



Using Plantations to Catalyze Tropical Forest Restoration

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Introduction

The extent of tropical forest degradation is of increasing significance worldwide as the demand for wood and wood products continues to rise. As societal concern has increased, so have the efforts to reverse forest degradation. This paper describes one approach that holds promise for restoring native forests in the tropics. A description of how tree plantations can serve as catalysts for restoration is presented, followed by summaries of several case studies from around the world and recommendations for future research.

Background

Monoculture tree plantations using exotic species have been established worldwide to provide wood and to alleviate pressure on remaining blocks of natural forest. Increasing interest in biodiversity has called into question the extensive use of non-native species and has highlighted the ecological drawbacks of exotic monocultures. These drawbacks include lower levels of plant and animal diversity, higher susceptibility to disease and insect infestation, the fact that some exotics become weedy invaders well beyond plantation sites, and that certain species exhibit allelopathic tendencies in their ability to compete for soil and water resources (Parrotta, 1997; Florence, 1996). While the benefits of using native species may seem obvious, the primary reason why exotics are preferred in plantations and rehabilitation efforts is that they are well known (Lugo, 1997). Silvicultural knowledge for many native species is largely unavailable.

Heightened concern about the need for land rehabilitation and forest restoration has focused new attention on how to *accelerate* restoration processes. The simple but all too common practice of leaving degraded forest land to recover through natural processes of succession has proven to be inadequately slow, especially when site degradation is severe (Parrotta, 1997). A new and more intensive approach is needed. Conclusions from a recent symposium in 1996 demonstrated the significant role that tree plantations can play in accelerating forest restoration. By modifying the physical and biological conditions of a site, research has shown that tree plantations often enhance forest succession (Parrotta, 1997). Complementing increased efforts to rehabilitate and restore tropical forests are increased efforts to use native trees in new plantations. How do plantations serve as catalysts for restoration and what lessons have been learned from research?

Plantations and the catalyst process

Several studies have shown that natural recolonization by native trees often takes place in the understory of tropical tree plantations. In the cases where these trees are allowed to persist they will overtake the plantation, leaving behind a more naturalized forest. While forest restoration was not the original purpose of most plantations, this unanticipated benefit is now receiving much attention. Some research has focused on the intentional use of plantations to restore native forest, while other research has examined the successional process in plantations where

restoration was not the original intention. "The use of plantation monocultures to restore diverse tree vegetation seems paradoxical, but research helps clarify why this use of tree plantations may be an effective tool for land and vegetation rehabilitation" (Lugo, 1997). A basic step-by-step summary of how plantations serve as catalysts for restoration is summarized below:

1. Plantation trees are carefully selected to match site conditions and then planted. These are usually fast growing pioneer species intended to stabilize the site and/or to provide fuelwood, construction materials, or timber. In some cases inoculation with mycorrhizal fungi is needed to enhance survival.
2. Tree growth leads to improved site conditions. These include increased complexity of vegetative structure, improved plant and animal diversity, the buildup of litter and organic matter, improved soil structure, moisture, and fertility, provision of shade and suppression of grass competition, and moderation of temperature regime.
3. This newly forming forest structure attracts animals to the site, which help accelerate the process by dispersing seed of native trees. Wind and water may also bring in propagules of native trees from adjacent sites.
4. A woody understory of native trees begins to develop, and ideally, is protected from grazing and harvesting activities.
5. Since plantation trees are usually pioneer species, they do not regenerate well under their own canopy. Planted species become less common and native species become more common, especially when plantation trees are carefully and selectively harvested.
6. A diverse set of native tree species becomes better established and the site reverts back to a natural forest. The time required for this to take place is highly variable and depends on specific site conditions, choice of plantation species, and management activities (Lugo, 1997).

While much remains to be discovered about the role of plantations as catalysts for restoration, several factors are known to impact the rate and trajectory of the restoration process. These include the original degree of site degradation, the proximity of a plantation to remaining stands of natural forest, the existence or absence of animals, the choice of plantation species, spacing of plantation trees, the use of native trees, and the impacts of monocultures versus mixed species plantations (Parrotta, 1997).

In terms of site degradation, the catalytic impact of plantation trees increases as the severity of degradation increases and as moisture levels increase (Parrotta, 1997). Some examples of highly degraded sites include mined lands, areas suffering heavy losses of topsoil, mechanically cleared rainforest, and abandoned pasture that was once under heavy grazing pressure (Uhl, 1988). Plantations accelerate recovery processes more in these areas because harsh site conditions often preclude natural recovery and regrowth. Matching particular species with particular site conditions can overcome the limiting factors which prevent natural regeneration (Lugo, 1997). The rate of recovery also improves as the distance to remnant stands of natural forest decreases. These forests are critical because they serve as a seed source and provide the habitat for animals that disperse the seed.

The role of animal seed dispersal in catalyzing the restoration process

Animal seed dispersal in the tropics has major impacts upon tree regeneration. In neotropical forests 66% of canopy species were found to be dependent upon animal seed dispersal. This contrasted sharply with results found in temperate forests, where less than 33% of tree species depended upon animal seed dispersal (Wunderle, 1997). The impact that animals can have on restoration is significant because light demanding pioneer species generally have smaller seeds more easily dispersed by wind, while secondary and climax species tend to have larger seeds, requiring dispersal by animals. In a tree plantation, wind dispersed pioneer species have difficulty becoming established due to low light conditions. Only the larger seeded shade tolerant secondary and climax species are able to colonize the understory. Therefore, the lack of animal seed dispersers will limit the establishment of secondary and climax species under the plantation canopy. Even when animal seed dispersal mechanisms are operating, the problem of seed size will impact regeneration because seed mobility decreases as seed size increases (Wunderle, 1997). Larger birds and mammals are the main dispersing agents for larger seed, and yet these are often the first animals to suffer from land and forest degradation. If full restoration of species diversity is to be achieved in a plantation, large-seeded species often need to be actively planted (Wunderle, 1997).

One obvious implication for restoration is to design a plantation to maximize its attractiveness to wildlife. Apparently, broadleaf tree species tend to yield better results than conifers because they provide better wildlife habitat and seed germination conditions (Parrotta, 1997). In addition, mixed species plantations of native trees attract the most wildlife, and native tree monocultures are generally more attractive than exotic monocultures (Wunderle, 1997). Other suggestions to improve seed dispersal as offered by Wunderle (1997) include: 1) provide perches and roosting sites for birds, 2) encourage vegetative complexity, 3) plant some fruit bearing plants, especially those that might attract generalist seed dispersers, 4) increase the plantation's edge effect by establishing smaller plots rather than a single large plot.

The role of native trees, monocultures, and mixed species plantations.

New efforts in forest restoration are focusing on the ideals of using native species in plantations as well as the use of species mixtures. In addition to accelerating restoration by attracting animal seed dispersers, there are other potential benefits of native and mixed species plantations. Ecological benefits include improved conservation of biological diversity, improved site protection/maintenance of fertility, and greater resistance to insect infestation or disease (Keenan et al. 1995; Ball et al. 1995). Social and economic benefits include improved productivity when synergies between several species permit more efficient use of the site, the reduction of economic risk that comes with dependence on more than one species, and the ability to provide a wider range of socially relevant products (Ball et al. 1995).

Two separate studies examined the productivity of mixed species plantations using native trees in Costa Rica. Both studies concluded that a mixed species plantation can be almost as productive if not equally productive as a monoculture, and that in some cases they will be even more productive (Montagnini, 1995; Menalled et al. 1998). To achieve this, however, species used in a mixed plantation need to be carefully chosen to minimize interspecific competition. When species selected for a mixed plantation differ in such characteristics as shade tolerance, rooting depth, and crown structure, they are more likely to make better use of a site by using

resources differently (Menalled et al. 1998). While the idea of mixed species plantations sounds appealing, good research on the subject is lacking and so there are a number of drawbacks. Some of these include the difficulties of finding species which work well together, locating viable seed sources, managing different germination requirements or different growth rates, and knowing which combinations might be better than others.

In spite of these drawbacks, the studies mentioned above highlight how native monocultures and mixed species plantations hold significant implications for restoration efforts. Plantations of native trees can be more socially relevant and better meet the needs of local people. They can also provide a more diverse set of desired forest products and be as productive or even more productive than monocultures of exotic species. The increasing use of native monocultures and mixed species plantations will cause a certain degree of "restoration" to be accomplished unintentionally. This will serve to complement and assist other restoration efforts that are more intentional. Competing environmental, social, and economic goals all stand to benefit.

Case studies from around the world

The following section summarizes five case studies. Situations in Columbia and Puerto Rico demonstrate how monoculture plantations of native and naturalized trees served as catalysts in restoration. A study from China describes a successful restoration effort that began with exotic eucalyptus plantations. Five years later the eucalyptus was replaced with mixed species plantations of native trees. The final two examples come from Malawi and India, where exotic tree plantations of eucalyptus did not facilitate the recovery of native trees in their understory.

Columbia

Carolina Murcia of the Wildlife Conservation Society conducted a study in Columbian cloud forest where 30-year-old native Andean alder (*Alnus acuminata*) plantations were evaluated for their catalytic effect on forest recovery. This species has been commonly used in the Andes for revegetation projects on steep slopes and is considered a good catalyst for several reasons. It is fast growing, performs well in nitrogen poor conditions due to its association with nitrogen-fixing actinomycetes, and has wind dispersed seeds that germinate quickly. In some cases it has also increased productivity of traditional crops where it has been planted as an overstory tree (Murcia, 1997). Since its usefulness in accelerating the recovery process was established, this study specifically looked at how the alder impacted the recovery of species diversity. Tree diversity within the plantations was compared to the diversity on plots outside the plantations left to natural regeneration.

Alder plantations facilitated more rapid recovery of forest cover and establishment of native species compared to naturally regenerating sites. Several species found in both sites performed better in the plantations, but the plantations also had one-third fewer species per plot compared to adjacent plots left to natural regeneration. While the presence of alder permitted some species to become established that did not survive well outside the plantations, other species only became established outside the plantations. This fact led Murcia to conclude that for restoration on a large-scale basis aimed at achieving a high level of biodiversity, the best strategy might be to use a mosaic of alder plantations intermixed with sites left to natural regeneration. While the

presence of alder influenced what species became established, the long-term impact of alder on species composition was unknown (Murcia, 1997).

Puerto Rico

A similar study conducted in Puerto Rico reached similar conclusions by comparing plantations of *Albizia lebbek*, a naturalized leguminous species, with control plots left to natural regeneration processes. The plantation and control sites were located on a degraded area that had been subjected to multiple disturbances of cultivation, grazing, and sand extraction. An added component of this study was to examine how the plantations performed in the production of biomass and how they impacted soil fertility. In this case the *Albezia* plantations encouraged the development of several native tree species in the understory, but no tree regeneration occurred on the control sites (Parrotta, 1992). The degree of site degradation on control plots hindered natural regeneration, while plantation plots greatly accelerated the process of plant succession, resulting in a significantly higher level of species richness (Parrotta, 1992).

Nutrient levels and biomass production were also higher in the plantations. When *Albizia* trees were 4.5 years old, levels of mineral soil organic carbon and total nitrogen were 1.90 and 1.64 times higher compared to control plots. An 11-fold increase in aboveground biomass and a 7-fold increase in root and forest floor biomass also characterized the plantations in comparison to control plots (Parrotta, 1992). The success of this project was attributed to the choice of *Albezia lebbek* for use in the plantations. As a leguminous species, *Albizia lebbek* is also a multipurpose tree providing several products to local people. It grows well in a wide variety of conditions, including saline, alkaline, and rocky or sandy soils. One of Parrotta's comments summarizes a key lesson which was also evident from the study in Columbia: "The choice of plantation species is likely to greatly influence both the rate and trajectory of rehabilitation processes" (1992).

China

Fang and Peng (1997) evaluated an effort to restore tropical evergreen forest in the Guangdong Province of China. The recovery site was highly eroded, leaving behind bare subsoil. Levels of organic matter, total nitrogen, and soil moisture were low compared to nearby vegetated sites. Fang and Peng point out that because rainforests have a high degree of adaptation and interdependence among community members, restoration can be more difficult. In this case several sites in close proximity to one another were planted with exotic eucalyptus to stabilize the areas and establish vegetative cover. After five years the eucalyptus was cut and different sets of 2-3 native tree species were planted on different sites. Nearly 30 years later each site had recovered from just 2-3 species to an average of 25 species, most of which were native to the area. Results showed that regardless of what species were originally planted, separate patches of "restored" forest became more similar to one another and moved towards the climax community typical of the area (Fang and Peng, 1997). Native trees either became as prevalent as originally planted species or they completely replaced original species, highlighting the catalytic impact of plantation trees (Fang and Peng, 1997).

In this study results demonstrated that originally planted tree species did not significantly impact which native species colonized the area. In Columbia and Puerto Rico findings differed, showing

that the choice of plantation species had a greater impact on incoming species. This difference may be due to the fact that mixed species plantations were used in China, while monocultures were used in Columbia and Puerto Rico.

The usefulness of certain exotic trees is also evident in this study. A species like eucalyptus can be helpful on highly degraded sites because of their ability to withstand harsh environmental conditions. Even though exotic plantations are less popular due to negative environmental impacts, in the right circumstances they can serve as catalysts to assist the growth of native trees.

Malawi

In the African country of Malawi wood is a critically important resource because it provides for 93% of the nation's energy needs (Bone et al. 1997). To combat wood shortages, plantations of exotic *Eucalyptus camaldulensis* and *E. tereticornis* have been widely planted. These species were chosen primarily for their drought tolerance. The native Miombo woodland, dominated by the genera *Brachystegia* and *Julbernardia*, also has species adapted to dry conditions, but they were not used in plantations. They were likely not selected because knowledge about native species by those promoting the plantations was lacking and because restoration was not the primary objective. The focus of research was to examine vegetative composition and diversity on an unplanted control plot in comparison to the understory of an 8-year-old *Eucalyptus camaldulensis* plantation.

Results showed that the plantation did not accelerate native tree regeneration in the understory (Bone et al. 1997). Species richness within the plantation was very similar to the naturally regenerating control site. Furthermore, a survey of public opinion regarding the eucalyptus showed that local people preferred nine different native tree species over and above the eucalyptus, even though the plantation provided fuelwood and building materials. The remaining patches of native Miombo woodland provided 13 different products, while plantation trees only provided 4 products. Discussions with the local people revealed that the native woodland was much more highly valued because of its ability to provide multiple products (Bone et al. 1997). In this case the exotic monoculture proved to have marginal social and environmental benefits. The situation highlights the potential for increased benefits when plantations make use of native trees.

India

As in Malawi, similar situations have occurred across India, where plantations of exotic eucalypt species were established to alleviate wood shortages. Research by Shiva and Bandyopadhyay (1987) showed that in many plantations very little regeneration of native trees took place, and this often included a general lack of valuable understory vegetation needed by grazing animals. From a social standpoint, the eucalyptus was not favored for cooking because it burned too quickly. Other research also showed that the exotic eucalypt species did not prove to be more highly productive when compared with several fast growing native species. In fact, local complaints about high rates of water consumption and allelopathic properties of eucalypts resulted in some community-led anti-eucalyptus movements (Shiva and Bandyopadhyay, 1987).

The complexity of environmental and social issues related to monocultures, the use of exotic species, and its implications for restoration are evident in both this example and from Malawi.

Research needs and questions

As the emphasis in forestry around the world slowly shifts towards a greater use of native tree species, what are some of the research questions related to restoration efforts? The idea that plantations can catalyze the recovery of forests in the tropics is a relatively new approach in restoration forestry, and numerous unknowns still exist. Here are some of the most pertinent questions that need to be addressed as identified by various researchers.

1. Other than using native tree species and considering ways to attract wildlife, are there other management activities that would accelerate the restoration process? For example, will certain native tree species facilitate plantation-based restoration more quickly than others?
2. Research is needed to identify how the absence of a certain animal species may delay or inhibit the rehabilitation process, especially in the case of micro-fauna (Lugo, 1997).
3. How important is timing in management interventions in terms of improving or accelerating the recovery process?
4. When should natural succession be left to take its course, with no outside interventions or intensive management? Rehabilitation efforts can be costly.
5. How does the growth of secondary forest under plantation trees impact the productivity of the planted tree crop and the purpose for which it was planted (i.e. for timber)? Can the new mix of species adequately provide a diversity of products to satisfy economic and social needs while at the same time serving the purposes of conservation or restoration?
6. Locally relevant research is needed in the use of native tree plantations, the use of mixed species plantations, and how these possibilities compete with the use of exotics.

Conclusions and recommendations

Studies reviewed in this paper show that the ‘catalytic plantation’ holds a great deal of promise for tropical forest restoration. It is an approach that is gaining popularity because it demonstrates the possibility for resolving some of the competing interests in land-use and their social, economic, and environmental implications (Parrotta, 1997). With the use of native tree plantations greater potential exists for meeting both the needs of people and achieving a higher degree of environmental health and integrity. However, an important issue must be carefully examined in future studies. While plantations may in fact serve as places where natural forests can be regenerated, the demand for a wide variety of forest products is continuing to rise with population growth. This raises the question of whether or not the approach will be feasible in the numerous third-world conditions found in the tropics. Widespread scarcity of forest resources is already a significant problem, and for most plantations at least some level of harvesting activity will take place on a continual basis. In these situations such activity will heavily influence and perhaps limit the recovery of native forests within the ‘catalytic plantation’ setting. Successful use of plantations as catalysts in forest restoration will depend heavily on integrating sound scientific knowledge with the needs of local people, where close cooperation and involvement of local people is encouraged throughout the forest planning and management process. Clearly the

most immediate and critical research need is to identify which native tree species are most suitable for use in plantations. An international collaborative research effort is needed to identify, on a region by region basis, which species are socially, economically, and ecologically appropriate for a specific area. With this information newly established plantations would have improved ability to serve as catalysts for restoration and provide improved conditions for maintenance of biodiversity. Once this is accomplished the same approach should be taken in the more difficult challenge of researching the use of mixed species plantations. The "catalytic plantation" would then reach its fullest potential in forest restoration.

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