Restoration Ecology
THE JOURNAL OF THE SOCIETY FOR ECOLOGICAL RESTORATION INTERNATIONAL

REVIEW ARTICLE

Agro-Successional Restoration as a Strategy to Facilitate Tropical Forest Recovery

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Abstract

With the increasing need to restore former agricultural lands worldwide and in the tropics, in particular, it is critical to explore different models for how to restore these lands in a cost-effective manner which best simulates natural forest recovery and provides for human livelihoods. We propose that agro-successional restoration, which we define as incorporating a range of agroecology and agroforestry techniques as a transition phase early in forest restoration, could be used more widely to overcome socioeconomic and ecological obstacles to restoring these lands. Over centuries, farmers and scientists have developed various agroforestry techniques that aim to cultivate crops and trees, in a range of crop types, time periods of cultivation (a few years to several decades), and complexity of species planted. The management practices used in these systems, such as weeding and increasing soil fertility, parallel those used in many forest restoration efforts. The synergism between these approaches is evidenced by many existing agro-successional examples currently used by smallholders in the tropics. Benefits of the agro-successional model include extending the management period of restoration, offsetting some management costs, providing food security for small landholders, and involving small landholders in the restoration process.

Key words: **agroecology, agroforestry, succession.**

Introduction

Abandoned agricultural land has been increasing in several tropical countries in recent years, a trend that is likely to continue (Lamb et al. 2005; Wright & Muller-Landau 2006; Chazdon 2008). A growing movement to restore tropical forest is being motivated by legislation enforcement, environmental responsibility of companies through international market pressure, international and governmental incentives, and efforts to compensate for carbon emissions (Holl & Howarth 2000; Chokkalingam et al. 2006; Nawir et al. 2007; Wuethrich 2007; Lees & Peres 2008). In the tropics, however, the lack of funding to restore huge areas of land is particularly acute, and, like elsewhere, the funding for restoration is often allocated for 1–3 years, a short time span to restore forests. Moreover, often restoration conflicts with the need to provide for human livelihoods and respect social and cultural values (Lamb et al. 2005), and is disconnected from the normal agricultural activities of the farmer with the result that new technologies are not adopted (Altieri 2004; Peneireiro et al. 2005). These competing needs require restorationists to explore creative models for restoring forest in the tropics and elsewhere.

We propose that agro-successional restoration, which we define as incorporating a range of agroecology and agroforestry techniques as a transitional phase early in forest restoration, could be used more widely to overcome socioeconomic and ecological obstacles to restoring these lands. There is an extensive body of literature on agroforestry techniques that aim to cultivate crops and trees, in a range of crop types, time periods of cultivation, and complexity of species planted. They span systems as simple as intercropping one tree species with one crop species, frequently named "taungya" (Menzies 1988; Haggar et al. 2003; Kobayashi 2004) to systems quite similar to a native forest with respect to species diversity and function, horizontal and vertical structure, and successional dynamics (e.g., Nair 1991; Wiersum 2004; Miller & Nair 2006; Michon et al. 2007). These approaches to crop production benefit smallholders in several ways and help conserve biodiversity across the landscape (McNeely & Schroth 2006; Bhagwat et al. 2008).

What rarely has been discussed in the restoration literature is the idea that a range of agroforestry systems could be used as a transitional phase in restoration that simultaneously helps provide for human livelihoods, reduces the initial costs of restoration, and extends the time period of management of restoration. It also may serve to connect farmers to restoration activities (Ewel & Putz 2004). We note that the techniques we

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doi: 10.1111/j.1526-100X.2009.00570.x

Table 1. Characteristics of typical tropical forest restoration, agroforestry systems, and agro-successional restoration.

System characteristics	*Forest restoration*	*Taungya*	*Successional agroforestry*	*Agro-successional restoration*
Goals	Accelerate secondary succession and create a vertically stratified forest	Simultaneously produce crops and timber to provide land owners with food and income over time	Simultaneously produce a range of annual and perennial crops and trees that provide food and income over time; create a vertically stratified agricultural system that mimics natural succession	Accelerate secondary succession and create a vertically stratified forest; produce crops in initial stage to minimize restoration costs and to engage farmers in restoration activities
Planted species	Tree seedlings	Tree seedlings and annual or biennial crops	Tree seedlings; tree seeds; annual, biennial, and perennial crops	Tree seedlings; tree seeds (in some cases); annual, biennial, and/or perennial crops
Diversity of plantation	Few to many tree species; large number of native species recommended	Few crop species and few to many tree species	Many crop and tree species with high functional diversity[a]	Few to many crop species and few to many tree species; large number of native species with high functional diversity[a] recommended
Typical management practices (vary among sites depending on limiting factors)	Controlling weeds; fertilizing; and irrigating	Controlling weeds; fertilizing; and irrigating	Controlling weeds; pruning trees and shrubs to manage succession; using clippings for green manure; and substituting annual crop species with long-term crop species (e.g., fruits)	Controlling weeds; pruning trees and shrubs to manage succession; using clippings for green manure; substituting crop species with later-successional tree species
Management period	Generally 1–3 years	Few years	Few years to decades[b]	Few years to decades[b]
Environmental changes over time	Ameliorate microclimate; improve soil fertility; increase animal seed dispersal; and shade out ruderal grasses and forbs	Ameliorate microclimate; improve soil fertility; and shade out ruderal grasses and forbs	Ameliorate microclimate; improve soil fertility; increase animal seed dispersal; and shade out ruderal grasses and forbs	Ameliorate microclimate; improve soil fertility; increase animal seed dispersal; shade out ruderal grasses and forbs

[a]Diversity of species with respect to time-to-yield crops, overall life-span, leaf decomposition rates, growth strata, and animal attraction.
[b]Longer-term management allows directing succession, such as pruning to increase light levels and planting later-succession species when microclimatic conditions are more favorable.

discuss draw on centuries of experimentation by farmers and scientists.

Our goal is to promote agro-successional restoration as an approach that could be used more widely to expand forest restoration efforts temporally and spatially. We begin by briefly reviewing the "typical" forest restoration model and two general agroforestry models that are compatible with restoration. We then highlight the ecological and socioeconomic benefits of combining these approaches in agro-successional restoration. We focus on using agro-successional restoration for tropical forests, given that is where the agroforestry systems we describe are most widely used. However, we draw on some temperate forest examples and think that this approach may be applicable in some regions outside the tropics.

Forest Restoration Model

The rate of tropical forest recovery in abandoned agricultural lands varies greatly depending on the ecosystem, proximity to propagule sources, and past land use intensity (reviewed in Chazdon 2003, 2008; Holl 2007). Although some former agricultural lands recover rapidly, often there are numerous barriers to forest species establishment, including lack of seed dispersal, stressful microclimatic conditions, competition with grasses and agricultural weeds, low soil fertility, and high soil compaction (reviewed in Holl 2002; Meli 2003).

The most common restoration strategy to overcome these obstacles is to plant tree seedlings, which, as they develop, provide canopy architecture, increasing animal seed dispersal, ameliorating microclimate conditions, and shading out aggressive light-dependent species common in agricultural lands (Holl 2002; Meli 2003; Table 1). Frequently restoration projects plant only native or non-native pioneer tree species (e.g., Lugo 1997; Lamb 1998; Kanowski et al. 2005; Cummings & Reid 2008) but some projects include trees of different successional stages (Kageyama & Gandara 2000; Ashton et al. 2001*a*; Souza & Batista 2004).

Although these trees often establish rapidly, the time and cost of planting and maintaining them for the first few years can be substantial (Stanturf et al. 2000; Engel & Parrotta 2001; Holz & Guillermo 2008). Planting seedlings requires either constructing nursery facilities or purchasing them from existing sources, which is more costly. It is often necessary to control grasses and herbs during the first years of planting to guarantee tree survival and growth (Ashton et al. 1997; Chapman & Chapman 1999; Slocum et al. 2006). And, depending on rainfall patterns and soil conditions, fertilization and/or irrigation may be necessary (Table 1). In premontane forest in Costa Rica, planting with seedlings at 3×3 m spacing costs approximately \$600 per hectare for labor and seedlings, whereas clearing pasture grasses around seedlings for the 2.5 years, necessary for trees to overtop grasses, costs approximately \$1,500 per hectare (K. D. Holl, unpublished data). Holz and Guillermo (2008) estimate that circa 36% of tropical forest restoration costs in Argentina are spent on seedling maintenance.

In most tropical forest restoration projects, it is assumed that once the tree canopy establishes the remaining flora and fauna will establish naturally, following the "field of dreams" approach (Hilderbrand et al. 2005). This approach is often a necessity given scarce resources for restoration. Past research in sites planted with trees suggests that aboveground biomass recovers more rapidly than species composition, which often varies greatly depending on the overstory species planted (e.g., Parrotta et al. 1997; Aide et al. 2000; Kanowski et al. 2003; Holl 2007; Marin-Spiotta et al. 2007). Some large-seeded, later-successional species may not colonize naturally (Finegan 1996; Ashton et al. 2001*a*; Martínez-Garza & Howe 2003).

Agroforestry Models

For centuries, small farmers have refined a range of agroforestry techniques that combine the production of agricultural crops with growing trees to provide firewood, fruit, construction materials, and other products (e.g., Nair 1991; Altieri 2004; Miller & Nair 2006; Michon et al. 2007). These agroforestry systems face the same obstacles to growing crops and trees as restorationists; therefore, farmers have developed strategies for their particular systems to ameliorate moisture limitation, nutrient conditions, weed competition, and pest effects (Table 1). Here, we focus on two general approaches in agroforestry that we consider most compatible with restoration: taungya and successional agroforestry systems.

Taungya

Planting annual crops in the initial stage of reforestation is a relatively common practice around the world, often called taungya. Farmers grow crops such as beans, cassava, or corn during the first few years while they plant a range of tree species for timber production (e.g., Nwonwu 1987; Watanabe et al. 1988; Shankar et al. 1998; Schlönvoigt & Beer 2001; Haggar et al. 2003; Mercer et al. 2005; Table 1). Taungya provides food or income for farmers while the trees grow. Farmers simultaneously manage for both crop and tree species by weeding, fertilizing, and/or irrigating, which improves survival and growth of both types of species (Kapp & Beer 1995; Nissen et al. 1999; Somarriba et al. 2001).

Taungya systems have been developed in which the cultivation of crop species does not compete with tree growth (Schlönvoigt & Beer 2001; Haggar et al. 2003) or in which the complementary effects (e.g., improving microclimate, generating leaf litter to avoid soil transpiration, and enhancing soil fertility) exceed competitive effects (Nissen et al. 1999). For example, cultivating the legume "guandu" bean (*Cajanus cajan*), a shrubby bean frequently used in Brazil for food and green manure, with forest tree seedlings, increases tree survival and growth compared with planting trees alone (Silva 2002; Beltrame & Rodrigues 2007).

The financial returns on these systems have been widely debated (Nwonwu 1987; Nissen et al. 1999; Haggar et al. 2003, 2004; Ehiagbonare 2006). However, these systems provide other benefits to smallholders such as improving food security and providing opportunities for on-farm labor (dos Santos 2005). Since most agricultural crops are adapted to full sun, shading by trees may reduce crop productivity compared with non-intercropped agriculture as trees grow. Most important from the standpoint of agro-successional restoration is that these systems reduce tree maintenance costs relative to planting trees alone (Nwonwu 1987; Nissen et al. 1999; Haggar et al. 2003, 2004).

Successional Agroforestry or Ecosystem Analogous Successional Crop Systems

Although taungya systems mix crops and trees at the outset, a second type of agroforestry systems mix crops and several tree species progressively through time-increasing income, biodiversity, and ecosystem structure and function. Hart (1980) argued that in a chronosequence of crops, as in natural succession, each stage "produces the physical environment required by the next stage"; thus, less input is necessary to develop a late successional community of crops and/or native species when a series of crops are introduced (Ewel 1986, 1999; Vaz 2000). During the successional process in both natural systems and analog crop systems, short-lived species are gradually replaced by long-lived species over a period of months to years to decades, as species requirements for soil fertility and light change, and vertical stratification increases.

Related systems (e.g., successional agroforestry systems—Peneireiro 1999; regenerative analog agroforestry—Vaz 2000; forest gardens—Wiersum 2004; and domestic forests—Michon et al. 2007), which expand the temporal scale of agroforestry, have been developed and tested in various areas of the world. Hart (1980) outlines a successional crop system for humid forests of Central America, in which beans, maize, cassava, and banana are planted together and leave the system at various times. Coconut, cacao, and rubber, later-successional species, are planted after 1 year and remain in the system up to 50 years. For successional agroforests of Alto Beni in Colombia and northeastern Brazil, agroforesters have classified 139 tree and crop species into five successional classes, based on species lifespan, and light and soil requirements (Yana & Weinert 2001; Silva 2002). Optimal timing of planting (at the outset or after a canopy has established), spatial location with respect to soil conditions, and density of each species are determined based on these groupings.

Ernst Götsch has developed a complex successional agroforestry system in abandoned pastures of northeastern Brazil (Peneireiro 1999; Silva 2002) in which: (1) crop species are chosen from observations of the reference forest and local traditional crop systems; (2) many species are allowed to regenerate naturally or are planted for pest protection, to improve soil quality, or for compensatory growth (see theory in Ewel 1986, 1999); and (3) the natural self-thinning process is accelerated with selective pruning to increase light levels in the understory strata and nutrients input from clippings to facilitate the growth of later-successional species. Soil quality is fundamental to species selection in successional agroforestry systems because abandoned agricultural areas have variable soil fertility at a range of spatial scales, as a result of the natural substrate and past land use (Holl 2007).

Agro-Successional Restoration

As is evident from the discussion above and Table 1, there are many parallels between the typical forest restoration approach and the agroforestry systems discussed here. We propose that in many cases the two approaches can be combined, as illustrated in our agro-successional restoration model (Table 1). In this model, agricultural crops are planted at the same time as early successional native tree species. They are managed simultaneously, as similar techniques are used. During this initial period, which might range from 3 to 20 years depending on the system, crops are harvested, forest species regenerate naturally, and some mid-successional species may be introduced. Over time, as the canopy closes, agricultural production will likely decline, given that most agricultural annual and biennial crops are light demanding, whereas light, soil, and moisture conditions will become more favorable for later-successional species. At this point, agricultural crops are removed, which is typical as crops senesce (Hart 1980; Ewel 1999). In many cases, focal later-successional species that do not establish naturally are introduced.

Although we are not aware of examples of exactly what we propose, several examples of similar approaches support the viability of our proposal. For example, settled landless people in southeastern Brazil are using a taungya approach to restore 20% of their farms to comply with legislation (Valladares-Padua et al. 2002; Rodrigues et al. 2007). In an initial study, settled families interplanted seedlings of greater than 60 native tree species with mostly maize and cassava, which resulted in positive net present values to the families (Rodrigues et al. 2007) and did not interfere with seedling growth (Rodrigues 2005). In Argentina, tala (*Celtis* sp.) is invading the Atlantic forest. After mechanical removal of tala, Yerba mate (*Ilex paraguariensis*) is being cultivated as part of forest restoration efforts to attract birds and enhance natural seed dispersal, provide ongoing control of tala reestablishment, and provide income to farmers (Holz & Guillermo 2008).

Silva (2002) compared three systems to restore riparian forest in southeastern Brazil: (1) forest—planting trees and periodically weeding grasses; (2) simple agroforestry—planting trees intercropped with two leguminous shrubs; (3) complex agroforestry—same as simple agroforestry plus planting 11 fruit tree species and weeding at 4-month intervals for the first year. Ten native forest tree species, five pioneer and five non-pioneer, were planted in all treatments. After 15 months, four of the five non-pioneer species were tallest in simple agroforestry, intermediate in complex agroforestry, and shortest in the forest system. Three pioneer species had lower survival in the complex agroforestry probably because of low light levels. Simple agroforestry requires less labor than the forest system when legume planting and pruning are mechanized, so it is best suited for larger farmers. Complex agroforestry requires eight times more labor than the other two systems but results in more food security for the land owner and reduces the costs of restoration by approximately 16% compared with simple agroforestry by reducing weeding frequency; so it is recommended for small farmers who use familial labor and do not have tractors (Silva 2002).

Peneireiro (1999) compared two contiguous abandoned agricultural areas in Brazilian Atlantic Forest. One area was left to regenerate naturally, and the other was used for successional agroforestry for 12 years (Fig. 1). The agroforestry area was successively planted first with two pioneer species, bananas (*Musa* spp.) and cassava (*Manihot esculenta*); cacao (*Theobroma bicolor*), papaya (*Carica papaya*), citrus trees (*Citrus* spp.), palm heart (*Bactris gasipaes*), and six fruit and non-fruit tree species after 3 years; and later pineapple (*Ananas comosus*) and several later-successional tree species. In the first few years, the plot was selectively weeded leaving remaining tree seedlings, and throughout trees were pruned to open the canopy, leaving the biomass from weeding and pruning to provide mulch. The various crops provided income over the entire 12-year period. After 12 years, the number of individuals and species of native, non-crop species was higher in the natural regeneration area, but the agroforestry site had more vertical stratification. The natural regeneration area was characterized by low vertical stratification, more horizontal heterogeneity, and high liana and herbaceous density. Moreover, the natural regeneration area was dominated by mostly pioneer families, such as Melastomataceae, Asteraceae, and Cecropiaceae, whereas the agroforestry area had a more equitable distribution of species with a predominance of late successional families, including Mimosaceae, Lauraceae, Caesalpinaceae, and Apocynaceae.

Figure 1. Successional agroforestry system (A) and a natural regeneration area (B) in eastern Brazilian Atlantic Forest (Ernst Götsch's farm, Bahia state, lat 13° 45'S long 39° 17'W). The areas were used for cassava plantation until soil became degraded. See description in "Agro-Successional Restoration" for details of management. Photos were taken 12 years after agroforestry establishment. In (A), note cacao (*Theobroma bicolor*), banana (*Musa* sp.) and medium size trees; a thick litter layer; and a mature-forest-like structure; and in (B) note a dense herbaceous strata with grasses and many thin stems from pioneer species, and a low canopy with a gap in the trees.

Benefits of Agro-Successional Restoration

Extending the Management Period to Parallel Natural Succession

An important benefit of agro-successional restoration is that it may extend the time period of restoration. Often restoration budgets are allocated on a year-to-year basis or for relatively short periods (e.g., 1–3 years), which forces restorationists to plant all species simultaneously. However, the later-successional species that should be the focus of restoration efforts because they are less likely to colonize naturally (Martínez-Garza & Howe 2003; Lamb et al. 2005) need an established canopy under which they tend to establish (Parrotta & Knowles 1999; Ashton et al. 2001*a*; Bonilla-Moheno & Holl in press). Therefore, many authors have suggested that these species should be introduced in stages over time as site conditions become appropriate (e.g., Ashton et al. 2001*a*; Parrotta & Knowles 1999; Martínez-Garza & Howe 2003), but this approach often conflicts with the funding reality.

Agro-successional restoration can help overcome this temporal mismatch. Where ongoing management methods are similar for farmers, the temporal scale of restoration can be expanded, so that later-successional species can be introduced 5, 10, or even 20 years into the restoration. In Bolivia and Brazil, successional agroforestry systems are planned to be managed for decades, when the most profitable crops are in full production, such as cacao, coffee (*Coffea arabica*), and Brazil nut (*Bertholletia excelsa*), along with highly valuable woods (Götsch 1995; Yana & Weinert 2001). As farmers manage for these species, they can simultaneously introduce later-successional forest tree species.

Reducing Costs

Another potential benefit of the agro-successional restoration approach is to defray the costs of the initial stage of restoration. We do not suggest that incorporating agroforestry systems into the early stages of restoration will cover all restoration costs, particularly since the profitability of taungya systems has been shown to be highly variable (discussed previously). Rather we suggest that the management costs for restoration will be reduced since farmers provide maintenance for native trees, in addition to their crops, and interplanting crops has been shown to enhance tree growth rates in some cases (Beltrame & Rodrigues 2007; Rodrigues et al. 2007). How these costs would be shared between farmers and restorationists would be case specific, but we envision that if a restoration site was owned by a government or non-profit agency that might allow farmers to use the land for no or reduced cost in return for maintaining trees.

Providing for Human Livelihoods

Often restoration is seen as in conflict with providing for human livelihoods. Agro-successional restoration provides food and potentially some income from selling agricultural goods of small farmers. Agroforestry systems are particularly interesting to smallholders (Altieri 1987) because of their intrinsic traits, such as (1) labor demands and crop production are well distributed throughout the year and over multiple years; (2) the productive capacity of the system generally improves over time; (3) crop diversity decreases risk of loss from market fluctuations, disease, and pest outbreaks; (4) nutrient and water use are optimized, which decreases costs; and (5) farmers have increased autonomy due to reduced inputs (Altieri 1987; Götsch 1995; Gliessman 1998; Krishnamurthy & Ávila 1999; Peneireiro 1999). Agro-successional restoration systems provide similar types of benefits to small land owners while simultaneously promoting forest recovery, and the smallholder, low agrochemical input agriculture may earn them a price premium through fair trade or one of the various environmental certification systems (Bacon 2005; Wollni & Zeller 2007).

Ultimately, agro-successional restoration lands would be transitioned out of human management, but given the large areas of lands to be restored in the tropics we contend that there would be opportunities for farmers to move to other lands. Taungya systems in Africa or Asia historically have been established on large parcels of governmental or company land. Villagers generally have contracts to plant the trees and are allowed to plant their crops for some years before they leave the area (Nwonwu 1987; Menzies 1988; Chamshama et al. 1992; Hoekstra 1994). This system could work well on large farms that are required by law or market pressures to restore land, such as areas of Brazil where certain industries (e.g., sugar cane) are under pressure to restore large areas to meet the 20% forest cover required by law (Rodrigues & Gandolfi 2007). The sugar cane growers have to spend money on planting and maintaining trees; thus, the growers could contract smallholders or landless rural workers to establish agro-successional restoration in their areas.

Certainly, long-term protection of restored lands from subsequent degradation is a concern and requires sufficient funding (Lamb et al. 2005; Ehiagbonare 2006). Fortunately, there are a growing number of financial incentives for restoring environmental services, including carbon sequestration (Landell-Mills & Porras 2002; Wunder 2007), and those are likely to increase. However, the design and implementation of such systems are paramount in how effective they will be in conserving forests and providing for human livelihoods (Landell-Mills 2002; Tschakert et al. 2007; Wunder 2007).

Involving Farmers in the Restoration Process

Integrating agriculture and restoration offer the opportunity to exchange ideas among farmers, scientists, and land managers, which can serve to both break down barriers and misconceptions among these communities and to involve farmers in the restoration process (Altieri 2004; Peneireiro et al. 2005; Almeida et al. 2006; Chazdon 2008). Farmers often have extensive knowledge of propagation methods, species suitability for specific light and soil conditions, and management methods for a range of crop and tree species (Diemont et al. 2006; Isaac et al. 2007) which can help in designing restoration projects.

Although agro-successional restoration has many socioeconomic advantages, it does not guarantee adoption by farmers. Modifying practices is a challenge when the changes interfere with standard agricultural production practices, which result from the interaction of cultural, social, economic, and environmental forces. To favor the adoption of agro-successional restoration, new practices need to consider the local context, value community knowledge, and recognize existing constraints (Chambers 1996; González 2006; Manuel-Navarrete et al. 2006). A first step is a participatory exploration of the environmental and economic issues and potential. Then, research must be planned and carried out with all stakeholders. Finally, the results need to be communicated widely. If farmers are included in the experimental process, they are more likely to adapt technology according to their reality, share their experiences, and innovate (Shanley & Rodrigues Gaia 2002; Peneireiro et al. 2005).

Applying Agro-Successional Restoration More Broadly

We close by reiterating that there are enormous opportunities to include agroforestry systems as a stage in restoration, which have the potential to improve forest restoration efforts and incorporate small farmers in the restoration projects. The examples we discuss are largely from the tropics and for smallholder agriculture systems, because these are the systems in which existing agroforestry practices most closely resemble forest restoration practices, and agro-successional restoration holds the most promise. There are, however, other systems in which agricultural management practices may be compatible with the early stages of forest restoration. For example, along the Sacramento River in California, restoration organizations have planted native tree, shrub, vine, and herb species in an effort to restore greater than 2,500 ha of riparian forest (Golet et al. 2008). Restorationists use planting, irrigation, and weed management techniques that parallel those used in tree orchards (e.g., walnuts, plums, and almonds) previously cultivated there, and orchard farmers are hired to plant and maintain the restoration plantings.

We have focused on incorporating agricultural crops as a transitional stage of restoration because of the parallels in the management regimes, but note that there are a range of other agricultural and agroforestry techniques that might be integrated with restoration to develop semi-natural ecosystems with high conservation value that provide income to land owners. Examples include enriching logged forests with timber, fruit trees, or other economically valuable crops (Ramos & del Amo 1992; Schulze et al. 1994; Ricker et al. 1999; Ashton et al. 2001*b*), and managing fallows in shifting cultivation systems (Tschakert et al. 2007; Diemont & Martin 2009) to improve the economic value of forests. Plantations of fast growing, often non-native, tree species for pulpwood have been shown to provide short-term income, reduce restoration costs, and accelerate succession (e.g., Ashton et al. 1997; Carnevale & Montagnini 2002; Feyera et al. 2002; Janzen 2002). Moreover, some have suggested managing grazing animals in a way that facilitates succession (Posada et al. 2000; Miceli-Méndez et al. 2008).

Certainly, some of the land that is available for restoration is highly degraded from the past agricultural use, which may reduce productivity of agricultural crops. However, agroforestry systems in the tropics have been developed to cope with and improve nutrient deficiencies typical in these soils. Therefore, in only the most degraded sites (e.g., laterization and post-mining) agro-successional restoration would not be an option to consider. Moreover, areas dominated by aggressive ruderal and/or invasive species may require intensive management at the outset to reduce competition with crops, but many of these aggressive species are controlled by shading once an overstory cover is established (Ashton et al. 1997; Hooper et al. 2005; Slocum et al. 2006).

We are certain there are many more examples of agro-successional restoration than we have noted here, but many of these systems, including some that we cited, are not documented in the scientific literature. We acknowledge that this approach will not work in all cases, and how specific management systems are combined will be site specific. We encourage restoration ecologists in collaboration with both scientists and farmers involved in agroforestry to think about how these systems might be combined in different situations.

Implications for Practice

- Successful tropical forest restoration in the future requires integrating ecology, agronomy, and traditional knowledge in a way that engages farmers in resource conservation.
- Given the many parallels between forest restoration and some agroforestry systems, restorationists should increasingly explore opportunities for agro-successional restoration (i.e., incorporating agriculture as a transitional phase in restoration).
- Agro-successional restoration offers many benefits to restoration efforts including extending the management period of restoration, offsetting some management costs, providing food security for small landholders, and involving small landholders in the restoration process.

Acknowledgments

We appreciate helpful comments from Bruce Ferguson and two anonymous reviewers on an earlier version of this manuscript.

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