NAT. HIST. BULL. SIAM SOC. 44 : 155–160, 1996

Can Tree Plantations Restore Degraded Tropical Forests?

About 15 million km^2 of the tropics is classified as "degraded". One way to rehabilitate degraded land and take the pressure off remaining forest is to establish plantations of fast-growing timber trees. However, many conservationists oppose tropical tree plantations, claiming that their uniform structure supports low biodiversity, especially if invading vegetation is regarded as weeds and cut back. Exotic plantation trees are considered particularly detrimental to wildlife since native herbivores often cannot eat them. However, such views may need to be substantially revised, following a recent international symposium and workshop on "Accelerating Native Forest Regeneration on Degraded Tropical Lands" held in Washington, DC, USA during June 11–14 1996 which explored how tropical plantations might enhance biodiversity and accelerate regeneration of natural forest ecosystems. Organized by the International Union of Forestry Research Organizations, the World Bank and the United States Department of Agriculture (USDA) Forest Service, its main purpose was to assess the results of an 18 month research program entitled "The Catalytic Effect of Tree Plantings on the Rehabilitation of Native Forest Biodiversity: an Exploratory Analysis" (sponsored by the World Bank, USDA Forest Service, the Centre for International Forestry Research and the Overseas Development Administration of the U.K.) which assessed biodiversity in various tree plantations throughout the tropics. In addition, researchers from similar projects, not part of the WB–USDA–CIFOR–ODA research program, were invited to present comparable papers. Eighty-one participants, representing 24 countries, attended.

In the keynote speech, A. Lugo pointed out that, although plantations currently cover only about 10 million ha (1%) of tropical land, 758 million ha of degraded land is potentially ready for planting, including more than 136 million ha of logged forest. Plantation tree species can be carefully selected to overcome the environmental constraints that limit natural tree establishment on degraded sites. Plantations ameliorate the micro-climate, rapidly recycle nutrients and attract seed-dispersing wildlife, thus enabling native woody plant species to proliferate.

Most studies compared plantations with adjacent non-planted land (with a similar history of degradation), using the species richness and density of colonizing woody plants as measures of the extent of natural forest regeneration. One problem with this approach was that in most cases, levels of biodiversity before the plantation trees were planted were unknown, so it was possible that differences between the planted and non-planted sites may have existed even before the plantations were established. Another problem was a difficulty in comparing between studies from different countries, because different measures of natural forest regeneration were presented by different speakers. Nevertheless, although the plantations studied had widely differing objectives (production of timber or other forest products, soil recovery, wildlife conservation etc.) and were in areas with very different levels of degradation, a clear picture emerged of plantations supporting more natural forest regeneration than non-planted sites, with few exceptions. However, the speed of regeneration varied enormously, depending on a host of interacting factors, of which the plantation tree species was one of the most important.

In comparing three monoculture plantations in North Queensland, Australia, D. Lamb *et al.* found that *Flindersia brayleyana* supported the most colonizing tree species (70)

followed by *Araucaria cunninghamii* (40) and the exotic, *Pinus caribaea* (20). In combination, the plantations supported 65% of the local tree flora. On Hawaii, R. Harrington and J. Ewel investigated colonization of various plantations by both native and exotic trees. *Eucalyptus saligna* supported 42 species, *Fraxinus uhdei* 39 and *Flindersia brayleyana* 36. However, density of native forest plants was three times higher under *Fraxinus* than under the two other plantations. The abundance of native plants decreased as the plantation trees matured and canopy density increased. C. Geldenhuys extolled the plantation-assisted approach to restoring mixed evergreen forests on fire prone grasslands in S. Africa. *Eucalyptus* stands had a higher density and species richness of colonizing woody and herbaceous plants than stands of various pine species. He concluded that the most cost effective way to restore forests is to allow plantations to foster regeneration. No planting of native trees is necessary and the thinning and eventual harvesting of the plantation trees can finance the whole operation.

However, other speakers reported impressive results from using plantations of mixed native species. In Brazil a mixture of 70 species of local forest trees were planted on disused, open-cast bauxite mines. Within 10 years these mixed plantations were invaded by a further 75 woody species whilst non-planted control plots remained dominated by grass with only 11 colonizing woody species. The cost was about 25,000 baht/ha for tree planting and 37,500 baht/ha for site preparation (J. Parrotta *et al.*). N. Tucker also advocated direct planting of native trees for ecological restoration of degraded agricultural land in Queensland, Australia. Tree seedlings, raised in a nursery staffed by volunteers, were planted by local farmers on abandoned fields. The plantations attracted birds which dispersed the seeds of a wide range of other native forest trees. The system was most successful in lowland areas close to existing forest. In China both exotic and native trees were planted in a two-stage approach to restoring land degraded almost to bare soil. First eucalypts and acacias were planted which, after soil fertility rose, were replaced with a mixture of native species. These man-made forests were quickly invaded by 47 native tree species. F. Wei and P. Shaolin concluded that no matter what tree species are initially planted, a man-made forest will eventually develop towards the zonal climax.

One of the rare instances of plantations not accelerating natural regeneration was in Columbia where Andean alder (*Alnus acuminata*) plantations contained one-third fewer tree and shrub species than naturally regenerating forest (C. Murcia). The seed rain and levels of seed predation were similar in both, but soil in Andean alder plantations appeared to inhibit seed germination of some species. J. Powers *et al.* reported mixed results within 7-year-old monocultures of 11 tree species, but only two of them (*Hyeronima alchorneoides* and *Virola koschnyi*) supported a species richness of woody colonizers similar to or lower than that in non-planted abandoned cattle pasture. Factors favouring establishment of woody species were rapid shading out of grasses, reduction in soil bulk density and accumulation of soil nitrogen.

Whilst most papers concentrated on empirical results, very few dealt with the mechanisms of tree seedling establishment. Both K. Hardwick *et al.* and C. Hau stressed the need to analyse the factors which might limit each stage in the process of seedling establishment (seed dispersal, predation, germination and seedling growth). C. Hau showed that intense seed predation by rats, on degraded sites in Hong Kong, is likely to limit the effectiveness of planting tree seeds in such areas to species with hard seed coats, which

can resist predation. K. Hardwick *et al.* showed how appropriate methods to accelerate regeneration of different tree species could be devised by identifying and counteracting the constraints (lack of seed availability, low dispersal, poor establishment) which slow the process down.

Colonization of plantations need not necessarily wait for natural seed dispersal, especially if economic species are desired. C. Gunatilleke *et al.* described an enrichment planting system in different sized gaps within a *Pinus caribaea* plantation in the buffer zone of Sinharaja World Heritage Site, Sri Lanka, using both commercial timber and non-timber trees. Most of the trees tested performed best in gaps created by cutting three rows of pine trees (spaced 2 m apart). The forest now produces a more diverse range of products, which discourages local people from burning it, thus protecting the integrity of the buffer zone and the World Heritage Site within. Enrichment planting can also be used to hasten recovery and add value to logged-over secondary forests, which retain vegetation and fertile soil. F. Montagnini *et al.* experimented with line enrichment planting where tree basal area has dropped below 10 m^2/ha in the state of Misiones, Argentina. They identified several native tree species, which not only grow well, but also improve the local economy. The method is considered economically viable only at small or medium scales, but if complemented by management of natural regeneration between the lines, it becomes more widely applicable.

K. Wightman emphasized the importance of improving nursery practices to produce seedlings of the highest quality, whether they are for enrichment planting, establishing plantations or reconstructing complete forest ecosystems. Root training containers with air pruning and compost, instead of forest soil, improve post–planting survival and reduce costs. Inoculating seedlings with mycorrhizal fungi also produced impressive results in Indonesia (Y. Setiadi). The work of Thailand's Forest Restoration Research Unit, which is developing techniques to grow a wide range of native forest tree species, to help restore Thailand's degraded forests, was also presented (S. Elliott *et al.*).

Along with the symposium, two workshops were held to identify areas of agreement among participants and draft recommendations: the first focused on ecology and silviculture whilst the second tackled management and policy issues. The first workshop addressed four key questions:

1. Under what site conditions can plantations accelerate forest recovery? All participants agreed that plantations can significantly speed up regeneration on highly degraded sites, whilst on less degraded sites the benefits were more questionable. Other important factors include the distance from the nearest forest, its size and type, the presence of suitable seed dispersers and their ability to cross the intervening landscape.

2. What is the effect of plantation species on subsequent colonization by native forest flora? Most agreed that regeneration in the understory is largely dependent on the environment created by the canopy trees and different species affect light levels, leaf litter, grass cover, soil moisture and nutrients in different ways. However, as yet there is no list of "good" and "bad" species. Mixed species plantations were considered more effective than monocultures in attracting wildlife, but very large mixtures might occupy all available niches and thus exclude new immigrating woody plant species by competition.

3. What is the role of wildlife? Time after time, the importance of birds and bats as dispersal agents was stressed and any measures taken to encourage them, such as including fleshy fruited species in the plantation design, was predicted to accelerate natural forest regeneration. Dispersal of large-seeded trees is limited, however, so planting such species was recommended to increase biodiversity.

4. How can plantations best be managed to promote biodiversity? In heavily degraded areas, any site preparation which favours the plantation will also favour the regeneration it fosters, but on less degraded sites, preparation will knock back the regenerating biodiversity. On the subject of weeding, a lively debate developed between the ecologists who favour biodiversity and foresters who often regard it as a euphemism for "weediness". The compromise reached was that plantations should be weeded for the first two years to allow their establishment (especially on dry sites), after which natural regeneration should be encouraged (e.g. by reducing weed control and later thinning canopy trees). It was concluded that foresters would have to accept less than maximum financial returns, if they wanted to increase biodiversity in plantations.

Workshop two (management and policy) was less conclusive due to a lack of social scientists and economists amongst participants and a lack of data (because the WB–USDA–CIFOR–ODA research program had been designed to address only ecological questions). More questions than answers were generated, such as what incentive would land owners have to allow biodiversity to flourish in plantations? Would a more diverse range of forest products suffice or would financial subsidies be necessary? In an elegant economic analysis J. Kuusipalo demonstrated that in southeast Asian dipterocarp rain forests, it is always profitable to restore degraded land after logging, but that financial profitability declines with increasing levels of degradation. He suggested that rehabilitation of degraded tropical land is of global importance and should attract international funding.

Several participants thought that the main question was one of plantation design. We need to design systems to harvest timber from plantations without destroying the natural regeneration. Perhaps lessons could be learned from the silvicultural systems used to exploit secondary forest in Indonesia? P. Parthama and H. Alrasjid evaluated 3 systems: selective cutting and replanting, strip cutting and replanting and the creation of artificial gaps. Different systems suited different forest types, depending on the density and size of the trees.

A fundamental problem is the very long-term nature of forestry. How can we plan today to meet the needs of future generations, when we don't know what those needs will be? Perhaps plantations supporting diverse natural regeneration provide a possible solution, by keeping open several management options, e.g. i) remove the plantation species and use the revenue to cover costs and manage for biodiversity; ii) manage for a diverse range of forest products for community forestry or buffer zones for protected areas; or iii) management for intensive timber or pulp production. We are entering an era of man-made tropical ecosystems which could be flexibly managed to optimize either economic productivity or biodiversity, as future society demands.

It was concluded that, having shown that *technically* plantations can be effective in restoring degraded sites in the tropics, the economic and social aspects should be explored

by another international project. Such a project should examine the role of plantations supporting diverse natural regeneration within experimental landscapes over a minimum of 3 years. The aim should be to evaluate use of the technical results of the symposium by local communities to increase productivity and restore biodiversity of degraded landscapes. The project should include further ecological and socio-economic research, demonstration areas, education and training and the development of a standardized monitoring system.

There are two ecological issues which we feel require further research (1) defining more clearly the situations where plantations can be most effective at restoring natural forests and (2) improving techniques for enriching plantations with the large-seeded tree species which do not disperse naturally into plantations or deforested areas. Other priorities include standardization of how the amount of natural regeneration is quantified and controlled experiments to test sustainable methods to harvest plantations without destroying the accumulated biodiversity. Socio-economic research should steer away from theory and concentrate on evaluating real-life projects. Such an approach would both maximize the practical value of the research findings and suit future projects for funding by organizations such as World Bank whose main aim is to alleviate poverty.

Personally we both found the meeting to be an immensely rewarding experience and came away with a host of practical ideas to improve our own research on restoring Thailand's degraded forests. The organizers are to be congratulated for keeping conference "frills" to a minimum, so that sponsorship was available to bring together such a diverse, yet highly focused, group of participants, thus enabling real progress to be made.

The proceedings, which will be published as a special issue of Forest Ecology and Management (Elsevier press), are likely to become essential reading for forest managers throughout the tropics, whether they are concerned with reconstructing complex forest ecosystems for conservation or increasing biodiversity in commercial plantations. For further information please contact John Parrotta, USDA Forest Service, International Institute of Tropical Forestry, P.O. Box 25,000, Rio Piedras, PR 00928–5000, USA, Tel +1–787–7665335; fax +1–787–766–6302; e–mail: /s=j.parrotta/ou=r12a@mhs–fswa.attmail.com.

Acknowledgments: The authors' participation in the symposium was made possible through generous sponsorship from the World Bank and the University of Wales, Bangor. We are especially grateful to John Parrotta for his efforts which enabled our attendance.

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