

# Invited Feature

## Land Use Change around Nature Reserves: Implications for Sustaining Biodiversity<sup>1</sup>

The modern concept of protected areas evolved in the late 1800s as the New World was colonized by Europeans and wild lands were being rapidly converted to agricultural and urban landscapes. By removing the influence of humans, it was thought that natural ecosystems would continue to maintain native species and ecological processes. Some 8% of the earth's land surface is now in a protected status, and these reserves are considered the cornerstone of the global conservation strategy.

Many protected areas, however, are not functioning as envisioned. Some have undergone changes in climate and ecological processes such as natural disturbance regimes. Invasive species and exotic diseases are penetrating nature reserves. Perhaps most alarming, native species have gone extinct within reserve boundaries since they were established. Such losses of ecosystem function and biodiversity raise questions about the causes of these changes and about management solutions to mitigate negative changes.

Since the 1970s scientists have realized that negative human impacts may cross the boundaries of protected areas. Accordingly, UNESCO's Man in the Biosphere Program recommended creating buffer zones of intermediate human land use to reduce the impacts within protected areas. The first studies of change in land use during the period of high-resolution satellite data (1973 to present), however, are finding rapid loss of wild habitats in these buffers and other lands surrounding protected areas in the world's tropical and temperate zones. These surrounding lands have been increasingly converted in recent decades to agriculture, rural settlement, and urban land uses. Yellowstone National Park, for example, is the world's first national park and is still considered one of the wildest. Yet, some 37% of the surrounding lands have been converted to intensive human uses. In the Masai Region of East Africa, centered on Serengeti National Park, human agriculture and settlements now occupy 53% of the unprotected lands. Much of this land use intensification around reserves has happened in recent decades.

These land use trends around protected areas raise fundamental questions about conservation and about the provisioning of human needs. To what extent does land use intensification outside of nature reserves degrade ecosystem function and biodiversity within reserves? Are there ways to provide for human needs outside reserves while maintaining conservation values within reserves?

As the science of ecology progresses, we increasingly realize that protected areas are often parts of larger ecosystems. However, the spatial dimensions of the ecosystems surrounding reserves have not been well quantified. The ecological principles that govern interactions between protected areas and the surrounding ecosystem have not been adequately synthesized. And management strategies to maintain the function of reserves in the face of land use intensification on surrounding lands are not fully developed.

The goals of this Invited Feature are to draw attention to this issue, better understand interactions between protected areas and surrounding lands, and help guide policy aimed at sustaining nature reserves and surrounding human communities. Key questions addressed are: (1) What are the rates of land use change and intensification around protected areas and what factors are driving these changes? (2) To what extent is biodiversity within protected areas influenced by land use change in surrounding areas? (3) What ecological mechanisms govern interactions between protected areas and surrounding lands? (4) Based on scientific understanding of these mechanisms, what management approaches maintain both ecological function and human land use options around protected areas?

<sup>1</sup> Reprints of this 67-page Invited Feature are available for \$10.00 each, either as PDF files or as hard copy. Prepayment is required. Order reprints from the Ecological Society of America, Attention: Reprint Department, 1707 H Street, N.W., Suite 400, Washington, DC 20006 (esaHQ@esa.org).

This collection of papers evolved from a NASA-funded study to synthesize among six regional case studies of land use change around protected areas. The studies were selected to include a variety of biome types and geographic locations, land use types, and human cultural and economic systems.

The first paper by Hansen and DeFries draws on the case studies and general ecological theory to develop a framework for understanding ecological interactions between nature reserves and surrounding lands. A conceptual model is offered of nature reserves as portions of larger surrounding ecosystems. Within this model, general ecological mechanisms are identified by which land use outside of reserves may influence biodiversity within reserves. These mechanisms involve change in effective size of a reserve relative to the larger ecosystem, altered flows of materials and disturbances in and out of a reserve, effects on crucial habitats outside reserves, and exposure to human effects at reserve edges. The mechanisms are then used as a basis for design criteria for management of the larger ecosystem containing the nature reserve.

In southern Yucatan, the vast forest, which developed following the collapse of the Mayan civilization, is undergoing deforestation by swidden agriculture by resettled farmers. Vester et al. conclude that much of the biota is adapted to this form of disturbance and may be adequately protected within existing reserves. However, the oldest primary forests have been disproportionately logged, and management issues center on maintenance of adequate area of this habitat type.

In the Greater Yellowstone ecosystem, strong biophysical gradients lead to many organisms requiring areas outside of the nature reserves for some or all of the year. Rural homes of wealthy people seeking natural amenities are disproportionately placed in the locations most important for native species. Gude et al. quantify the impact of past, present, and possible future exurban development on several elements of biodiversity as a basis for management strategies to place future development to minimize negative impacts.

Wolong Reserve in western China has undergone massive reduction in habitats for the giant panda in and around the reserve due to expansion of indigenous people. Viña et al. document the success in government policies to provide alternative resources for these people in restoring panda habitat.

The concluding paper by DeFries et al. focuses on the challenge of sustaining both protected areas and local human communities. Drawing on the case studies, the paper identifies the types of reserves that are most vulnerable to land use change and describes management strategies crafted to the local ecosystem and local human system.

In total, this collection builds on previous work on land use and protected areas in several ways. We provide a synthesis of ecological theory on the mechanisms by which human activities outside of protected areas influence ecological dynamics within protected areas. We demonstrate in three case studies how recent advances in remote sensing and spatial analysis can be used to quantify the boundaries of the larger ecosystem containing protected areas and the rates of change in land use and key habitats across these ecosystems. Thirdly, we describe how knowledge of land use change and key ecological mechanisms can be used to derive design criteria for managing protected-area-centered ecosystems to sustain ecological dynamics in the face of land use intensification. While we do not directly consider the economic and social feedbacks from protected areas to surrounding human communities, we provide a framework for future research that casts nature reserves as the centers of coupled human natural systems. It is imperative that these opportunities to better manage protected-area-centered ecosystems be realized now and in the coming decades to prevent the loss of global treasures such as large mammal migrations in Yellowstone and in East Africa, giant panda in China, Orangutan in Indonesia, and a host of less visible species.

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*Key words:* biodiversity; land use change; nature reserves; regional management; sustainability.