Restoring Biodiversity and Forest Ecosystem Services in Degraded Tropical Landscapes

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The importance of landscapes…

- Ecosystems and their biota are interconnected, linked by ecosystem processes (e.g., hydrological and biogeochemical), disturbance regimes, and life histories of species across landscapes at different spatial and temporal scales

People are important

Human societies have developed their distinctive cultures and livelihood patterns in the context of the ecosystems they inhabit, and have exerted profound influences on the structure and function of terrestrial ecosystems and landscapes for thousands of years, particularly in the tropics.

Change is inevitable

Ecosystems are dynamic and undergo constant structural and functional changes in response to natural disturbances of varying frequencies and intensities, creating a shifting mosaic of habitats across landscapes

Changes in the laws, institutions, land tenure, economic and social conditions, and the needs and aspirations of people result in shifts in land use and intensity of management of agricultural, forest and water resources , adding an additional layer of complexity to patterns of ecosystem (and biodiversity) change across landscapes.

Biodiversity, forest ecosystem services and human well-being: making the connections

In human-dominated tropical landscapes, protected areas, while important, are insufficient to conserve biodiversity and the ecosystem services that biodiversity provides – opportunities to further these goals must be found elsewhere on the landscape, and be compatible with economic and social sustainability goals.

Understanding the context and establishing priorities

The ecological context: distribution, dynamics and interrelationships of ecosystems, habitats and species; patterns of ecosystem service provision across the landscape; historical and ongoing changes in land cover/land use and their effects on biodiversity and ecosystem services.

The social context: policies, laws, governance and social structures, land ownership and tenure, cultural influences, religious beliefs, traditional knowledge, livelihood needs and aspirations

Understanding the context and establishing priorities

Given the ecological and socioeconomic complexities of human-dominated landscapes, opportunities for enhancing biodiversity and ecosystem services will take different forms, under different land uses, with numerous stakeholders – individual landowners, people whose livelihoods depend directly on forest resources, communities, government agencies and NGOs.

Dialogue, mutual education, and consensus-building among scientists and stakeholders regarding which components of biodiversity and which ecosystem services are important, and where on the landscape they can be conserved (or enhanced) is a prerequisite for success. Flexibility and commitment to monitoring and adaptive management important.

Monitoring and adaptive management

Importance of:

- Periodic assessments of restoration success or failure based on criteria and indicators linked to agreed-upon goals and objectives.
- Incorporation of monitoring results into management planning

Enhancing biodiversity and ecosystem services in tropical production systems: *agriculture*

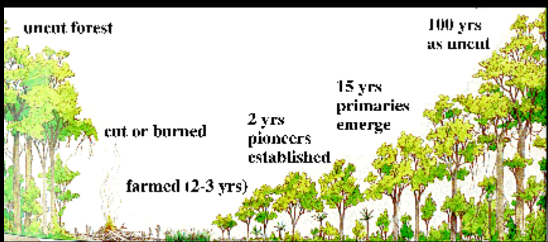
Conventional agricultural and systems:

- Promotion of practices that conserve diversity of agricultural crops, improve farmer incomes, increase efficiency of water, external energy and nutrient use and reduce dependence on chemical fertilizers and pesticides, etc.

Agroforestry systems:

- Technical, policy and market support for existing (traditional) and market-oriented agroforestry management practices that conserve, expand, or diversify habitat for economically beneficial (or neutral) insects, birds, mammals …

Enhancing biodiversity and ecosystem services in tropical production systems: *agro-forest landscape management*



Traditional agro-ecosystem management: Sustainable shifting cultivation and secondary forest vegetation management systems based on traditional ecological knowledge and related governance structures have contributed to biodiversity conservation and sustainable livelihoods for centuries.

Although under threat from a number of external and internal political, economic and social forces and trends, opportunities exist to conserve and revitalize these practices to meet changing conditions and needs of their practitioners.

Enhancing biodiversity and ecosystem services in tropical production systems: *degraded and secondary forest management and restoration*

Long undervalued by ecologists and forest managers, secondary forests are the *only* forests in many tropical landscapes, and have high value for biodiversity, support livelihoods and provide essential ecosystem services.

Traditional and modern scientific practices exist for their improved management to increase their conservation and ecosystem service values (ITTO, 2002).

Enhancing biodiversity and ecosystem services in tropical production systems: degraded forest lands

Created by poor management (excessive harvesting of wood and/or non-wood forest products, overgrazing…), repeated fire, and other disturbances that have damaged soils and vegetation to a degree that inhibits or severely delays natural recovery of secondary forest after abandonment

Management options:

Wait (usually decades for recovery of structure, improved ecosystem functions and services, and biodiversity)

Planted forests: selected, preferably native, timber species, or restoration plantings for recovery of biodiversity values and ecosystem services:

(a) mixed native species methods (relatively expensive);

(b) less expensive plantings of relatively short-lived, fast-growing, site/soil-improving species that accelerate ("catalyze") native species regeneration.

Case study: Puerto Rico

- By the 1940s, over 90% of the island's original tropical forest cover had been converted to agricultural – sugarcane, coffee, subsistence agriculture since Spanish colonization in the 16th century

Case study: Puerto Rico

- From 1950 onwards, rapid economic and social change – industrialization, urbanization and migration, rapid decline in agriculture, and land abandonment.
- By 2005, forest cover estimated to be >40% with no known loss of plant or animal species at the landscape level, the result of natural forest regeneration processes.
- *Lesson:* Despite forest conversion, long-term intensive agriculture and soil degradation in many areas, the high resilience of tropical forest ecosystems in the Caribbean enables recovery of their structure, ecological functions, and species composition within decades provided that remnant patches of native forests exist within the landscape matrix.

Case study: central Sao Paulo State, Brazil

- Forest cover in Atlantic forest region of eastern and southern Brazil, a biodiversity "hotspot" and home to 70% of the country's population, has been reduced by 90% of its original extent;
- Forest loss and degradation due to successive "boom-and-bust" cycles of agricultural development – coffee, livestock, and sugarcane

Case study: central Sao Paulo State, Brazil

- The good news: Current Brazilian law, aimed at reversing deforestation and protecting the region's biodiversity, agricultural soils, water resources and hydroelectric generation capacity, requires protection of remaining Atlantic forest remnants and restoration of forests on 20% of all rural properties and in riparian zones.
- The bad news: Owners of small- and medium-sized properties lack the financial resources to meet these requirements, the knowledge and technical expertise to restore forests, and require options that will allow them to generate incomes from these activities.

Case study: central Sao Paulo State, Brazil

In 1997, the State University of Sao Paolo initiated a research/demonstration project designed to evaluate the productivity, biodiversity outcomes and economic viability of alternative restoration options at three deforested sites characterized by different soil types at different stages of degradation

Treatments:

1. Direct seeding with 5 early successional species
2. Modified agroforestry system: 22 fuelwood and timber species + locally grown annual crops
3. Mixed plantings of 27 multipurpose and commercial timber species
4. Mixed plantings of 40 native forest species of varying successional stages (max. biodiversity restoration option)
5. Unplanted control plots

Case study: central Sao Paulo State, Brazil

Results:

- The project is demonstrating that degraded sites that are generally considered to be “lost” can be economically restored to provide a desired combination of ecological (biodiversity) and socio-economic benefits (farmer income and compliance with environmental laws).

- Valuable new information is being generated regarding the compatibility of a variety of annual crops with native tree species (agroforestry models) on degraded soils, the success/failure of native species established on degraded sites, and post-establishment enrichment of restored forests by native trees, non-woody plant species, and wildlife from remnant native forests and trees on the landscape, as well as soil fertility development and nutrient cycling processes in these systems.

Case study: restoration of a bauxite mine site in the Brazilian Amazon

Location: Porto Trombetas, Para

Saraca plateau minesite

Case study: restoration of a bauxite minesite in the Brazilian Amazon – *the process*

Immediately following bauxite ore extraction

Replacement of topsoil within 6 months

Case study: restoration of a bauxite minesite in the Brazilian Amazon – *restoration treatments*

Standard reforestation: plantations of 70-100 native forest tree species following site preparation.

Alternative (rejected) treatments:

- Standard reforestation "failure": same as above, but with inadequate topsoil application.
- Direct seeding: 48 early successional tree species, mostly native.
- Mixed commercial species: 5 *Eucalyptus* spp., *Acacia mangium* & *Sclerolobium paniculatum*.
- Natural regeneration: topsoil only.

Case study: restoration of a bauxite minesite in the Brazilian Amazon – *the process*

Mixed plantings (direct seeding, stumped wild seedlings, nurstry-grown seedlings) of 70-100 native forest species

6 months after planting – dominance by pioneer species shading later successional species

Adaptability of 160 native tree species tested at Trombetas bauxite minesite

37% of species well-adapted to site, growth rapid, survival >75% after 2 years

19% of species showed good growth and survival rates 50-75%

44% with poor performance, survival <50%

Restoration of a bauxite minesite in the Brazilian Amazon –*biophysical indicators*

Structural attributes

- Tree growth rates
- Stand basal area
- Canopy closure

Forest floor development

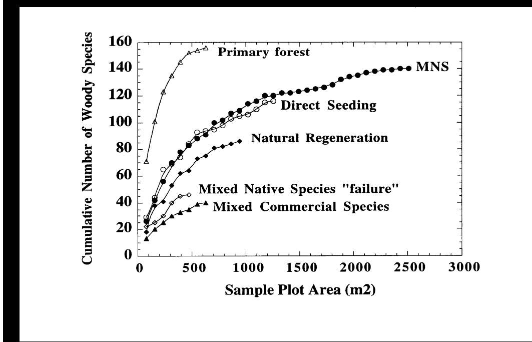
- Litter accumulation
- Humus depth

Floristic diversity development

- Species composition: trees, shrubs, vines, herbs and grasses;
- Tree species richness, diversity and similarity to undisturbed primary forest;
- Sources: planted, soil seed bank, external colonists;
- Expected longevity of trees: potential for avoiding arrested succession.

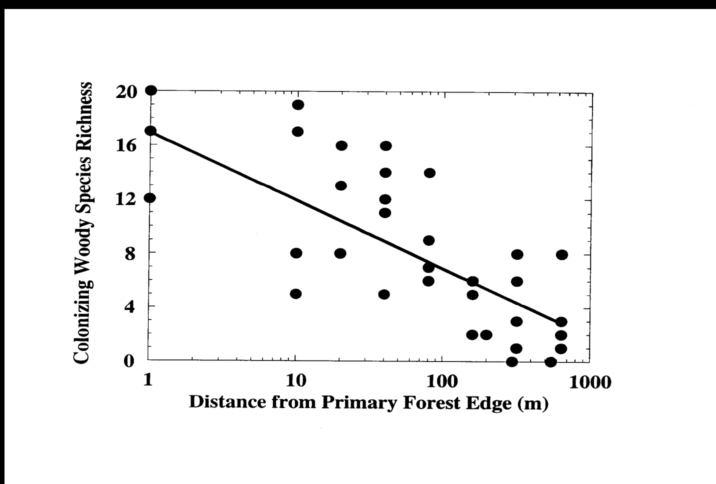
Species-Area relationships among restoration treatments

Mixed native species plantings at 10 years of age

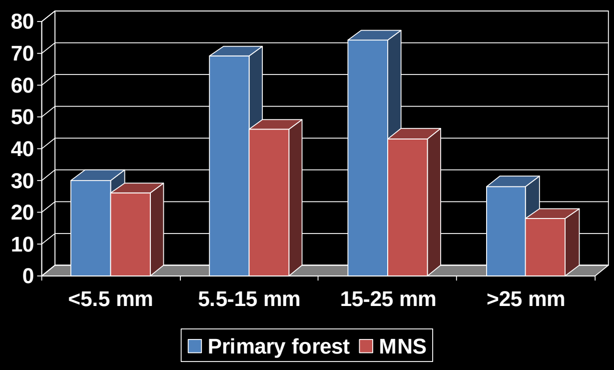


Although less expensive alternatives were more productive (basal area development), the mixed native species approach showed was more diverse and least susceptible to arrested succession in the future.

Post-plantation floristic enrichment is highly dependent on seed-dispersing wildlife and is affected by proximity to seed sources (i.e., surrounding primary forests).

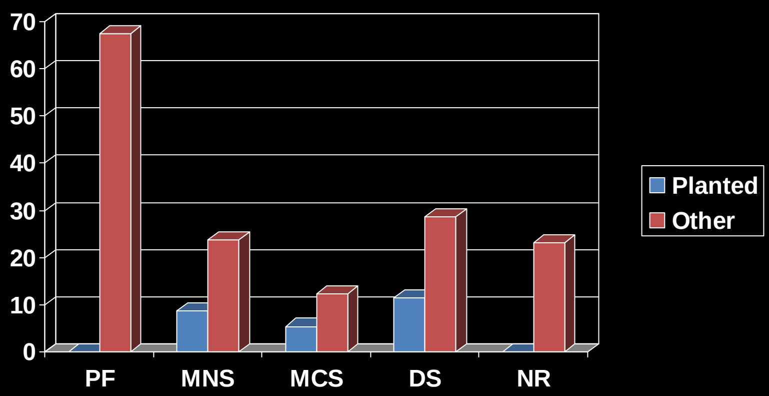


Average seed length distribution for primary forest trees and restoration area colonists



Enrichment plantings of larger-seeded, initially shade-demanding species, esp. those with specialized dispersal agents, are recommended to ensure long-term restoration success.

Tree Species Richness: No. species per 79m^2 plot



All plantation treatments were effective for re-establishing forest cover and facilitating natural regeneration during the first 9-13 years after establishment.

Conclusions

- The interconnections between ecosystems in human-dominated tropical landscapes, and the dynamic nature of both ecological systems and human societies require a landscape perspective on conservation and restoration of forest biodiversity and ecosystem services.
- Close collaboration among stakeholders (including scientists) can help identify "win-win-win" opportunities for biodiversity conservation, ecosystem service provision, and enhancement of livelihoods and food security.

Conclusions

- Contrary to popular belief, even the most degraded and abused forest ecosystems can recover their structure, species richness, and ecological functions and provide ecosystem services to society – most tropical ecosystems are more resilient than generally thought – working together, with nature, forest scientists and stakeholders can help to reverse the tide of biodiversity loss and livelihood insecurity in many tropical landscapes.

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