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Land Use Changes Directed Towards Sustainable Development in Los Santos Forest Reserve, Costa Rica

Resumen

Este artículo discute brevemente los cambios presentes y del pasado que los sistemas de uso de la tierra que suceden en una área de bosque tropical montano en Costa Rica. Desde el inicio de la colonización hace medio siglo, el área ha sufrido por la conversión de los bosques a la ganadería. A finales de los años 1970s ocurrieron cambios en el uso de la tierra, estimulados por la presencia de la Reserva Forestal Los Santos. La producción comercial de frutales en las parcelas pequeñas y la introducción del ecoturismo han causado el abandono de los pastizales poco productivos en las zonas altas de la Reserva. Los bosques secundarios que se desarrollan en las tierras degradadas por medio de recuperación natural parecen ofrecer posibles usos de la tierra alternativos en un largo plazo. El manejo del bosque maduro, la agroforestería y la reforestación con especies nativas pueden convertirse en opciones serias de usos alternativos de la tierra. Se cree que los cambios recientes y los que se esperan en el cambio de uso de la tierra contribuirán a una gestión sonora como parte del proceso regional hacia el desarrollo sustentable.

Introduction

The 62,000-ha Los Santos Forest Reserve (LSFR) in south-central Costa Rica is an interesting example of a protected tropical montane cloud forest area in which land patterns have been changing over the past two decades from inappropriate, often destructive, short-term agricultural practices, towards ecologically more wise land management options. Indeed, as in many tropical areas, deforestation in the LSFR had been taking place at alarming rates during the 1950s, 1960s, and early 1970s. However, since the establishment of the forest reserve in 1975 and the introduction of fruit trees and ecotourism activities in the early 1980s, regions such as the upper Río Savegre watershed area have shown an increase in socioeconomic development on an ecologically sound basis (Kappelle and Juárez 1995). The present paper puts these land use changes in a historical context and discusses the different sustainable land use options that have been implemented.

Administrative Status

The LSFR is administered by the Costa Rican Ministry of Environment and Energy. It is situated on the pacific slope of the Cordillera de Talamanca, where it borders the 612,570-ha Amistad Biosphere Reserve (ABR) (see Figure 1). Declared a biosphere reserve in 1982 by UNESCO, ABR has also been partially classified as a World Heritage Site (Whitmore 1990), and has been recognized as an 'Endemic Bird Area' (Long 1996) and a 'Centre of Plant Diversity' (Groombridge 1992). The LSFR is actually functioning as a buffer zone vital to the ABR, as it separates the densely populated central valley of Costa Rica from the remote largely undisturbed core areas of the ABR (Kappelle and Juárez 1994). Recently, the LSFR and the ABR have been included in the Amistad Conservation Area (ACA), which covers 7.8% of the Costa Rican territory and forms part of the National System of Conservation Areas (SINAC), which was created in 1989 to facilitate the administrative management of forest areas and the biodiversity conservation of the country in an integrated manner.

Ecological Characterization

The LSFR (9°25'–9°45' N; 83°40'–84°00' W) is located in the Cordillera de Talamanca, which is formed of intrusive and Tertiary volcanic rocks, alternated with marine sediments (Weyl 1980). Elevation ranges from about 500 m up to 3,500 m. Soils (Andosols: Histi Hapluland) are of volcanic origin, rich in organic matter, well-drained, and rather acidic, with pH values ranging from 3.7 to 5.0 (Kappelle et al. 1989; van Uffelen 1991) The climate is humid to perhumid with a relative humidity varying from 30% to 95% and an average annual rainfall of 2,812 mm at

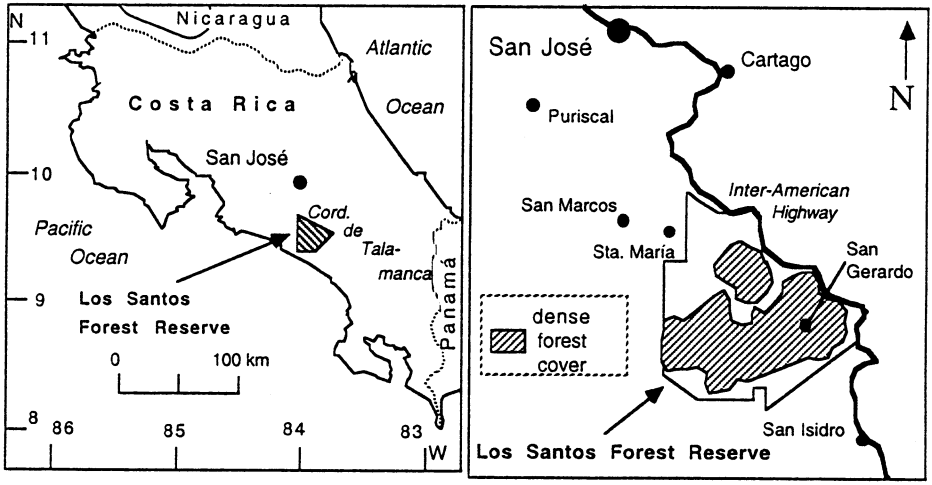

Figure 1. Location of the Los Santos Forest Reserve in central Costa Rica (left) with the reserve's dense forest cover as estimated in 1992 (right)

3,000 m altitude. The dry season lasts from December to April. Average annual temperature range from 14.5°C at 2300 m to 10.9°C at 3,000 m (IMN 1988; Kappelle 1992).

The vegetation of the upper Savegre watershed in the northeastern comer of the LSFR is characterized by patches of mature primary forest and 10- to 33-year-old recovering (secondary) forests, dense inaccessible shrublands, fern brakes, pasturelands with isolated trees, and fruit tree orchards (Kappelle et al. 1994, 1995). This diverse multifaceted landscape mosaic is the result of a past history of intensive logging and burning, and subsequent changes in land use (Kappelle and Juárez 1995).

Scattered and shredded tracts of mature tropical montane cloud Forest *(sensu* Hamilton et al. 1995) are still present throughout the LSFR. They are dominated by different 30- to 35-m-tall oak species: *Quercus costarricensis, Q. copeyensis, and Q. seemannii.* The subcanopy is characterized by tree species belonging to genera such as *Ardisia, Cornus, Ilex, Ocotea, Oreopanax, Nectandra, Myrsine, Persea, Styrax, Symplocos, Vaccinium, Viburnum, Weinmannia, and Zanthoxylum.* The understory consists of Chusquea bamboo clumps, geonomoid dwarf palms, cyclanths and shrubs within the Asteraceae, Ericaceae, Melastomataceae, Rubiaceae and Solanaceae. Epiphytic bromeliads, orchids, ferns, mosses, liverworts, and lichens blanket the branches of canopy and subcanopy trees (Kappelle et al. 1989).

Recent estimates suggest a total of about 3,300 vascular plant species in the LSFR (Kappelle 1996); Gómez (1989) indicated that some 1,000 species of vascular plants are to be expected in the ABR, most of which are non-tree species such as orchids and ferns. Probably about 30-40% of this vascular flora is endemic to the region. Zoological studies in the LSFR and ABR are scarce but the following native mammal species are known to reside in these protected areas: the ocelot *(Felis pardalis),* the puma *(Felis concolor),* the jaguar *(Panthera onca),* the coyote *(Canis latrans),* the tapir *(Tapirus bairdii),* the brocket deer *(Mazama americana),* two species of rabbits *(Silvilagus brassiliensis and S. dicei),* five species of mice (in *Oryzomys, Peromyscus, Reithrodomys, and Scotinomys),* the white-faced monkey *(Cebus capuchinus),* the howler monkey *(Alouatta palliata),* and the spider monkey *(Ateles geofroyi),* as well as a number of indigenous bats (Mora and Moreira 1994). Bird life is extraordinarily rich (Wilms and Kappelle, in preparation), the resplendent quetzal *(Pharomachrus mocinno costaricensis)* being the most spectacular of all.

Patterns in Land Use History

Ureña (1990) discussed the start of the colonization and deforestation process which took place in the 19th century with the introduction of coffee cultivation in the northeastern corner of the LSFR. Subsequently, migration of farmer families occurred

in a southeasterly direction into the greater part of today's LSFR, as a consequence of an increase in the area's population. The construction of the Pan-American highway by U.S. engineers in the 1940s boosted the development of small villages created in the early 1920s and 1930s when landless peasants settled down in the central part the LSFR. In the 1930s, the areas were colonized and cleared for land (Ureña 1990). Farmers dwelling at elevations of about 2,000 m dedicated themselves principally to timber extraction fuelwood collection, charcoal production, and blackberry cultivation. Forest lands were converted into extensive grasslands for low-intensity dairy-cattle ranching as well as for potato croplands. Indiscriminate deforestation by both local colonists and commercial lumber companies took place during the 1950s, 1960s, and early 1970s (Kappelle and Juárez 1995).

In order to halt further forest conversion, the Costa Rican government created the LSFR in 1975 (Bonilla 1983). As forest clearing became prohibited by law, lumber companies left and local peasants changed their inappropriate land use practices. Accidentally, fruit trees (apple, peach, plum) were introduced to the region at the same time as the establishment of the LSFR. Fruit tree orchards were established successfully from the beginning of the 1980s in several of the region's river valleys, such as the upper Rio Savegre watershed area.

Recovery Potential of Degraded Land

It has been demonstrated that most of the land use systems implemented between the 1950s and 1980s have been far from sustainable (Kappelle and Juárez 1995). Environmental mismanagement has included indiscriminate clearing and uncontrolled burning, leading to local fuelwood scarcity and severe land degradation, including irreversible soil erosion. Tropical montane forest habitats have become shredded and fragmented throughout the LSFR. Water resources for irrigation purposes have been reduced, limiting potato cultivation on arable lands. Water pollution from overuse of pesticides may have caused a decrease in the supply of good drinking water and an increase in health problems in the southeastern region of the LSFR (Kappelle and Juárez 1995). In the past, reforestation efforts were scanty, with plantations being less than a few hectares in size. In general, plantations made use of exotic tree species of the genera *Cupressus, Eucalyptus,* and *Pinus*. Unfortunately, plantations of promising native species, such as *Alnus accuminata* ssp. *arguta* are much less often seen. Agroforestry systems, such as the innovative combination of the native alder and different indigenous blackberry shrubs, are still in an experimental stage.

Recent research has shown that abandoned pastureland may recover from degradation through a process of secondary succession (Kappelle et

al. 1994, 1995). Ecological data from a chronosequential sere, including 8- to 32-year-old secondary forest and mature montane oak-dominated cloud forests in the LSFR, have shown that maximum canopy height and basal area increased linearly during the first three decades of recovery. A period of at least 80 years was estimated as the theoretically minimum time needed for structural recovery. However, the maximum canopy height and basal area recover two to five times slower in upper montane cloud forest than in lowland neotropical forest (Kappelle et al. 1996). Terrestrial vascular plant diversity as measured by Shannon-Wiener's index appeared to be equal or even higher in secondary forests compared with primary montane forests due to downslope migration of numerous subalpine species into cleared and recently abandoned montane sites. Using linear regression, the minimum time required for floristic recovery following disturbance and abandonment was estimated at about 65 years. A comparison with other studies shows that secondary forests in the upper-montane forests of the LSFR can be as diverse as those in the tropical lowlands (Kappelle et al. 1995).

Some key factors influencing the rate of forest recovery on abandoned lands are the nearness of seed sources, the presence and success of seed dispersers, and the size and composition of seed banks. Ten Hoopen and Kappelle (in press) studied the effects of forest vicinity on soil seed banks in pasturelands at forest edges in oak-dominated forests of the LSFR. They took soil seed-bank samples along four 50-m-long forest interior–edge–exterior transects and placed the samples in a greenhouse for a germination experiment. After a four-month period, a total of 4,096 seedlings in 50 species had emerged. Significantly fewer species germinated from soil seed-bank material collected in mature forest in comparison with pastureland, stressing the recovery potential of the latter.

Research on frugivorous bird species' diets, behaviour, distribution, diversity, and habitat preferences in the LSFR's mature and secondary montane cloud forests and pasturelands has demonstrated the presence of a number of avian seed dispersers playing a key role in forest restoration (Wilms and Kappelle, in preparation). Data suggest that fragmented forest depends on seed dispersal by birds for a successful recovery and regeneration process. Indeed, the presence of isolated ornithochorous tree species in open successional plant communities seems to be an important factor for attracting birds from mature forests and accelerating the process of forest restoration. Bird attracted to lauraceous tree species have been recommended for the restoration process.

Towards Sustainable Development

During the last two decades many changes in land use have occurred in the LSFR. These changes have made this forest reserve into a better func-

tioning buffer zone bordering the megadiverse ABR. New land use options directed towards an environmentally sound socioeconomic progress are presently being developed. One of these options concerns sustainable mature forest management. This has been proposed for the Costa Rican montane oak forests by different authors (e.g., Aus der Beek and Sáenz 1992; Jiménez and Picado 1992; Chaverri and Hernández 1995). Jiménez and Picado (1992) propose silvicultural treatments at two levels: (a) felling and extraction of some overmature and mature canopy trees, and (b) felling and extraction of subcanopy individuals, with the aim to improve the proportion of commercial species in relation to non-commercial ones. According to Chaverri and Hernández (1995), such a silvicultural treatment must be selective, thus ensuring the actual age structure, and must include two different felling intensities in order to utilize 8% of the trees with dbh values over 90 cm. Of course, damage to the remaining vegetation should be minimized and extraction should be monitored. Stadmüller and Aus der Beek (1992) did experiments during which 20-30% of the basal area was extracted in the LSFR bordering Rio Macho Reserve. However, Stadmüller (1993), in his study on the impact of selective logging on the herbaceous vegetation, showed that these treatments probably need refinements, as pioneer species seem to have taken most advantage of the disturbance, suppressing the establishment of primary forest species, at least temporarily.

Another possible land use option concerns the management of secondary forests. Recently, there has been an increase in knowledge about tropical lowland secondary forest management (Finegan 1992; Sips 1993); still, little is known on the potential of second growth in the montane tropics (Kappelle 1994). As has been pointed out earlier, montane secondary forests in the LSFR may establish on old abandoned fields and extensively used pasturelands through a process of succession. Their area is rapidly expanding as pasturelands are becoming abandoned. During the last decades, dairy-cattle ranching has become relatively less profitable, since yields from recently established fruit orchards were increasing substantially and farmers needed less area for fruit cultivation. Secondary forest management in the LSFR appears to be a low-cost and high-benefit socioeconomic option, because these recovering forests can grow without much human labor. After clearing, a decade of grazing and subsequent abandonment, a still healthy forest recovery process may start—given nearby seed sources and seed dispersers. In this way, ecosystem recovery and restoration of key ecological functions are stimulated, and a new, natural resource with a socioeconomically high potential value is created. Initially, the second growth's vegetation cover protects the fragile soils against erosion and restores the area's hydro-

logic function, while in the longer term they may be used for timber production and fuelwood collection. They also may form corridors connecting isolated patches of pristine primary forests, and thus increase the survival chances of numerous animal species. As succession proceeds, the usefulness of recovering forests may be improved by favouring desirable native tree genera such as *Alnus, Buddleja, Cornus,* and Lauraceae through thinning and enrichment practices. In this manner, a high-yield, multipurpose forest resource may be obtained, which in the long run takes away the pressure from the mature montane forests.

A serious alternative for development may be reforestation with native species. At this moment, exotic species dominate reforestation programs, despite that their often negative effect on soils and herbaceous vegetation is well known (cf. Lines and Foutnier 1979; Morris 1985). Arnáez et al. (1992) have demonstrated the reforestation potential that have species native to the LSFR, such as *Brunellia costaricensis, Cleyera theaeoides, Cornus disciflora, Drymis granadensis, Laplaceae* sp., *Magnolia poasana, Nectandra whitei, Ocotea* spp., *Podocarpus macrostachyus, Prumnopityus standleyi, Schefflera rodriguesiana, Weinmannia pinnata,* and different species of *Quercus.* However, the presence of soil ectomycorrhiza is a fundamental condition for a successful planting programme which include *Quercus* spp., *Alnus acuminata,* and *Salix* sp. (I. Rojas and G. Mueller, personal communication).

Agroforestry is another land use system promising a high level of sustainability in the region. Mata (1992) mentions the combination of *Alnus* and *Rubus* as a land use type with a high potential for the more elevated parts of the LSFR. Such an agroforestry system may help control soil erosion on steep slopes as the combination of different vegetation layers at one point strongly reduces the erosive impact of local rainfall.

Over the last ten years, ecotourism has been booming in Costa Rica and its montane cloud forest areas (Aylward et al. 1996). Presently, the upper Río Savegre watershed area is one of the main centers of ecotourism activities in the LSFR. As this watershed area, including the village of San Gerardo de Dota, is situated along the Pan-American highway at a two-hour drive from the capital San José, it has become an excellent site for nature-loving visitors, especially bird-watchers. Today, local farmers are earning an additional income as guides, taking tourists on a trip along nature trails through the bird-watcher's paradise, the tropical montane cloud forests. Spectacular birds include the resplendent quetzal and the emerald toucan. It is believed that ecotourism may become a significant alternative source of income for many farmer families in the near future; however, it is stressed that ecotourist activities should be controlled, taking into account the maximum capacity of the area and the number of

visitors the LFSR's montane cloud forest can bear. Only in this way can the requirements of a truly sustainable form of ecotourism be met, promoting economic development which is socially just and ecologically sound.

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References

Arnáez, E., I. Moreira, F. Rojas, and G. Torres. 1992. Especies forestales nativas: Una estrategia para las zonas altas de Costa Rica. PP. 26-28. In: *Resúmenes II Congreso Forestal Nacional.* San José, Costa Rica: Imprenta Lil.

Aus der Beek, R., and G. Sáenz. 1992. *Manejo forestal baso en la regeneración natural del bosque: Estudio de caso en los robledales de altura de la Cordillera de Talamanca, Costa Rica.* Informe Técnico 200. Col. Silvic. Mn, Bosq. Nat. 6. Turrialba, Costa Rica: CATIE. 47 pp.

Aylward, B., K. Allen, J. Echeverría, and J. Tose. 1996. Sustainable ecotourism in Costa Rica: The Monteverde Cloud Forest Preserve. *Biodiversity and Conservation* 5:315-343.

Bonilla, A. 1983. *Reservas Forestales y Zonas Protectoras.* Cartago, Costa Rica: Ed. Tecnológico de Costa Rica. 310 pp.

Chaverri, A., and O. Hernández. 1995. Ecology and management in montane oak forest: An option for conserving biodiversity. Pp. 609-617 in S. Churchill, H. Balslev, E. Forero, and J. Luteyn (eds.), *Biodiversity and Conservation of Neotropical Montane Forests.* The New York Botanical Garden, Bronx.

Finegan, B. 1992. The management potential of neotropical secondary lowland rain forests. *Forest Ecology and Management* 47:295-321.

Gómez, L. D. 1989. *Unidades Naturales: Estado y Uso Actual de los Ecosistemas y Recursos Naturales, Beneficios Potenciales y Riesgos Naturales en la Región de la Reserva de la Biósfera de Talamanca-Amistad.* San José, Costa Rica: Consultoría para la OEA. 13 pp.

Groombridge, B. (ed.) 1992. *Global Biodiversity: Status of the Earth's Living Resources.* World Conservation Monitoring Centre. London: Chapman and Hall. 594 pp.

Hamilton, L. S., J. O. Juvik, and F. N. Scatena. 1995. *Tropical Montane Cloud Forests.* New York: Springer-Verlag. 407 pp.

IMN. 1988. Catastro de las series de precipitaciones medidas en Costa Rica. Instituto Meteorológico Nacional. San José, Costa Rica: MIRENEM. 363 pp.

Jiménez, W., and H. Picado. 1992. Estudio ecológico y prospecciones silviculturales para el manejo del robledal de La Esperanza, Reserva Forestal Rio Macho, Costa Rica. Pp. 104-

105 In: *Resúmenes II Congreso Forestal Nacional.* San José, Costa Rica: Imprenta Lil.
Kappelle, M. 1992. Structural and floristic differences between wet Atlantic and moist Pacific montane Myrsine-Quercus forests in Costa Rica. Pp. 61-70 in H. Balslev and J. Luteyn (eds.), *Paramo: An Andean Ecosystem under Human Influence.* London: Academic Press.
———. 1994. Management of montane secondary forests in Costa Rica: an environmentally-sound economic alternative? P. 19 in D. Vartanián and A. C. Pérez (eds.), *Down to Earth, Practical Applications of Ecological Economics.* Program and Abstracts of the III Biennial Meeting of the Society for Ecological Economics. San José, Costa Rica: IICA and Universidad Nacional.
———. 1996. *Los Bosques de Roble (Quercus) de la cordillera de Talamanca, Costa Ritca: Biodiversidad, Ecología, Conservación y Desarrollo.* Amsterdam and Santo Domingo de Heredia, Costa Rica: Universidad de Amsterdam and Instituto de Biodiversidad (INBio). 336 pp.
Kappelle, M., and M. E. Juárez. 1994. The Los Santos Forest Reserve: A buffer zone vital for the La Amistad Biosphere Reserve. *Environmental Conservation* 21(2):166-169.
———. 1995. Agroecological zonation along an altitudinal gradient in the montane belt of the Los Santos Forest Reserve, Costa Rica. *Mountain Research and Development* 15(1):19-37.
Kappelle, M., A. M. Cleef, and A. Chaverri. 1989. Phytosociology of montane Chusqrea-Quercus forests, Cordillera de Talamanca, Costa Rica. *Brenesia* 32:73-105.
Kappelle, M., P. A. F. Kennis, and R. A. J. DeVries. 1995. Changes in diversity along a successional gradient in a Costa Rican upper montane Quercus forest. *Biodiversity and Conservation* 4:10-34.
Kappelle, M., Van Velsen, and W. H. Wijtzes. 1994. Plant communities of montane secondary vegetation in the Cordillera de Talamanca, Costa Rica. *Phytocoenologia* 22:449-484.
Kappelle, M., T. Geuze, M. Leal, and A.M. Cleef. 1996. Successional age and forest structure in a Costa Rican upper montane Quercus forest. *Journal of Tropical Ecology* 12:681-698.
Lines, N., and L. A. Fournier. 1979. Efecto alelopático de Cupressus lusitanica (Mill) sobre la germinación de las semillas de algunas hierbas. *Revista de Biología Tropical* 27(2).
Long, A. J. 1996. Establishing conservation priorities using endemic birds. Pp. 35-46 in S. Harcourt and J. A. Sayer (eds.), *The Conservation Atlas of Tropical Forests: The Americas.* New York: Simon and Schuster.
Mata, F. 1992. Datos preliminares sobre cosecha en el sistema agroforestal de jaúl (Alnus acuminata spp arguta [Schlechtendal] Furlow) combinado con mora (rubus spp) en la zona alta de Cartago. Pp. 211-212 in *Resúmenes II Congreso Forestal Nacional.* San José, Costa Rica: Imprenta Lil.
Mora, J. M., and I. Moreira. 1984. *Mamíferos de Costa Rica.* San José, Costa Rica: EUNED. 175 pp.
Morris, A. 1985. Forestry and land-use conflicts in Cuenca, Ecuador. *Mountain Research and Development* 5(2):183-196.
Schumaker, A. 1993. Ökologische Untersuchungen der bodennahen Vegetationsschicht eines Eichen-Nebelwald (Costa Rica) Thesis. Univ. Marburg, Germany. 71 pp.
Sips, P. 1993. *Management of tropical secondary Rain Forests in Latin America.* Wageningen, The Netherlands: Stichting BOS. 71 pp.
Stadmüller, T., and R. Aus der Beek. 1992. Development of forest management techniques for tropical high mountain primary oak-bamboo forest. Pp. 245-259 in F. Miller and K. Adam (eds.). *Wise Management of Tropical Forests.* Proceedings of the Oxford Conference

on Tropical Forests. Oxford: Oxford Forestry Institute.
Ten Hoopen, G. M., and M. Kappelle. In press. *Initial germination from soil seed banks at forest edges in a Costa Rican montane cloud forest.* 1998. Symposium and Annual Meeting of the Association for Tropical Biology and Organization for Tropical Studies. San José, Costa Rica.
Ureña, A. 1990. *Reseña histórica del Cantón de Dota.* San José, Costa Rica: Ed. Serrano Elizondo. 379 pp.
Van Uffelen, J. G. 1991. A geological, geomorphological and soil transect study of the Chirripó Massif and adjacent areas, Cordillera de Talamanca, Costa Rica. M.Sc. Thesis. Wageningen Agricultural University. Internal report. 72 pp.
Weyl, R. 1980. *Geology of Central America.* Stuttgart: Gebr. Bornträger. 371 pp.
Whitmore, T. C. 1990. *An introduction to Tropical Rain Forests.* Oxford: Clarendon. 226 pp.
Wilms, J. A. M. and M. Kappelle. In preparation. *The role of frugivorous birds in montane cloud forest restoration in Costa Rica.*

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