Integrating Agricultural Landscapes with Biodiversity Conservation in the Mesoamerican Hotspot

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Introduction

The major challenge in tropical land management is to meet the ever-growing demand for agricultural products while conserving biodiversity, providing critical ecosystem services, and maintaining rural livelihoods. This challenge is particularly acute in the Mesoamerican biodiversity hotspot, a region of high conservation value for both wild and domesticated species that is undergoing rapid human population growth, ecological degradation, and loss of traditional farming systems (Myers et al. 2000; Harvey et al. 2005*a*). Approximately 80% of the region's vegetation has been converted to agriculture, threatening biodiversity. More than 300 of the region's endemic species of flora and fauna are threatened, including at least 107 that are critically endangered (CI 2007). With continuing habitat loss (deforestation is 1.2%/year in Central America and Mexico combined; FAO 2005) and fragmentation of remaining forests, pressure on the region's biodiversity will intensify.

Habitat destruction and fragmentation are not the only drivers of biodiversity loss in the region, however. Globalization of market forces, agricultural industrialization, migration, public policy, and cultural changes are driving the transformation of diverse, traditional, smallholder agroecosystems into agroindustrial systems dependent on chemical inputs and mechanization (Conway & Rosset 1996; Perfecto et al. 1996; Angelsen & Kaimowitz 2001). Agroindustrial intensification is often accompanied by significant reductions in tree cover, fallow vegetation, habitat diversity, and forest connectivity. These transformations directly threaten species dependent on natural habitat and undermine indigenous management practices that coevolved with this biodiversity for over 10,000 years (Nigh & Levy Tacher 2008).

Despite considerable efforts to protect biodiversity in reserves and parks in Mesoamerica, many of these refuges are small, fragmented, isolated, or poorly protected (Miller et al. 2001), and not all ecosystems or species are represented adequately (Powell et al. 2000; Rodrigues et al. 2004). Besides having inadequate dimensions, most protected areas are embedded within an agricultural landscape, and existing buffer zones are inadequate to alleviate effects of fragmentation, contamination by agrochemicals, hunting, and unsustainable or illegal logging (DeFries et al. 2005). The fate of biodiversity within protected areas is therefore inextricably linked to the broader landscape context, including how the surrounding agricultural matrix is designed and managed (Wallace et al. 2005; Vandermeer et al. 2007).

Protecting biodiversity while sustaining agricultural productivity, indigenous cultures, and rural livelihoods,

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requires a new approach to conservation, particularly in regions such as Mesoamerica, where substantial habitat conversion has already occurred. In contrast to the prevailing trend of managing protected areas and productive lands separately, we propose integrated landscape management in which conservation and production units within the agricultural matrix are managed jointly for long-term sustainability. We do not advocate agricultural intensification to spare further forest conversion (e.g., Green et al. 2005) because this approach is unlikely to have the intended outcome, for reasons discussed elsewhere (Vandermeer & Perfecto 2005, 2007; Matson & Vitousek 2006). Instead conservation efforts should be based on the recognition that how agriculture is conducted and how different land uses are distributed spatially and temporally determine the region's biodiversity (Perfecto & Vandermeer 1997; McNeely & Scherr 2003). Lasting conservation will therefore require alliances among conservation biologists, farmers, and land managers to actively plan the future of Mesoamerican landscapes.

Here we use an integrated landscape approach to highlight opportunities for achieving long-term conservation in Mesoamerica. We provide an overview of the potential for agricultural landscapes and traditional smallholder farming to conserve biodiversity, propose an urgent action agenda to guide conservation in agricultural landscapes and stem the loss of biodiversity and traditional farming systems, and outline key socioeconomic, legal, and political conditions needed for successful implementation of the action plan. Although our examples and recommendations focus on Mesoamerica, our approach is relevant to other regions where there are similar challenges to conserving biodiversity in human-modified landscapes.

Potential for Agricultural Landscapes to Sustain Biodiversity

An increasing number of studies in Mesoamerica show that certain agricultural landscapes and traditional smallholder practices contribute to biodiversity conservation (e.g., Estrada & Coates-Estrada 2002; Daily et al. 2003; Mayfield & Daily 2005) and at the same time contribute to increased food production and rural income (Pretty et al. 2003). In particular, heterogeneous agricultural landscapes that retain abundant tree cover (as forest fragments, fallows, riparian areas, live fences, dispersed trees, or shade canopies) provide complementary habitats, resources, and landscape connectivity for a significant portion of the original biota (e.g., Harvey et al. 2006*a*; Sekercioglu et al. 2007). Landscape configurations that connect forest patches, maintain a diverse array of habitats, and retain high structural and floristic complexity generally conserve more species than landscapes lacking connectivity or habitat complexity (Benton et al. 2003; Bennett et al. 2006). In addition, agricultural landscapes with abundant tree cover serve as buffers for remaining natural areas (Wallace et al. 2005) and contribute regionally to the maintenance of important ecosystem services, such as natural pest management, carbon sequestration, and water and soil conservation (Daily 1997; Soto-Pinto et al. 2002).

Within agricultural landscapes, forested and nonforested habitats contribute to biodiversity conservation. Forest fragments, riparian forests, tree plantations, and other types of remnant and introduced tree cover serve as habitats for many species, enhance landscape connectivity, and retain potential for forest regeneration and restoration (Chazdon 2003; Harvey et al. 2006*a*). Nevertheless, other types of land uses, such as diverse coffee agroforestry (e.g., Moguel & Toledo 1999; Komar 2006), cocoa agroforestry (Rice & Greenberg 2000; Harvey et al. 2006*b*), silvopastoral systems (Harvey et al. 2005*b*, 2006*a*), and traditional agroecological land uses (such as diverse polycultures, organic farming, and swidden agriculture; Finegan & Nasi 2004) also harbor high levels of both wild and agricultural biodiversity and offer much greater conservation value than the agroindustrial systems that typically replace them. In general, biodiversity-friendly land uses are those that mimic the structural and floristic diversity of native vegetation and rely the least on agrochemicals (Tscharntke et al. 2005).

The diverse agroecology systems and landscapes described above are typically (but not always) managed by smallholders (*campesinos*) and indigenous farmers. Although most environmentally friendly farming practices are not scale-specific in principle, landscapes that are composed of many small farms often demonstrate a high potential for sustaining both biodiversity and rural livelihoods (Rosset 1999). Small farmers are more likely to know their land intimately, embrace complexity and multifunctionality, retain multiple traditional varieties, focus on inputs of knowledge and labor rather than purchased agrochemicals and mechanization, and grow food for nearby consumption instead of commodities for export (Netting 1993; Nazarea 2006). Thus, conservation of biodiversity will often be well served by policies that favor smallholders, promote diverse farming landscapes, and support dissemination of traditional practices and agroecological knowledge (Castillo & Toledo 2000).

An Action Agenda for Biodiversity Conservation in Mesoamerica

On the basis of existing evidence and experiences, we propose an action agenda to seize opportunities to reconcile farming and biodiversity conservation and to respond to the immediate threats of biodiversity loss and unsustainable farming. The goal of the action agenda is to achieve sustainable and resilient landscapes in which conservation and agricultural production objectives are accomplished in mutually reinforcing ways. The specific conservation goals are to conserve plant and animal biodiversity; maintain intact habitats, ecological communities, and ecosystem functions; buffer existing protected areas; maintain landscape connectivity; and retain landscape resilience to disturbance and climate change. The agricultural goals are to fulfill human livelihood needs, sustain yields, conserve indigenous and smallholder agroecosystems and associated knowledge and culture, diversify products, minimize reliance on external inputs, and reduce vulnerability to natural disasters and climate change.

Our action agenda contains six strategies (Table 1). The first consists of working with stakeholders in a participatory approach to identify priority landscapes where action for conservation and agricultural sustainability will bring the greatest results. Numerous tools already identify areas with high conservation value and the greatest need for protection (e.g., key biodiversity areas [Eken et al. 2004] and priority ecoregions [Olson & Dinerstein 2002]), but these tools rarely include information on rural livelihoods and agricultural systems. We advocate combining the analysis of biodiversity hotspots (Myers et al. 2000) with the identification of rural hotspots, where traditional smallholder livelihoods are most vulnerable and where agroecological systems and knowledge are being rapidly lost. This approach would allow the identification of landscapes where conservation priorities and rural development priorities overlap and where integration is most likely to succeed. Landscapes that are likely to emerge as priorities include those located near protected areas or in key biological corridors, those that conserve high diversity of traditional and indigenous crops, and those with high forest and tree cover that are being rapidly encroached upon by intensive agriculture or urbanization. In contrast, agricultural landscapes that are already dominated by agroindustrial production (such as industrially grown sugarcane, pineapple, or banana) are less likely to warrant attention because the chances of reconciling farming and biodiversity conservation there are slim.

Table 1. Strategies to conserve biodiversity and sustain rural livelihoods in agricultural landscapes of Mesoamerica.

1. Identify and prioritize rural hotspots, where the conservation of biodiversity and rural livelihoods can be achieved jointly.
2. Identify and mitigate key threats to biodiversity conservation within priority agricultural landscapes.
3. Conserve remaining native habitat within the agricultural matrix.
4. Protect, diversify, and sustainably manage tree cover within the agricultural matrix, including riparian strips, forest fallows, live fences, windbreaks, agroforestry systems, and silvopastoral systems.
5. Promote and conserve indigenous, traditional, and ecologically based agricultural practices.
6. Restore degraded, unproductive lands through reforestation, natural regeneration, and enrichment planting.

The second strategy is to address major threats to biodiversity within priority landscapes. Common threats include illegal logging, irresponsible use of agrochemicals, forest degradation by cattle grazing, shortening of fallows, unsustainable collection of firewood and other products, and conversion of diversified agricultural systems to agroindustrial monocultures with low biodiversity value (Carrillo & Vaughan 1994; Harvey et al. 2005*a*). Measures should be taken to mitigate these threats. For example, planting multipurpose trees on farms offers an alternative to firewood extraction from native forests (Barrance & Hellin 2003); integrated fire management (including prescribed burns, establishment of fire breaks, and training in sensible fire use) reduces unintended burning of native forests (Myers 2006); and adopting organic practices and integrated pest management can reduce dependence on pesticides (Kogan 1998; Morales & Perfecto 2000). Nevertheless, these promising approaches need to be applied systematically over large areas, with active participation and leadership of local rural communities (Nelson 1994).

The protection of remaining native habitat (whether intact forest, wetland, or grassland) constitutes the third key strategy for conserving biodiversity and maintaining rural livelihoods in agricultural landscapes. Native habitat protection should continue to form the cornerstone of conservation activities because they provide resources to native species, maintain intact ecological communities, serve as genetic sources for recolonization of the agricultural matrix, and buffer against extreme weather events and climate change (Bengtsson et al. 2003; Taberelli & Gascon 2005). Large, contiguous areas of native habitat and vegetation along riparian areas (that form natural corridors) are of particularly high conservation value and should be priorities. Nevertheless, even small (<5 ha) and degraded forest patches can be important for some species, providing additional resources and landscape connectivity (Sekercioglu et al. 2007). Protecting native habitats within the agricultural landscape also benefits rural communities by providing products and ecosystem services such as pollination, pest management, flood control, and nutrient cycling on which agricultural systems (and farmers) depend (Ricketts 2004; Naidoo & Ricketts 2006).

A fourth key strategy is to protect, diversify, and sustainably manage the heterogeneous tree cover within the agricultural matrix. On-farm tree cover contributes to biodiversity conservation by providing additional habitats and resources for plant and animal species and enhancing landscape connectivity (Schroth et al. 2004; Harvey et al. 2005*b*). In addition, tree cover in pastures and fields confers benefits to farmers, providing products (fruit, wood, fodder for livestock), ameliorating microclimatic conditions, and increasing soil fertility (Nair 1989). Nevertheles, trees may also reduce agricultural productivity through competition for light, water, and nutrients and serve as hosts for pest species (Ong & Huxley 1996). A key challenge is therefore to integrate tree species in densities and spatial arrangements that minimize competition and shading of agricultural land, yet still provide biodiversity benefits. Low densities of trees scattered across the agricultural matrix and linear plantings of trees along farm and field boundaries are often compatible with existing production systems and therefore are easily adopted by farmers (Harvey et al. 2005*b*).

A fifth strategy is to promote and conserve traditional and ecologically based agricultural practices and indigenous knowledge practices, such as agroforestry, swidden agriculture, home gardens, low-input agriculture, polycultures, and traditional milpas. These agroecological systems conserve high levels of both agrobiodiversity and wild biodiversity, ensure better soil management, and minimize agrochemical use. Throughout Mesoamerica, numerous academic, governmental, and nongovernmental organizations (e.g., CATIE, ECOSUR, EARTH, Campesino a Campesino, PROMECAFE, ACICAFOC, Sustainable Agriculture Network; Harvey et al. 2005*a*) already promote the use of ecological agriculture and traditional knowledge, but these efforts need to be scaled up to cover a greater proportion of the region's agricultural lands and communities.

Last, agricultural land that is highly degraded, unproductive, or unsuitable (e.g., prone to erosion or colonized by exotic species) should be reforested or allowed to regenerate naturally (Montagnini 2001; Lamb et al. 2005). Restoration goals can range from restoring soil fertility for agricultural use to establishing tree plantations or forests for timber or biodiversity conservation. Reforestation efforts should include diverse mixtures of native tree species, including species that provide resources to wildlife and species that have high timber value and provide future income to local farmers. Information on many native species that could be used in large-scale restoration efforts is available (e.g., Hooper et al. 2002; Wishnie et al. 2007). Restoration can also be achieved through natural regeneration, especially where remaining tree cover provides a source of propagules. Natural regeneration can be facilitated by fencing off areas to prevent cattle entry (Guevara et al. 2004), permitting light grazing to reduce competition from grasses on tree seedlings (Posada et al. 2000), using cattle to disperse tree seeds (Miceli-Méndez et al. 2007), or retaining isolated trees or live fences that serve as nuclei for natural regeneration (Slocum 2001; Zahawi & Augspurger 2006). The use of enrichment planting in fallows can also facilitate soil restoration (Finegan & Nasi 2004).

Implementation of the Action Agenda

An efficient implementation of the six strategies outlined above requires that certain enabling conditions be in place at local, regional, and/or national levels. We focus here on 5 major types of programs that could facilitate our agenda: providing economic incentives, strengthening and enforcing legislation, encouraging farmer alliances, promoting sustainable agriculture certification programs, and ensuring political support (Table 2).

A variety of economic instruments can be used to encourage farmers to conserve forests, retain tree cover, adopt biodiversity-friendly cropping systems, and to cover additional costs these activities may involve. Payments for environmental services (PES) hold particular promise. A Costa Rican PES scheme, in which farmers receive payments for protecting existing forest and for integrating trees into their farming systems, has worked well (Pagiola et al. 2005*a*; Zbinden & Lee 2005) and similar schemes are now being applied in Honduras, Guatemala, Mexico, and Nicaragua (Kosoy et al. 2007). Although PES schemes appear to be successful in conserving forest cover, they could have a greater positive impact on rural landscapes and livelihoods if they included payments for a greater diversity of sustainable land uses, removed inappropriate access restrictions (such as minimum land size), lowered transaction costs, and carefully targeted priority landscapes that have the greatest potential to conserve both biodiversity and rural livelihoods (Grieg-Gran et al. 2005; Pagiola et al. 2005*b*).

Another economic tool with potential to reduce the conflict between conservation and farming is carbon financing for either enhancing carbon sequestration (e.g.,

Table 2. Socioeconomic, legal, and political actions that can promote biodiversity conservation and maintenance of rural livelihoods in Mesoamerica.

1. Use economic instruments (payments for environmental services, carbon financing) to encourage farmers to retain tree cover and adopt biodiversity-friendly cropping systems.
2. Improve environmental laws and enforcement to reduce deforestation, regulate logging, conserve on-farm tree cover, reduce agrochemical use, and address land tenure issues.
3. Strengthen local and regional alliances among farmers, agronomists, extensionists, foresters, and conservation biologists to promote ecologically sustainable production systems.
4. Broaden participation in biodiversity-friendly certification schemes for agricultural and forest products and ensure certification meets rigorous ecological and social criteria.
5. Leverage local and regional political support for biodiversity conservation and sustainable development, building on existing initiatives such as the Mesoamerican Biological Corridor.

reforestation, agroforestry, and improved agricultural land management) or reducing emissions from deforestation (Orlando et al. 2002; Moutinho & Schwartzman 2005). Reforestation activities are already eligible for funding under the Clean Development Mechanism (CDM) of the Kyoto Protocol, and the rapidly expanding voluntary markets for carbon offer new opportunities for forest restoration and conservation (Bayon et al. 2007). The complexity and high costs of CDM projects have so far generally precluded small landowners and farmer organizations from participating (Boyd et al. 2007), but as the carbon market matures and demand for forestry carbon increases, so will opportunities for farmers. Innovative initiatives, such as the Plan Vivo project in Mexico, which provides smallholder farmers with access to carbon markets, are already paving the way (de Jong et al. 1997; Klooster & Masera 2000).

In addition to creating economic incentives, our action agenda requires increasing law enforcement and developing new legislation that restricts deforestation, regulates logging and agrochemical use, oversees zoning regulations and land tenure issues, and promotes conservation of secondary forests, riparian vegetation, and on-farm tree cover (Cullen et al. 2005; Wallace et al. 2005). The 1996 Forestry Law of Costa Rica serves as a model of what can be achieved in the region: the law carefully defines *forest* (in terms of percent canopy and area), bans forest conversion to other land uses, restricts logging within 15–50 m (depending on slope) on either side of rivers, and establishes the framework for the PES scheme that pays landowners for forest conservation and reforestation (Asamblea Legislativa 1996). Drafting appropriate legislation is only the first step, however; without enforcement, laws are ineffective. Illegal logging recently accounted for 75–85% of hardwood production in Honduras and nearly 50% in Nicaragua (Richards et al. 2003). Increasing enforcement of forestry and environmental laws by systematically monitoring forest cover, applying penalties, and properly managing harvesting permits is critical for forest conservation. In addition, legislation that facilitates the establishment of private reserves, conservation easements, buffer zones, and conservation corridors will likely encourage natural habitat conservation on private lands (Langholz et al. 2000; Wallace et al. 2005).

The strengthening of alliances among farmers, agronomists, extension workers, foresters, and conservation biologists will also promote ecologically sustainable production systems and lead to genuinely collaborative approaches to biodiversity conservation and food security (Morales et al. 2007; Vandermeer & Perfecto 2007). The active participation of the more than 12 million Mesoamerican farmers (CIA 2006) will be critical for long-term conservation gains. Many institutions, alliances, and networks that promote interdisciplinary partnerships already exist, but these often lack sufficient resources to be effective, cover only a small proportion of the region's stakeholders, or have more-limited agendas than the integrated approach we advocate. Funds are urgently required to support these types of organizations and regional initiatives.

Our action agenda could also be enabled by efforts to link small farmers with niche markets for agricultural and forest commodities that have been produced with minimal negative impact on biodiversity. These biodiversity-friendly enterprises are largely supported by private-sector certification programs led by Rainforest Alliance, Fair Trade, Smithsonian Migratory Bird Center, International Federation of Organic Agriculture Movements, Forest Stewardship Council, and others (Gullison 2003; Raynolds et al. 2007). Most of the schemes require producers to comply with environmental standards, such as planting trees along roads, controlling erosion, limiting agrochemical use, and planting native vegetation along rivers. Many also protect farm workers and ensure they are paid fair wages, enjoy safe working conditions, and drink clean water. Nevertheless, compliance or enforcement of standards is often weak, transaction costs and paperwork often limit participation, and incentives are insufficient to attract high levels of participation (Gullison 2003; Molnar 2003).

Finally, broad political support at all levels is needed to catalyze the strategies outlined here. Already, there are positive signs that Mesoamerican governments are aware of the importance of biodiversity conservation and the need to link conservation with sustainable rural development. All Mesoamerican countries are signatories of the Convention on Biological Diversity and have thus agreed to develop biodiversity action plans that ensure protection and sustainable use of biodiversity (CBD 2005). In addition, there are many regional programs (e.g., Plan Ambiental de la Región Centroamericana, Estratégia Forestal Centroamericana, and Iniciativa Mesoamericana de Desarrollo Sostenible) and even a Regional Institute for Biodiversity (created in 2005) that address, to some degree, the need for reconciling biodiversity conservation and rural development. The countries have also collaborated to develop the Mesoamerican Biological Corridor, an effort to link existing protected areas within and between countries to facilitate movement of plant and animal species (Miller et al. 2001). To be successful, this large-scale initiative will require the careful management of the agricultural landscapes in which the protected areas are embedded and will depend on the strategies outlined in our agenda. Yet despite the generally positive and promising political arena, there is a dearth of action on the ground. In many cases the political will has not yet been translated into concrete actions, funding for implementation is inadequate, and support for technical assistance and capacity building is lacking. Governments must place greater attention on implementing their vision for sustainable development in rural regions with adequate resources and knowledge.

Conclusions

We call for a new approach to biodiversity conservation within human-dominated Mesoamerican landscapes—one that unites a focus on ecologically sustainable agriculture with existing efforts in protected areas to achieve lasting conservation outcomes at local and regional levels. This new approach recognizes farmers as stakeholders in conserving biodiversity and actively solicits farmers as partners to create resilient landscapes that foster wildlife and preserve rural livelihoods and local knowledge.

Our action agenda provides strategies for reconciling farming and conservation and identifies key socioeconomic, legal, and political actions that could enable their adoption. If implemented broadly, our agenda could catalyze significant positive changes for both conservation and farming. Action is urgently needed, however. Landscapes may soon be so degraded that conservation and restoration will no longer be effective, and traditional knowledge may be lost forever. We therefore urgently call conservationists, agronomists, farmers, decision makers, and other stakeholders to actively design and manage entire landscapes to secure a future for both biodiversity and rural livelihoods in Mesoamerica.

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