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Global Change Effects on the Vegetation of Tropical High Mountains and Savannas

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How do savannas and tropical mountain ecosystems respond to global change? What are the main changes in structure and functioning of these ecosystems when subjected to human modification and use? What are the ecological feedbacks? To answer these questions, we used two lines of research: analyses of changes taking place along natural and "human disturbance" gradients and analyses of ecological structure and dynamics at scales from landscape to organisms. This approach allowed scientists to shed light on how ecosystems or their components have responded to a range of environmental changes.

Some of this scientific information can be readily used in decision-making processes. For instance, our results were influential in showing the effects of large-scale transformation of natural landscapes into pastureland, from both Andean cloud forests and native savannas. Andean natural vegetation exerts a strong moderating effect on surface runoff, particularly during major rainfall events. This feature is lost when the natural vegetation is replaced by pastures. Floristic composition affects the magnitude of surface drainage, which in Colombian pasturelands reaches very high values (Ataroff and Silva 2005). The regulating effects of forests determine the magnitude of downstream flows and reduce the occurrence of flooding.

The scientists in our project translated scientific information for different audiences in order to influence decision-making processes. We were able to apply scientific information to regional land use decisions based on the balance between human needs and ecosystem function (Klink et al. 2005). The ongoing, rapid transitions to pasture and cropland taking place in the Cerrado savannas of Brazil have multiple consequences for biodiversity, watershed protection, carbon sequestration, and other ecosystem functions.

Box 18.1. Key findings

Cloud forests of the Andes capture atmospheric water and regulate flux and drainage from 3,000 m to the piedmont. Fragmentation of these forests, or their transformation into planted grasslands, may affect water flow, flooding, and landslides.

There is evidence of climatic change in the lowland of the Province ofTucuman, Argentina, with increased average annual rainfall, more intense rainfall events, and increased cloudiness, which causes lower day temperatures and higher night temperatures. This combination of changes has favored the transformation of natural ecosystems into agricultural systems.

Many of the dominant plant species of tropical high mountains are specialists and respond similarly to thermal and water stresses. Under climate change, they are likely to be replaced by fast-growing species with broad ecological niches. The most affected species would be caulescent rosettes and shrubs.

Avoidance is the main resistance mechanism to low temperature of the dominant rosette species. Low - growing plant species (cushion plants, grasses, herbs, and acaulescent rosettes) rely on freezing tolerance. Regarding water stress, species lie along an avoidance-tolerance gradient: Most shrubs and caulescent rosettes are avoidance types, while herbs and grasses are tolerant. *(continues in next page)*

The genus *Polylepis* is a unique ecological model for the study of plant distribution along altitudinal gradients because it reaches much higher elevations than any other angiosperm tree. *P sericea* has a wide altitudinal/latitudinal distribution range; therefore populations from low altitudes could replace those from high altitudes. *P australis* is restricted to extreme southern latitudes; therefore populations would not be replaced. Under climate change, the genus would persist, while species would be affected differently.
Drainage, topography, and dominant vegetation are the main factors to discriminate landscape and ecological units of the Cerrado, Brazil. Some edaphic features differ at the landscape scale but are less important in differentiating ecological units.
Landforms and soil types affect woody vegetation of the Llanos, Venezuela. Tree density is higher on sandy and more-stable surfaces despite lower water retention capacity in the topsoil. The increase of forest patches in the Orinoco Llanos in recent decades *is* not only the outcome of fire and grazing exclusion.
Ecological processes such as establishment of new woody patches in the grass matrix, coalescence of neighboring patches, and persistence of established patches may be related to changes in rainfall patterns: increased monthly averages in June and July (early wet season) and decreased monthly averages from October through December (transition to early dry season). This trend may have caused wetter growth seasons and drier transitions from wet to dry seasons. Seedlings can produce enough biomass during their first season to allow them to resprout and survive after a dry season fire in the Llanos. This tolerance to fire indicates that water deficit (in space and time) is more relevant to the regeneration of woody species.
Deep roots affect the hydrology of the Cerrado. During the dry season, deep soil compartments can contribute as much as 80 percent of the total water used by tree-dominated communities. When there is below-average rainfall during the growing season, deep roots seem to provide water for the vegetation. Replacing natural ecosystems with planted pastures may change the water balance of the Cerrado. There is evidence of biological activity and availability of phosphorus in deep Cerrado soil. It seems that phosphorus supply is dependent on the biological cycling.
The range of natural abundance of nitrogen-IS in Cerrado plant leaves is similar to that in other nitrogen-limited ecosystems. The variability in the abundance of nitrogen-IS found is due to the presence of nitrogen-fixing legumes, associations with mycorrhiza, depth-related variability of soil organic matter, the seasonality of nitrogen immobilization and mineralization in soils, and fire.
Carbon stocks in the natural Cerrado are larger than in planted pastures (which cover 25 percent of the Cerrado). In both ecosystems, most carbon stocks from biomass are underground, where fluxes are more intense. Carbon recycling is faster in pastures. Management practices can change the direction of transfer (from land to atmosphere or from atmosphere to land).

Therefore, the trade-offs between economically valuable production of beef, grain, and other agricultural products could be compared with multiple ecosystem functions over various temporal and spatial scales (Klink et al. 2005).

Communicating these trade-offs influenced how decision makers used scientific knowledge, for instance, in a white paper commissioned by the World Bank in support of the Sustainable Cerrado Initiative to be financed by the Global Environment Facility (Klink 2004) . In July 2005, this document became the basis for developing the Sustainable Cerrado program by the Brazilian Ministry of the Environment. The results of other initiatives that have implications for policy, training, and outreach related to global change are in the form of synthesis of results, such as the following: *Cambios globales, biodiversidad y el fimcionamiento de ecosistemas montanos y sabanas en Sudamerica* (Silva et al. forthcoming); *Ecofisiologia de plantas de paramo* (Az6car and Rada 2006); *Dinamica hidrica en sistemas neotropicales* (Ataroff and Silva 2005); and *Symposium: Cerrado Land-Use and Conservation: Assessing Trade-Offi Between Human and Ecological Needs* (Klink et al. 2005). Still others are in the form of databases: "Plantas vasculares paramos de Venezuela: botinica y ecologla" and "Plantas vasculares de las sabanas Lezuela: botanica y ecologla" (Silva and Ramirez forthcoming).

The proximity of scientists to practitioners and policy makers in environmental change issues can be positive for two reasons: Policy makers can incorporate scientific knowledge into their decision-making process, and scientists can guide their research toward problem solving. The key factor for a positive interaction is the willingness of both partners to participate in a dialogue. However, this is not an easy dialogue, because of the difficulties in understanding jargon and approaches, differences in time perspectives (particularly when practitioners ask scientists to put knowledge into use right right away and scientists usually are concerned about whether or not results are "ready" for use) and the occasional perception that scientists are researching themes or subjects that are not relevant to what policy makers need.

One area in which the dialogue can be very fruitful is capacity building, because both arenas recognize and prize this endeavor. Our network focused on training young ecologists in the region pursuing South-South collaboration (Silva 2005). The network provided methodological and theoretical training for over 45 students and professors through exchange programs, courses, and workshops. Two professionals who received their doctorates in the network now work in the Brazilian Ministry of the Environment (on international programs in conservation) and in the Ministry of Science (on climate change policies). Most exchange and training programs were associated with graduate programs within South America. This shows the maturity level of some academic centers in the region. Working in a Collaborative Research Network also helped to compensate for any weaknesses of the graduate programs involved. Students developed advanced research that was well integrated into the scientific program at relatively low cost. The effectiveness of the network is demonstrated by the number of scientific contributions made, most of them authored or coauthored by the students: 44 publications, 18 papers submitted, 13 articles in preparation, and 113 presentations at scientific meetings (Silva 2005).

The network also participated in outreach activities to link its scientific findings to the policy arena and society at large. Although we did not make systematic attempts to translate all of our results for a policy audience, some of our publications were translated into Portuguese and Spanish with that aim (Klink 2001; Az6car and Farinas 2003; Silva 2003; Silva et al. 2003; Ataroff and Silva 2005; Minetti and Gonzalez 2005).

What stands in the way of a better dialogue between scientists and policy makers? There are probably many responses to this question. The answers revolve around how to accommodate the dialogue into the strategic framework, how to compete for the best personnel for the job, and how to fund this as a long-lasting activity. To promote the dialogue between scientific disciplines and nonacademic arenas on environmental problems, it is crucial to identify instances of "ecological viability" that both transform our practice toward environmental change and help to find solutions to complex problems collectively (Agrawal 2005; Norgaard and Baer 2005). Therefore we suggest a more proactive role for the Inter-American Institute for Global Change Research and other funding agencies in this process, with scientists fulfilling the role of networkers with a full-time dedication and a well-developed agenda.

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Literature Cited

Agrawal, A. 2005. *Environmentality: Technologies of government and the making of subjects.* New Ecologies for rhe 21st Century Series. Durham, N.C.: Duke University Press.

Ataroff, M., and J. F. Silva, eds. 2005. *Dindmica hidrica en sistemas neotropicales. Investigaciones en Dinámica Hídrica de la red RlCAS.* Mérida, Venezuela: Instituto de Ciencias Ambientales y Eco1ógicas (ICAE). (48 pp.)

Azócar, A., and M. Fariñas. 2003. Páramos. In Aguilera, M., A. Azócar, A. E. Gonzalez-Jimenez, eds. *Biodiversidad en Venezuela, Tomo I.I.* Caracas, Venezuela: Ediciones Fundaci6n Polar y Fonacit. (pp . 716-33)

Azócar, A., and E Rada. 2006. *Ecofisiología de plantas de páramo.* Merida, Venezuela: Instituto de Ciencias Ambientales y Eco1ógicas (ICAE). (178 pp.)

Klink, C. A. 2001. O papel da pesquisa eco1ógica na gestao ambiental e manejo de ecossistemas. In Burstyn, M., ed. *A Dificil Sustentabilidade.* Rio de Janeiro: Garamond Universitaria. (pp. 77-84).

Klink, C. A. 2004. *Synthesis report for the Brazil Sustainable Cerrado Initiative.* Washington, D.C.: World Bank.

Klink, C. A., R. DeFries, and R. Cavalcanti, eds. 2005. *Symposium: Cerrado Land-Use and Conservation: Assessing Trade-Offs Between Human and Ecological Needs.* 19th Annual Meeting of the Society for Conservation Biology, Brasilia, Brazil, July 15 -19, 2005. Discussion drafts of papers published in CD-ROM. Washington, D.C.: Universidade de Brasilia and Conservation International.

Minetti, J. L, and J. A. Gonzalez. 2005 (submitted). El cambio climatico en la provincia de Tucuman. Sus impactos. *Serie Comervaci6n de la Naturaleza (Tucumán, Argentina).*

Norgaard, R. B., and P. Baer. 2005. Collectively seeing complex systems: The nature of the problem. *BioScience 55(11):953-60.*

Silva, J. F, A. Azócar, C. A. Klink, J. Gonzalez, and R. Herrera-Peraza. 2003. Ecologia Tropical Para El Cambio Global. In *Inter American Institute for Global Change Research Annual Report 2002-2003.* Sao José dos Campos, Brazil: Inter-American Institute for Global Change Research (IAI). (pp. 20-33)

Silva, J. F. 2003. Sabanas. In Aguilera, M., A. Azócar, A. E. Gonzalez-Jimenez, eds. *Biodiversidad en Venezuela, Tomo II.* Caracas, Venezuela: Ediciones Fundación Polar y Fonacit. (pp. 678-95)

Silva, J. F. 2005. Comparative study of the effects of global change on the vegetation of two ecosystems: High tropical mountain and tropical savanna. In *CRN-040 Final Report to IAI.* Mérida, Venezuela: Instituto de Ciencias Ambientales y Ecologicas (ICAE).

Silva, J. F. and M. E. Ramirez. Forthcoming. *Plantas vasculares de !as sabanas de Venezuela: botánica y* *ecologia.* Merida, Venezuela: Instituto de Ciencias Ambientales y Ecologicas (ICAE).

Silva, J. F., M. Ataroff, A. Azócar, M. Fariñas, C. Garcia-Nunez, J. Gonzalez, C. A. Klink, and F. Rada. Forthcoming. *Cambios globales, biodiversidad y el funcionamiento de ecosistemas montanos y sabanas en Sudamerica.* Mérida, Venezuela: Instituto de Ciencias Ambientales y Ecologicas (ICAE).