996).

We studied deforestation in the Sarapiquí region by means of remote sensing and geographic information systems (986 km^2, 10°15′–10°30′N, 84°11′–83°53′W; Fig. 1). We used landsat multispectral scanner (MSS) images from 1976 and thematic mapper (TM) from 1986, 1991, and 1996. Images were processed by means of a supervised classification and a technique developed by the NASA Pathfinder Project for tropical deforestation known as in-pair processing (Chomentowsky et al. 1994). Supervised classification permits quantification of changes in forest cover during a time-series analysis. Classified images were first georeferenced to a Lambert Conformal Conic projection and later transformed from raster to vector format to allow for thematic and spatial quality control. Final forest-cover maps were processed with the computer program FRAGSTATS in order to quantify parameters related to forest fragmentation (Sánchez-Azofeifa 1996).

Results

We found that important changes have taken place in the landscape of the Sarapiquí region (Fig. 1). The forest cover changed from 55% of the landscape in 1976 to 37% in 1991 and 34% in 1996. Total forest area changed from 513 km^2 in 1976 to 312 km^2 in 1996. The annual rate of deforestation differed according to the level of protection provided in different areas. The deforestation rate in those areas protected within national parks remained low and varied from 0.56% in 1976–1986 to 0.21% and 0.16% in 1986–1991 and 1991–1996, respectively. The deforestation rate in the area under private conservation declined from 1.7% in 1976–1986 to 1.4% in 1986–1996. The area under no protection showed the highest deforestation rate, with a value of 3.6% in 1976–1986, declining to 2.8% in 1986–1991, and then increasing to 3.2% during 1991–1996.

Extensive habitat fragmentation accompanied deforestation. The number of forest islands increased from 537 in 1976 to 1226 in 1986, decreased to 1146 in 1991, and increased to 1231 in 1996. Most of the changes in forest fragmentation occurred during the period between 1976 and 1991, when the number of fragments increased by 689. Deforestation also affected the size of remnant forest units. Average fragment size dramatically decreased from 0.95 km^2 in 1976 to 0.25 km^2 in 1996 (Table 1). The change in fragment size was correlated with the change in the number of fragments.

Discussion

Data developed in the course of this study demonstrate that the rate of deforestation in Costa Rica, considered a model of conservation worldwide, remains alarmingly high. The trend in the Sarapiquí region is confirmed by a recent, more comprehensive analysis of the land-cover change for the entire humid region of Costa Rica, which revealed the rate of deforestation to be 4% per year for central Costa Rica (Sánchez-Azofeifa 1996). The average

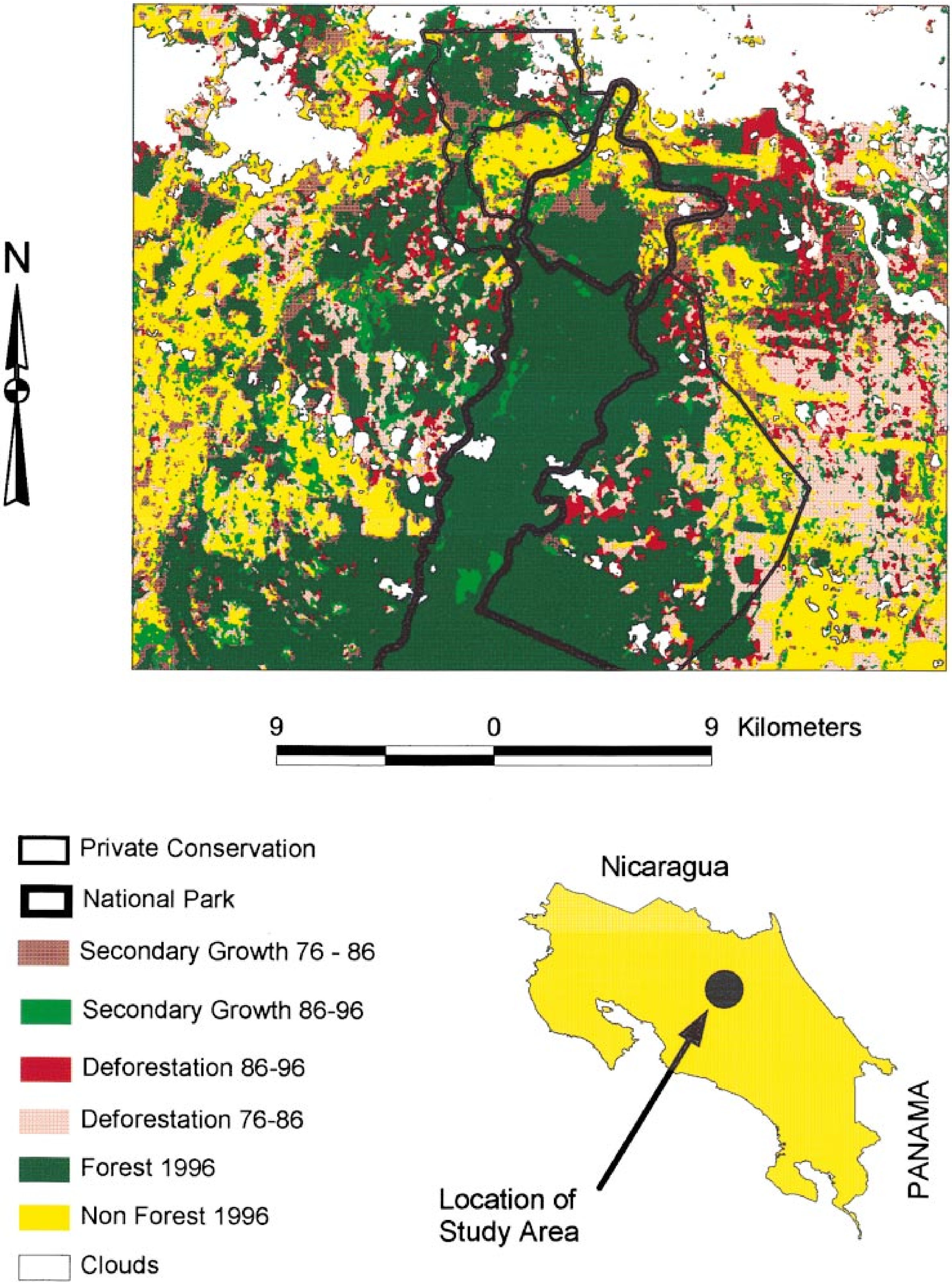

Figure 1. Location of study area, Puerto Viejo de Sarapiquí, Costa Rica. Map shows deforestation, isolation, and forest fragmentation in the Sarapiquí region between 1976 and 1996. The zone east of the conservation area is dominated by banana and pineapple plantations. Adapted from landsat multispectral scanner (1976) and thematic mapper (1986–1996) images.

Table 1. Forest fragmentation statistics for the Sarapiquí region, Costa Rica.

Parameter	*1976*	*1986*	*1991*	*1996*
Forest area (km^2)	513	381	345	313
Percentage of fragmented landscape	55	41	37	34
Number of fragments	537	1226	1146	1231
Average fragment size (km^2)	0.96	0.31	0.30	0.25

rate of deforestation for 1976–1996 for unprotected areas in the Sarapiquí region (3.2%) is comparable to that for the central portion of the country (4%).

The rate of deforestation for protected areas declined sharply, however, particularly after 1986, when Braulio Carrillo National Park was extended to the southern boundary of La Selva Biological Reserve. In areas dedicated to private conservation, which includes pastures, small-scale agriculture, and ecotourism, the rate was higher than in the national park but less than in areas dedicated to agrobusiness (Fig. 1). Protection is dramatically curtailing the rate of deforestation.

Apart from deforestation, notable changes in the forest landscape continue to occur at a rapid pace. The number of forest fragments increased between 1976 and 1986 and then again between 1991 and 1996. The increase in number of fragments was accompanied by a decrease in fragment size. Again, fragmentation occurred mostly outside protected areas. More than three-quarters of the fragmented area can be characterized as small forest islands with an average size of 25 ha.

The effects of deforestation and forest fragmentation on biodiversity are apparent from the following example. The adults of many large forest tree species in the Sarapiquí region occur at average densities of less than one individual per hectare (Clark 1994; Chase et al. 1996). Furthermore, these animal-pollinated trees are widely outcrossed with long-distance pollen flow, linking individuals of breeding populations over areas much larger than 25 ha (Bawa et al. 1985*a*, 1985*b*; Chase et al. 1996). Forest fragments, even without further decreases in size, are likely to rapidly lose populations of large trees, followed by the loss of other organisms. Small fragments are, in all likelihood, already devoid of large animals.

Conclusions

The causes of deforestation in the tropics are not fully understood (Pearce & Brown 1994). The main drivers probably vary from region to region (Bawa & Dayanandan 1997*a*, 1997*b*). In the Sarapiquí region, forest lands were mostly converted to pastures until the late 1980s. In more recent years, conversion to banana plantations has been a driving force behind deforestation (Hunter 1995). Interestingly, landscape alteration for banana plantations is more intensive than that for conversion to pastures, a process that accelerated after 1991 (Fig. 1).

How can we curtail further losses of forests and, thus, biodiversity? It is unlikely that all existing remnants of tropical forests can be brought under protection, and it is likely that, as forests outside of protected areas disappear, the pressure on protected areas will grow. Thus, it is important to conserve biodiversity outside protected areas, at least as buffers for protected areas. Implementation of this type of conservation practice will, however, require ecological, economic, and social evaluation of the remaining forest ecosystems outside protected areas to ascertain their uniqueness and value for the well-being of human societies. It will also require the development of management plans for the monitoring, management, and preservation of biodiversity in fragmented landscapes.

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