



Biodiversity conservation in human-modified landscapes of Mesoamerica: Past, present and future

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ABSTRACT

Mesoamerica provides a unique context for biodiversity conservation in managed landscapes because of its geography, history of human intervention, and present conservation and development initiatives. The long and narrow form of the Mesoamerican landmass, and its division by a central mountain range, has served as both a bridge and a barrier. Conservation efforts in Mesoamerica are unique for the emphasis they place on regional connectivity through the Mesoamerican Biological Corridor and on biodiversity conservation in managed landscapes. The emphasis on conservation in agricultural systems has fostered innovations in payment for ecosystem services, and provides novel insights on the functional role that biodiversity plays in the provisioning of ecosystem services. The increasing rate of economic development in the region and the advent of new payment for ecosystem service schemes have provided new opportunities for forest regeneration and restoration. However, the small scale of private landholdings and the diversity of land uses featured in the region, while contributing to biodiversity conservation due to their structural and floristic complexity, present challenges for biodiversity monitoring and management.

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1. Introduction

Mesoamerica's geographic setting strongly influences the context for biodiversity conservation in the region. Mesoamerica is both a land bridge between two major continents and a barrier between two major oceans. The joining of North America and South America about three million years ago facilitated the Great American Biotic Interchange (Stehli and Webb, 1985), which witnessed species such as opossum and armadillo moving north across the isthmus while ancestors of llamas, felines, and bears crossed into South America. Major exchanges of avian (Weir et al., 2009) and plant (Gentry, 1982) biodiversity also occurred. In part because of this biogeographic history, Mesoamerica is considered one of the original 25 global biodiversity hotspots (Myers et al., 2000), and is home to more than 5000 endemic vascular plant species and 210 endemic mammal species (Greenheck, 2002).

The biogeographical designation of Mesoamerica is distinct from the geopolitical designation of Central America, which ex-

cludes Mexico, Panama, and sometimes Belize. Mesoamerica stretches from the five southernmost states of Mexico (Quintana Roo, Yucatan, Campeche, Chiapas and Tabasco) to the Darien in eastern Panama. The region is narrow (80 km at its narrowest), bordered by the Pacific Ocean to the west and the Caribbean Sea to the east, and divided by a volcanically active central mountain range reaching elevations of 4220 m on Mt. Tajumulco in Guatemala, and 3820 m on Chirripó in Costa Rica. Both the oceans and the mountain range that divides them influence the distribution of four terrestrial biomes and 19 terrestrial ecoregions in Mesoamerica (Estado de la Región, 2008). These biomes vary widely in climate and in natural and anthropogenic disturbance regimes. The tropical dry broadleaf forests of the Pacific slope are strongly influenced by annual dry seasons. These forests are heavily fragmented by agriculture, with 3% officially protected (Estado de la Región, 2008). Tropical coniferous forests and xeric shrublands have 10% and 19.7%, respectively, of their original extent protected (Table 1; Estado de la Región, 2008). The tropical moist broadleaf forests of the Caribbean slopes are less affected by human disturbances but subject to regular hurricanes; 28% of their area is officially protected.

Mesoamerica is home to numerous local and regional conservation programs that initially developed from the US conservation

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Table 1

Species richness for amphibians, birds, mammals and reptiles in each of Mesoamerica's biomes and ecoregions. The proportion of the region is each biome is indicated along with the proportion of that area that is in officially designated protected areas. Data adapted from [Corrales \(2010\)](#) and [Estado de la Región \(2008\)](#).

Biome/ecoregion	Amphibians	Birds	Mammals	Reptiles	Area (km ²)	Regional percent	Percent protected
Tropical moist broadleaf forests					260 575	55.3	28.6
Central American Atlantic moist forests	38	429	172	143	90 513	19.2	21.4
Chocó-Darién moist forests	138	600	215	200	10 294	2.2	50.3
Costa Rican seasonal moist forests	40	373	186	99	7566	1.6	9
Isthmian-Atlantic moist forests	118	518	217	168	45 431	9.6	13.6
Isthmian-Pacific moist forests	99	407	190	143	42 965	9.1	10.8
Petén-Veracruz moist forests	103	468	191	226	2778	0.6	49.3
Central American montane forests	73	303	191	111	17 828	3.8	38
Chiapas montane forests	49	325	163	61	5633	1.2	0
Chimalapas montane forests	19	294	145	31	2096	0.4	ND
Eastern Panamanian montane forests	30	327	198	102	1871	0.4	80.8
Sierra Madre de Chiapas moist forests	44	315	148	118	13 490	2.9	1.2
Talamancan montane forests	124	450	204	132	20 110	4.3	59.2
Tropical dry broadleaf forests					93 113	19.8	3
Central American dry forests	36	330	195	99	74 632	15.9	3.3
Chiapas Depression dry forests	33	188	160	106	13 415	2.8	0
Panamanian dry forests	22	273	165	59	5086	1.1	0.4
Tropical coniferous forests					114 906	24.4	9.9
Central American pine-oak forests	107	349	203	194	97 494	20.7	9.1
Miskito pine forests	0	240	128	0	17 412	3.7	10.7
Xeric shrublands					2200	0.5	0
Motagua Valley thornscrub	23	115	138	88	2200	0.5	19.7

movement but later evolved in response to local conditions by integrating protected areas with conservation in managed landscapes. To this end, Mesoamerica has become an innovator and global leader in developing policy and incentive instruments for promoting conservation outside protected areas, particularly payment for ecosystem service (PES) and eco-certification of agricultural crops ([Pagiola et al., 2005, 2007](#)).

Although each country in the region maintains its own ministries of the environment, all participate in the Central American System of Protected Areas (SICAP) formed in 1992. The system currently includes 669 protected areas totaling 124 250 km², with approximately 24 new reserves added per year between 1980 and 2007 ([Estado de la Región, 2008](#)). Another regional program, the Mesoamerican Biological Corridor (MBC), integrates regional scale connectivity of protected areas with sustainable development and improvement of human livelihoods. Maintaining connectivity is particularly important and challenging in Mesoamerica because of the region's altitudinal and latitudinal gradients, which pose natural barriers to species movement that can increase the vulnerability of biodiversity to climate change and agricultural expansion.

In this paper, we explore the history of human interaction with biodiversity and the current status of biodiversity conservation in Mesoamerica. We focus on current conservation strategies, including the MBC, conservation in protected and managed forests, and conservation in landscapes dominated by agriculture. Next, we review the potential for forest regeneration and ecosystem restoration and discuss the critical need for effective biodiversity monitoring tools to assess and improve the conservation value of managed landscapes. We conclude with a prognosis for the future of Mesoamerican biodiversity and recommendations for safeguarding this unique biodiversity while promoting sustainable development.

2. Effects of prehistoric human occupation on biodiversity in Mesoamerica

Human have inhabited Mesoamerica, and impacted its biodiversity, for at least 10 000 years. Few lowland areas of Mesoamerica lack archaeological remains ([Gomez-Pompa and Kaus, 1990](#)). In the Petén region of Guatemala, late Classic population densities

ranged between 200 and 300 individuals per km² ([Rice and Rice, 1990](#)). In the central Maya lowlands, as much as 75% of the landscape was altered by intensive cultivation prior to 1200 BP ([Whitmore et al., 1990](#)). This activity left three long-lasting legacies: (1) forest burning, agriculture, and soil erosion; (2) silviculture and forest management; and (3) landscape modifications involving raised fields, canals, and terraces.

The development and spread of agriculture after the Pleistocene (11 500 BP) profoundly impacted the structure and composition of vegetation ([Piperno, 2007](#)). Pollen, charcoal, and plant phytoliths in lake and swamp sediments from numerous sites in Mesoamerica show sequences of burning coincident with crop cultivation and declines in arboreal pollen during the early and middle Holocene, 7000–10 000 BP ([Neff et al., 2006; Piperno, 2006; Horn, 2007](#)). Throughout Mesoamerica, the abundance of burned phytoliths of Poaceae and *Heliconia* indicate human-set fires in early successional vegetation, evidence of short-fallow shifting cultivation ([Piperno, 2007](#)). Impacts of ancient agricultural land use are evident across the full range of tropical forest vegetation, including evergreen, semi-evergreen, and deciduous forest types, from Mexico to the Amazon Basin ([Piperno, 2007](#)). Overall, impacts were earlier and more sustained in the lowlands and in highly seasonal forests which have more fertile soils and were more easily cleared of vegetation than aseasonal forests ([Denevan, 2007; Piperno, 2007](#)).

Indigenous Mesoamericans cultivated trees, hunted game, and managed forest patches for over 4000 years ([Emery, 2007; Ford, 2008](#)). The Maya planted homegardens, practiced shifting cultivation, and managed forests as indicated by high-density aggregations of useful tree species in forests surrounding archaeological sites ([Gomez-Pompa, 1987; Ford and Fedick, 1992; Fedick, 1995; Campbell et al., 2006; Ross, in press](#)). Abundant tree species favored by the Maya include *Brosimum alicastrum* (Moraceae), *Bursera simarouba* (Burseraceae), *Manilkara zapota* (Sapotaceae), and *Attalea cohune* (Arecaceae). Maya forest gardens were so widespread during the Mayan Pre-Classic period (4000–700 BP) that contemporary forests of the southeastern Petén, eastern Guatemala and western Belize are widely considered to be dominated by species favored by human land-use practices ([Gomez-Pompa and Kaus, 1990; Peters, 2000; Campbell et al., 2006; Ford and Nigh, 2009; Ross, in press](#)).

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