BRINGING BACK THE FORESTS

Policies and Practices for Degraded Lands and Forests

Proceedings of an International Conference

7–10 October 2002, Kuala Lumpur, Malaysia

Food and Agriculture Organization of the United Nations
Regional Office for Asia and the Pacific
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Editors:
H.C. Sim, S. Appanah and P.B. Durst

Organised by:

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FOREWORD

Forests are important natural resources that fuel the continuous economic and social development of many countries. This is especially true for many of the developing countries in the Asia Pacific region. However, the rather rapid economic and social development experienced by many of these countries was partly fuelled through exploiting these natural resources in an unsustainable manner. Additionally, inappropriate logging practices, shifting cultivation, repeated burning and other human disturbances are also rampant in many of these countries. All these unsustainable practices and rapid expansion for agriculture production have resulted in vast tracts of degraded forests and lands. A critical consequence has been the reduction in productive forest area, lowering of genetic diversity, changes in global climate, greater frequency and severity of floods and storms, and increasing poverty.

Concerned with the severity of the problems, a number of countries in the region have initiated national policies and implemented numerous forest rehabilitation projects to *Bring Back the Forests*. While much knowledge and experience have been gained from these initiatives, they have not been widely publicized or adopted. There is an urgent need to bring this understanding to the natural resource managers and policy-makers so that appropriate action is taken and supporting policies are adopted. This International Conference on Bringing Back the Forests: Policies and Practices for Degraded Lands and Forests was therefore designed to bring together all the stakeholders, including the project planners and implementers, as well as beneficiaries, to exchange experiences and knowledge and to promote successful approaches. Besides new technological advances, much care was given to the critical issues of policy and implementation. Furthermore, the Conference also provided opportunities to establish closer collaboration and networking among all the concerned parties for future undertakings.

This volume, the proceedings of the conference, is a collection of some of the most valuable papers that have been recently produced on the subject. Professionals and practitioners in forest rehabilitation should find this volume valuable, and avoid repeating mistakes and errors and wasting already scarce resources in this region.

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and Regional Representative
for Asia and the Pacific
FAO Regional Office
for Asia and the Pacific

Dato' Dr. Abdul Razak Mohd. Ali
Chairperson,
Asia Pacific Association of Forestry Research Institutions
Director-General,
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The International Conference on **"Bringing Back the Forests: Policies and Practices for Degraded Lands and Forests"** was jointly organized by the Asia Pacific Association of Forestry Research Institutions (APAFRI), the Forest Research Institute Malaysia (FRIM), the Food and Agriculture Organization of the United Nations (FAO), the Forestry Research Support Programme for Asia and the Pacific (FORSPA) and the International Union of Forest Research Organizations (IUFRO) from 7 to 10 October 2002, in Kuala Lumpur, Malaysia.

The conference was attended by delegates from Australia, Bangladesh, China, Cambodia, Denmark, Germany, India, Indonesia, Lao PDR, Malaysia, Nepal, Netherlands, Papua New Guinea, Philippines, Sri Lanka, Sweden, Syria, Thailand, United States of America and Viet Nam. FRIM and Cambodia's Department of Forestry and Wildlife greatly facilitated the field trips in Malaysia and Cambodia.

A major portion of the funds for organizing this Conference was provided by FAO-FORSPA. A number of other organizations and private enterprises have also contributed financially and in kind.

We wish to thank the delegates and authors for their contributions to the Conference and the proceedings. Special thanks are due to the sub-committee headed by Dr. Raja Barizan of FRIM for the initial compilation of this publication.

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OPENING

1 Welcoming address on behalf of FAO

Patrick B. Durst*

Honorable Minister of Primary Industries, Datuk Seri Dr. Lim Keng Yaik,
Dato' Dr. M.A.A. Razak, Director-General of FRIM,
Distinguished Guests, Ladies and Gentlemen,

It's a great pleasure for me to be here this morning and to offer a few remarks on behalf of the Food and Agriculture Organizationof the United Nations (FAO). At the outset, allow me to convey the greetings of FAO's Assistant Director-General for Forestry, Dr. Hosny El-Lakany, who asked me to extend his warm regards and best wishes for the success of this conference. And likewise, I'd like to extend the greetings of my colleague, Dr. S. Appanah, Senior Adviser for the FAO-supported Forestry Research Support Programme for Asia and the Pacific (or FORSPA, as many of you know it), as FORSPA is also one of the organizers of this conference.

The origins of the *Bringing Back the Forests* Conference can be traced to a meeting of the Executive Board of the Asia Pacific Association of Forestry Research Institutions (APAFRI), held early last year in Chiang Mai, Thailand. Members of the Executive Board agreed that there was a need for APAFRI to raise its institutional profile by regularly organizing major technical and policy-oriented conferences on key forestry topics, in partnership with other leading organizations in the region. FAO and FORSPA were happy to support this idea and we went on to discuss potential topics.

Collectively, we agreed that an area with enormous potential synergies—and one desperately in need of critical attention in this region—is that of forest rehabilitation. Following the discussions in Chiang Mai, a group of energetic individuals from APAFRI, FORSPA, Forest Research Institute Malaysia, International Union of Forest Research Organizations and FAO have worked tirelessly to bring the vision of this conference to reality.

Many of you are probably aware that the United Nations Forum on Forests (UNFF) has given special attention to forest rehabilitation in its deliberations during the past two years. Coincidentally, and somewhat unfortunately (for those of us who can't be

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in two places at the same time), some of our colleagues are also meeting in Seoul, South Korea, this week, under the umbrella of IUFRO and the Korean Ecological Society, also to discuss forest restoration and rehabilitation. Several other national and international meetings and workshops have been held, or are being planned, to address these topics.

So why forest rehabilitation—and why now?

One important reason is that, until recently, rehabilitation has been one of the more neglected of the major strands of forest management. For decades, there has been intense efforts to conserve the remaining natural forests and protect their associated biodiversity. Enormous attention has also been given to plantation establishment, but primarily for timber production purposes.

In comparison, the focus on rehabilitating degraded forests and degraded lands has been much less intense, especially here in the Asia Pacific region. This is somewhat surprising when we consider that FAO's Global Forest Resource Assessment 2000 estimates that there are more than 140 million hectares of "other wooded land" in Asia. Most of these areas were once forest, but are now largely covered with shrubs or bushes, or too few trees to still be considered "forest."

Of course, there are also many tens of millions of hectares that still meet the formal definition of "forest," but which have been degraded or damaged—sometimes severely—as a result of inappropriate logging techniques, shifting cultivation, fire, insect attacks, and other factors.

Another area of concern and opportunity is the region's vast *Imperata* grasslands—which now extend across more than 50 million hectares in South and Southeast Asia alone. As I'm sure most of you know, *Imperata* is a highly aggressive grass that quickly dominates areas that are subjected to regular burning or grazing. And although perhaps not all of the 50 million hectares were historically forested, evidence suggests that most were indeed covered by trees at some point in the past. FAO has recently increased efforts to promote "assisted natural regeneration"—an approach developed in the Philippines to restore *Imperata* grasslands to more productive forest.

Just from this brief review of the areas involved, we can see that there is enormous scope for rehabilitation activities. There are also many good reasons for doing so. Obviously, when forests are cleared or heavily degraded, their economic, social and ecological contributions are removed or impaired. We may easily see, as a result:

- reduced capacity to supply wood, fiber, energy and biomass;
- increased release of greenhouse gases;
- deterioration of water quality;
- accelerated loss of biodiversity; and
- increased impoverishment of forest-dependent people.

To a large extent, broader recognition of these detrimental impacts—both locally and internationally—is helping to stimulate interest in forest rehabilitation. For starters, recent concerns about climate change, and subsequent interest in carbon offsets and the Clean Development Mechanism have brought renewed focus on improved forest management for enhancing carbon sequestration. Similarly, significant reductions in timber harvesting in many countries of the region highlight the need for new sources of wood. One alternative is to gear up production on degraded sites where current productivity is very low.

There's also growing appreciation of the potential for forest rehabilitation to advance objectives related to biodiversity conservation and protection of water quality.

Finally, the past decade has seen major advances in policies related to rural poverty and social stability. There's increased recognition of the contributions that forests make, both in providing subsistence "safety nets" for the poorest segments of society and in generating broad levels of employment and income. There's also greater understanding of the ramifications of failing to address rural poverty adequately.

Despite the heightened interest in forest rehabilitation, actual progress on the ground remains rather limited. While there are plans for ambitious forest rehabilitation programmes in a few countries, such as Vietnam and China, most initiatives are still small scale in nature. There's a tremendous need to "scale up" successful pilot activities, based on sound research and realistic financial incentives. In this respect, I would like to mention the role that FORSPA has played in supporting five large-scale rehabilitation research and demonstration sites—one each in Cambodia, Laos, Papua New Guinea, Sri Lanka and Vietnam. But, still, these efforts are minimal compared to the scale of the problem and the challenges.

It's important to recognize that the constraints are rarely technical in nature. The main constraints lie in the realm of policy, finance, land-ownership and related problems. Governments are gradually recognizing that their forest departments alone can't rehabilitate all the degraded areas needing attention. And yet, private companies and individual farmers are all too often viewed more as adversaries rather than as partners in rehabilitation efforts. If the laws or regulations of a country prevent a farmer from cutting, or transporting, or selling the teak tree that he's planted in his garden plot (as is the case in several countries), we will continue to find it difficult to bring back the forests. If neither corporations nor individual farmers can be assured of secure tenure over land and resources, how can we expect them to invest in forest restoration? If bribes have to be paid to corrupt officials in order to obtain cutting and transport permits, and at multiple checkpoints along the highway, what motivation exists for planting trees? If taxes on the sale of plantation-grown wood exceed 50 percent of gross revenue, who will be interested in bringing back the forests?

There are many such policy issues constraining forest rehabilitation. You will note, therefore, that we are giving strong emphasis to policy measures and financial instruments at this conference. It's only when these fundamental constraints are removed that we will likely see significant gains in forest rehabilitation.

Ladies and Gentlemen,

FAO is delighted to be a partner in organizing this Conference. I'd like to take this opportunity to thank our partner organizations–APAFRI, FORSPA, FRIM and IUFRO—for the fabulous job they've done in planning and preparing for this Conference, and particularly for ensuring such an impressive programme and comprehensive participation.

Speaking from a personal perspective, I'm very much looking forward to this Conference. Forest rehabilitation and regeneration are virtually etched into the soul of every forester. Probably nothing can be more rewarding for a forester than to return an area of scrub, or wasteland, or degraded pasture, back into thriving forest. And, while we're not going to rehabilitate any forests directly in the next four days, our programme should give us ample opportunity to discuss the key issues and learn about some potential solutions. It's the sincere hope of FAO that this Conference will sow the seeds for expanded forest rehabilitation throughout the region, and indeed throughout the world. I wish all of you a productive, rewarding, and enjoyable conference.

Thank you.

2 Introduction: restoration of degraded forests as opportunities for development

S. Appanah*

ABSTRACT

Despite earnest efforts by the international community, forest and land degradation has advanced to such a degree that many countries in the Asia Pacific region have practically lost a major income-earning sector. Besides, loss and degradation of forests are bringing a backlash of problems, environmental, social, and others which were never unexpected. Under the circumstances, there is now pressure to rehabilitate those degraded forests and lands. In the past, such activities were limited to monoculture plantings. Now, rehabilitation procedures seek to go beyond that of commercial timber production—trials are underway to increase biodiversity and ecological services as additional products. Fortunately, such efforts can also be linked to social development. The vast majority of forest restoration schemes can also provide additional income to rural communities, besides increasing their resources. Attempts are also underway to find more innovative ways to support such developments.

INTRODUCTION

Nature inherently has a duality about it—it can be benevolent or otherwise depending on how you treat it. When Unasylva, FAO's forestry journal was launched in 1947, Sir John Boyd Orr, the first Director-General, was enthusiastic when he wrote in the foreword that "The tie between forests and the good things of the earth runs back through history" (Orr 1947). Just half a century later, following much maltreatment, the forests may perhaps be revealing their other side too.

Not too long back, some states in Malaysia were reverberating from the shock of a viral epidemic. The effect on human life and the economy was devastating. An unknown virus, subsequently named the Nipah virus, spread from swine to humans and

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killed over a hundred of the latter. The epidemic could only be contained after about a million animals were culled. What is the connection between these sudden viral epidemics and forests? If new research is confirmed, there is a very strong link, at least with the Nipah virus (Helpin *et al.* 2000). The story goes that the huge forest fires in Borneo and Sumatra in 1997–1998 led to mass migration of flying foxes to Peninsular Malaysia. Here the bats were feeding on fruits in orchards, and their droppings with the Nipah virus were picked up by pigs that foraged on the floor. The virus was eventually transmitted to humans. This is perhaps a small indication that if we continue with the unabated destruction and degradation of the world's forests, the link between forests and bad things of the earth may become our future inheritance.

FOREST DEGRADATION AND DESTRUCTION—ASIA AND THE PACIFIC

In the same Unasylva issue (ibid.), Aubreville (1947) expresses strong concern about the disappearance of tropical forests (in Africa) and warns of the consequences which ensue such a folly, such as loss of timber wealth, climate change, impoverishment of soil, poverty and so on. Yet he did believe the process can be halted and even reversed. In his view, the salvation will be a gigantic task, and has to be undertaken on an international scale.

Five decades later, despite enormous efforts from national and international agencies, progress remains quite limited, however. A quick glance at the change in the forested land area in the last decade in the Asia Pacific region would convey the view quite trenchantly (Table 1).

Table 1. Change in forested land in the Asia Pacific region (1990–2000) (million ha) (FAO 2001)

Countries	Total land area	Total forest 1990	Total forest 2000	% of land forested in 2000	Change 1990–2000	% change per year
Australia and New Zealand	795.0	164.9	162.5	20.4	–2.4	–0.1
Central Asia	391.6	16.6	19.3	4.9	2.7	1.6
NW Pacific and East Asia	1 147.8	195.2	212.7	18.5	17.4	0.9
South Asia	640.3	86.3	85.3	13.3	–1.0	–0.1
Southeast Asia	434.5	234.7	211.4	48.7	–23.3	–1.0
South Pacific	53.9	36.4	35.1	65.2	–1.2	–0.4
Asia and the Pacific	3 463.2	734.0	726.3	21.0	–7.7	–0.1

The Asia and the Pacific, with more than half the world's population, has only about 20% of the world's forests. The average per capita availability of forest area in the region is only around 0.2 ha, which is very low compared to the world average of 0.65 ha per person (FAO 2001). Within the region, Southeast Asia had the highest deforestation, with a loss of about 2.3 million ha per year. The causes for deforestation and degradation have been well researched: they include population pressure, heavy dependence on fuelwood, timber and other products, along with conversion of forests to agricultural, urban and industrial land. Overgrazing, shifting cultivation and armed conflict have added to the toll. With continued degradation, fires have increasingly become major agents for forest loss in recent times. The Indonesian fires of 1996–97 are stark reminders of what disasters can be wrought with poor management. These are critical issues, as they accelerate loss of biodiversity, threaten ecosystem stability and the continuous flow of forest products, and the depletion of the natural resources underpinning many national economies (UNESCAP & ADB 2000).

NATIONAL AND INTERNATIONAL RESPONSES TO FOREST LOSS

The loss and degradation of forests is well recognized, and most governments have implemented a variety of instruments and programmes to counter the problems and bring about sustainable management. Some countries like Bhutan have mandated that 60% of the country should remain under forest cover. Others have introduced controls on clearance of land outside the conservation and production areas. Yet others have introduced logging bans—some 10 million ha in the region have been thus protected, albeit with mixed results. In many countries, implementation is still inadequate, while in a few cases like Sri Lanka and New Zealand it has been effective with harvesting shifting to alternative sources. Overall, the bans have also resulted in accelerated cuttings in neighboring countries. Countries like Malaysia and Thailand have adopted zero burning policies. Economic instruments have also been employed to conserve forests—China has introduced afforestation fees and licenses to strengthen cultivation, management and protection of forests. Plantations, although a poor substitute for natural forests in terms of biodiversity maintenance, have been stepped up as an alternative source of wood. Now the region has 60% of the world's plantation forests, although it will take a decade or more before they begin producing wood.

REHABILITATION OF FORESTS

Of all the measures, one that can reverse somewhat the process of deforestation and degradation is attempt to rehabilitate them. Research work on forest rehabilitation can be traced back to the very beginning (see Appanah & Weinland 1993). For example, those familiar with Malayan forestry research still recall the work of J.H.M. Robson in 1899 (in Wyatt-Smith 1963). When concern with over-exploitation of *Palaquium gutta* (gutta percha) grew, planting trials of the plants were conducted in forests depauperate of the species (Hill 1900). The work in Burma and India would date further back. The early work was mainly confined to rehabilitating degraded forests, and afforestation of denuded lands and mined areas. The importance of such work was seen to benefit landless communities, either as cash for labour or opportunities for cropping the land in the earlier planting years, e.g. the taungya system, developed in the 1830s in Burma by Brandis (in Champion & Seth 1968). Rehabilitation as a tool for development began thus. In fact, the bulk of the work FAO and other institutions initiated had social objectives primarily. It created employment, additional resources, use of land that otherwise had no agricultural value, and environmental benefits (FAO 1985).

Briefly, the following rehabilitation methods have been employed:

i. Secondary/degraded forests management

Logging using crawler-tractor systems have without exception caused much damage to the young regeneration and pole growth. The regeneration may be extremely depauperate or patchy. Enrichment planting, usually through line planting (Dawkins 1958) of desired species is the usual method to rehabilitate such areas. The success of these plantings has been rather variable (Adjers *et al.* 1995). The main problem is light—usually the canopies close back rapidly, and the small seedlings may be shaded out rapidly, pioneers may outgrow them, and creepers may entwine them. The problem has clearly been overcome—older seedlings, over 1 m in height have been tested, and plantings done in areas that have much more canopy openings. Height growth of 1 m per year has been achieved in Malaysia and Cambodia (unpublished, pers. obsns.). The advantages of rehabilitating secondary forests are the low costs, ensuring the many ecological services and retaining socially important products.

ii. Monocultures

The vast majority of afforestation and reafforestation work used single species, plantation concepts. This included rehabilitating extremely degraded forest sites, lands occupied by hardy weeds, mined lands, and sites that were prone to heavy erosion such as water catchment areas. Besides bringing about environmental benefits, commercial profits were also a consideration. As a result, many fast-growing exotics were used in such plantings.

iii. Multi-species plantations

Monocultures are not always the best options—they lack biodiversity, and the multiple other non-timber forest products which local communities seek. Planting mixtures of species, either upper-storey timber species or mix of species in various canopy levels, and meeting a variety of products, from timber, food, medicines, spices, etc. have been tried out. They are, however, complicated to establish. But properly constructed mixtures can have significant advantages in certain situations (Keenan *et al.* 1995). Mixtures can be less susceptible to disease, and enhance production arising from light and nutritional resources. A number of rehabilitation approaches are being tested out to achieve a semblance of the natural ecosystem. One is to accelerate restoration without consideration for commercial return. Degraded sites are rehabilitated by planting groups of relatively fast-growing species that are considered as ecosystem building blocks (Goosem & Tucker 1995). It only requires one planting, and thereafter depends on the local gene pool to increase species and structural diversity. This would work provided a neighbouring forest site is near enough to act as a seed source. When such a source is absent, a large number of mature phase canopy species can be planted. This would be more costly, however. Another related method includes establishing high-value mixed-species timber plantations in farmland.

Overall, there are several technical approaches available for rehabilitating tropical landscapes. All the approaches offer additional improvements in the ecological integrity of the new forest cover, while meeting the benefits of the communities that depend on them.

FAO'S RECENT INITIATIVES ON FOREST REHABILITATION

In recent years several international institutions have initiated new programmes on forest and land rehabilitation in the Asia Pacific region. They include ITTO's Criteria and Indicators, CIFOR's research on secondary forest, JIRCAS BIOREFOR initiative, Korea Ecological Society's Reforestation Programme, and FAO/FORSPA's own initiatives. Following is a brief outline of the work of FAO/FORSPA initiated in the region over the last few years:

i. Assisted Natural Regeneration Workshop in collaboration with the Department of Environment and Natural Resources, Philippines (2001)—Improved planting techniques, nursery practices, mixed-species plantings, biodiversity conservation, community participation, and economic issues were discussed.
ii. 100-ha Demonstration Plots—FORSPA developed a network of 100-ha demonstration plots in Vietnam, Cambodia, Laos, Papua New Guinea and Sri Lanka. The objective of the plots is to test out the best rehabilitation practices in a permanent site, and carry out the work long enough to demonstrate the success of the various planting designs, and estimate the costs. Establishment and management protocols have been developed, and preparation and treatment methods refined. The national scientists conduct most of the work, and hence technology transfer and future implementation in the countries are guaranteed.
iii. International Conference "Bringing Back the Forests: Policies and Practices for Degraded Lands and Forests" in collaboration with APAFRI (2002)—This current conference has brought together policy makers, researchers, managers and NGOs to review the status of forest rehabilitation in the region, and explore additional approaches, particularly the economic and policy issues needed to support rehabilitation work.
iv. Asia Pacific Forest Rehabilitation Network (APFReN)—FAO/FORSPA initiated this network, and is now managed by a group of researchers of the Forest Research Institute Malaysia. The purpose of the network is to bring about the critical mass of the researchers, and exchange information, ideas, and promote the development of their scientific work.
v. Documentation of the best practices in "Assisted Natural Regeneration Techniques for Southeast Asian Countries"—A team of experts will soon meet in Kuala Lumpur (2002) to produce a user's guidebook on the best practices in assisted natural regeneration suitable for managing Southeast Asian forests.
vi. Report "Rehabilitation of Degraded Forests and Lands in Southeast Asia: the Way Forward."—This work, to be done in collaboration with University of Queensland, will review the work so far undertaken in the region, the silvicultural knowledge, the linkage to alleviating poverty, economics and the policy settings to bring about development in forest and degraded land rehabilitation.

RESTORATION OF FORESTS AND SOCIAL DEVELOPMENT

Perhaps the most important development in restoration work in recent years is the direct link it has with alleviating poverty. There are many initiatives undergoing trials in various countries in the region. They include the Joint Forest Management in India, Food for Forests in China, and Farm Forestry Programme in Vietnam. With all these initiatives, the participatory processes are being refined so the most vulnerable people are brought into the centre-stage in deciding the future management of forest resources. The successes are already apparent both in the improvement of livelihoods of people and the increase in forested area. This is bringing back the original role of forests, which provides a safety net for indigent societies throughout the world. The question remains—how to increase the resources and opportunities for the landless communities. Through restoration work, forestry has been able to channel more income and protection to the rural communities. For one, it can provide labour to undertake such restoration work. With careful rehabilitation work, additional resources, mainly food, medicines and other plant materials directly needed by the communities, can be added into the planting schemes. Further development in the restoration work for benefiting the poor would be tapping funds from carbon credits, Clean Development Mechanisms, biodiversity conservation and payments for ecological services. While the potential is there to reverse the trends, and bring more responsible development to the poor through the above arrangements, it may still require considerable work and political pressure to bring such benefits. Finally, ownership of forest lands and the products of restored lands and forests, a real tricky issue must be tackled in an equitable manner if forestry is ever going to bring about real development for the rural poor. Overall, for a start forest restoration work has begun to bring some improvements for the rural communities, and has been able to recapture the ideals which forestry in the first place was meant for—a resource for the benefit of rural populations.

CONCLUDING REMARKS

It is possible to state that there are several reasonably good approaches already available for rehabilitation of degraded lands and forests in the region. There are several species trials and silvicultural methods well developed to undertake large-scale reforestation in the region. Even farm forestry techniques are now available to complement the progress made in natural forests. Considering many plantations have failed for a number of reasons, rehabilitation of degraded forests is a superior alternative. While the focus in the past was on production of timber, more attention is being given to optimizing ecological services such as watershed protection and biodiversity conservation. However, the pace of reforestation has not kept pace with deforestation. With this in view, I express a few thoughts on the future needs:

i. Research—Research is particularly important, but has never been well thought out. Most research explores the causes and problems with deforestation and degradation, but few offer pragmatic solutions. Researchers are often carried away trying to explain tiny nuances between whether the degradation came from anthropogenic origin or fire or other causes. While the causes are important, especially if they recur, no amount of solutions will work. However, at the end of the day, clear, pragmatic solutions have to be offered if one wishes to see actual development. Researchers need to place more emphasis on solutions if they are going to make any impact. Next, there is a lot of re-research going on—some work that has already yielded excellent results are forgotten, and researchers attempt to redo the whole work at great costs, instead of using the past research as a step forward. One good example is the eradication of lalang (*Imperata*) infested sites. For example, Strugnell (1934) developed very practical methods to eradicate lalang by planting hardy early successional species such as *Vitex pubescens*. Yet very recently, a whole volume was devoted to the subject of rehabilitating *Imperata* grassland with apparently no reference or knowledge of the earlier work (Friday *et al*. 1999). These are indications of problems, and the research community must work to overcome these serious difficulties.

ii. Networking—As indicated earlier, there are many initiatives on forest rehabilitation in the region. But I strongly doubt all the parties meet together, exchange views and ideas, and collaborate on at least a few common issues. This will seriously limit the overall success of each other's programmes, and it is time the various parties find additional mechanisms to work together and build on each others' strengths and successes.

iii. Some future needs—Several authors (this proceedings) have provided their insights into what needs to be immediately done. These can be paraphrased briefly into the following:

- reforestation systems which supply a wider range of goods and services;
- silvicultural systems designed for small-scale farmers (farm forestry);
- means to pay the land-owner for the additional environmental benefits societies receive from forest rehabilitation;
- cheaper finances for rehabilitation by private land-owners
- more robust application of improved enrichment planting techniques to degraded secondary forests;
- better communication of silvicultural knowledge and market information to small growers;
- better policies to facilitate rehabilitation and prevent further deforestation and degradation.

REFERENCES

Adjers, G., Hadengganan, S., Kuusipalo, J., Nuryanto, K. & Vesa, L. 1995. Enrichment planting of dipterocarps in logged-over secondary forests—effect of width, direction and maintenance method of planting line on selected *Shorea* species. *Forest Ecology and Management* 73:259–270.

Appanah, S. & Weinland, G. 1993. *Planting quality timber trees in Peninsular Malaysia—a review*. Malayan Forest Records No. 38, Kuala Lumpur, FRIM, 221 pp.

Aubreville, A.M.A. 1947. The disappearance of the tropical forests of Africa. *Unasylva* 1/1:4–15.

Champion, H.G. & Seth, S.K. 1968. *General silviculture for India*. Government of India.

Dawkins, H.C. 1958. *The management of natural tropical high forest with special reference to Uganda*. Commonwealth Forestry Institute Paper No. 34, Oxford.

FAO. 1985. *Tropical Forestry Action Plan*. Committee on Forest Development in the Tropics. Rome.

FAO. 2001. *Global forest resource assessment 2000*. FAO Forestry Paper 140. Rome.

Friday, K.S., Drilling, M.E. & Garrity, D.P. 1999. *Imperata grassland rehabilitation using agroforestry and assisted natural regeneration*. Bogor, Indonesia. International Centre for Research in Agroforestry, Southeast Asian Regional Research Programme.

Goosem, S. & Tucker, N.I.J. 1995. *Repairing the rainforest: theory and practice of rainforest reestablishment*. Cairns, Queensland, Australia, Wet Tropics Management Authority, 72 pp.

Helpin, K., Young, P.L., Field, H.E. & Mackenzie, J.S. 2000. Isolation of *Hendra* virus from pteropid bats: a natural reservoir of *Hendra* virus. *J. Gen. Virol.* 81(8):1927–1932.

Hill, H.C. 1900. *Report on the present system of forest administration in the Federated Malay States, with suggestions for future management of the forests of those States.* Her Majesty's Indian Forest Service. Selangor, Government Printer.

Keenan, R., Lamb, D. & Sexton, G. 1995. Experience with mixed species rainforest plantings in North Queensland. *Commonwealth Forestry Review* 74:315–321.

Orr, J.B. 1947. One World—one forest. *Unasylva* 1/1:1–3.

Strugnell, E.J. 1934. Lalang and its eradication. *Malayan Forester* 3:186–188.

UNESCAP & ADB 2000. *State of the Environment in Asia and the Pacific 2000*. Economic and Social Commission for Asia and the Pacific, Asian Development Bank, New York, United Nations.

Wyatt-Smith, J. 1963. *Manual of Malayan silviculture for inland forests*. Malayan Forest Records No. 23. Kepong, Forest Research Institute.

SESSION I

3 Is it possible to reforest degraded tropical lands to achieve economic and also biodiversity benefits?

David Lamb*

ABSTRACT

Deforestation has led to a simplification of the world's landscapes. Only some of this deforested land is now being used productively and large areas are available for reforestation. Reforestation can be carried out in a variety of ways. The most common forms of reforestation such as monocultures of fast-growing exotic species often provide only a limited range of benefit but are widely used despite this disadvantage. While such plantations have a role to play they should not be seen as the only option available. Other alternative forms of reforestation involving secondary forests and more complicated plantation designs can potentially provide a wider range of goods, services and functional benefits. The paper briefly reviews some of these alternatives.

INTRODUCTION

The last 100 years have seen a major reduction in global forest cover, especially in the tropics. This has occurred despite efforts to improve the silvicultural and management practices in production forests, to protect forests in national parks and other types of nature reserves and to overcome the rural poverty that is one of the causes of deforestation. These forest losses have helped feed a growing population but they have also led to a simplification of these species-rich and biologically diverse landscapes. These original forests have been replaced by a variety of simple agricultural monocultures such as rice or industrial forest monocultures made up of species such as *Pinus*, *Eucalyptus*, *Acacia* or *Tectona*. Large areas of degraded land have also been created. These are unproductive and are biologically impoverished. The changes have led to the loss of a variety of goods and services once provided by the original forests. They have also left many people still in a state of poverty.

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The question is—what should be done about this? The most common response until now has been to try and slow the loss of further forest lands and to use the lands already cleared for agriculture or plantation forestry. In most cases land managers have also sought to maximize the productivity of these by whatever means available. In the case of forest plantations, the most common approach has been to use fast-growing exotic tree species. This approach has achieved some notable successes and some large areas have been reforested to produce industrial timbers. On the other hand, it has done little to overcome the loss of the previously supplied variety of goods and ecological services. Can we do better?

OPTIONS FOR OVERCOMING FOREST DEGRADATION

There are, in fact, several other possible alternatives. One is to try to restore the original forest by re-establishing the previous plant and animal communities once present on these sites. This approach, referred to as *ecological restoration*, results in the return of the original biodiversity and the original productivity of the site. The task is difficult and some have expressed doubt whether true restoration is ever possible. However, promising examples of ecological restoration are now being reported from several tropical areas (Goosem & Tucker 1995, Dobson *et al*. 1997, Parrotta & Knowles 1999, Elliott *et al*. 2000). Another approach is to undertake forest *rehabilitation*. This means seeking to restore the original productivity and some, but not all, of the original biodiversity. In this case a trade-off is made between optimising productivity and optimising biodiversity. Again some interesting examples are being reported (Kelty 1992, Wormald 1992, Montagnini *et al*. 1995, Lamb 1998). The three approaches (i.e. reforestation with exotic monocultures, rehabilitation and ecological restoration) are summarised in Table 1.

Table 1. Definition of terms describing ways of overcoming forest degradation at a site level

Reclamation

To recover productivity (but little of the original biodiversity) at a degraded site. (In time the protective function and many of the original species may be able to recolonize if natural forests are not too distant.) Reclamation is often done with exotic species grown in plantation monocultures but may also involve monocultures of native species. In some highly degraded sites the only way of overcoming degradation may be by using exotic species because natives can no longer tolerate the new site conditions.

Rehabilitation

To re-establish the productivity and some, but not necessarily all, of the plant and animal species thought to be originally present at a site. For ecological or economic reasons the new forest may include species not originally present at the site. In time, the protective function and many of the ecological services of the original forest may be re-established. Rehabilitation can be carried out using mixed species plantations, plantation monocultures with diverse understoreys or by managing secondary or regrowth forests.

Ecological Restoration

To re-establish the presumed structure, productivity and species diversity of the forest originally present at a site. In time, the ecological processes and functions of the restored forest will match those of the original forest. This is most likely to be achieved in most tropical forests using secondary or regrowth forests with or without enrichment.

These three ecological alternatives can be matched with a conceptual model of the trade-offs between the ecosystem integrity of the reforested ecosystem and the human well-being reforestation promotes (Figure 1). *Ecosystem integrity* is an expression including both the degree of ecological authenticity achieved by the reforestation method used and the extent to which this reforestation provides environmental benefits or improves ecological functioning. Ecological restoration would obviously provide a greater degree of ecosystem integrity than would a monoculture of an exotic species. *Human well-being* is a measure of the ecological services or environmental benefits received from reforestation (e.g. watershed protection, the establishment of food or medicinal plants) and the social and economic improvements to rural communities following reforestation.

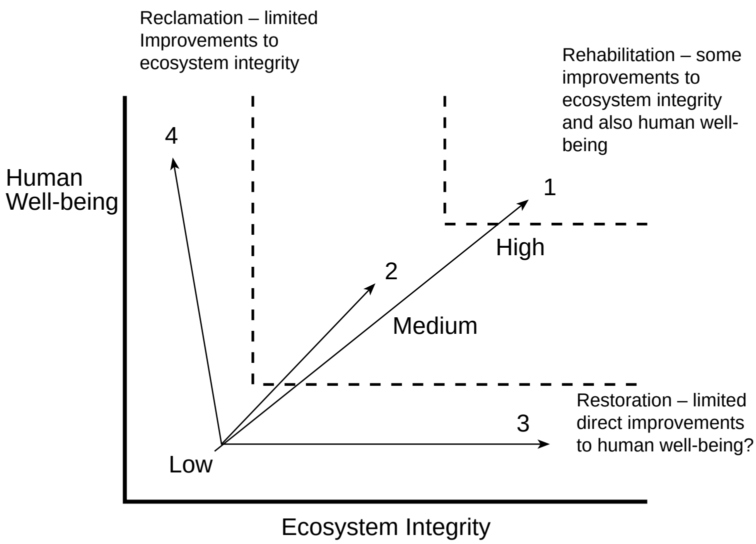

Figure 1. Trade-offs in reforestation

The best form of reforestation, therefore, would be that which improved both ecological integrity of a degraded site and which also increased the human well-being of people living in or around the area. Reforestation in the form of ecological restoration would certainly improve the ecological authenticity of a previously degraded site but may do little to improve human well-being, at least in the short term. This could result in the clearing of such reforestation by people living in the area. Reforestation in the form of industrial monoculture plantations of exotic species might not sufficiently improve the ecological services needed to help local people let alone directly improve their social or economic circumstances (with the benefits going primarily to the companies and their shareholders). Again the outcome would be sub-optimal. These trade-offs are illustrated in Figure 1.

This means we need some new options for dealing with degraded lands beyond simply improving the production of cellulose or timber. These new forms of reforestation need to be commercially attractive, to provide economic and social benefits for rural communities and be able to re-establish the key ecological functions of the original forest such as watershed protection, nutrient cycles, biodiversity protection, etc. Plantations of fast-growing exotic species will still have a place in some circumstances but these should not be seen as the only option available.

REHABILITATION METHODS

There are a variety of ways degraded forests might be rehabilitated to enhance both ecological authenticity and human well-being. Four key approaches are outlined below.

(a) Secondary forests management

Large areas of secondary forests are now common in many tropical countries (Finegan 1992, Chokkalingam *et al*. 2001). These have originated in a variety of ways but most commonly develop after intensive logging has created large canopy gaps or as regrowth following some form of agricultural clearing once these agricultural sites are abandoned. Until comparatively recently most forest management agencies have regarded these as being commercially worthless. By contrast, many rural communities living in or near these forests have recogniZed that many can have considerable value and have harvested a variety of resources from them including foods, medicines and building materials.

There are two options open to managers. One is to simply protect these forests from further significant disturbances (intensive logging, agricultural clearing, fire) and allow natural successional processes to re-establish the former forest structure. This may mean reaching some agreement with local people using the forest for subsistence purposes to constrain the degree to which they disturb this regeneration and succesional development. The other option is to seek to enrich the forest with commercially or socially valuable species. This might be done as line plantings or as clump plantings in areas where sufficient canopy openings are present. Past experiences with enrichment plantings have been varied (Adjers *et al*. 1995, Tuomela *et al*. 1995, Bebber *et al*. 2002). The responses have been promising in situations where care has been taken to use good planting stock and where weeds and overstorey cover have been controlled. In other situations, particularly where canopy cover is too great, many of the planted seedlings stagnate or are overcome by weed competition and the approach has failed (e.g. Ramos & Delamo 1992) . Methodologies need to be developed for the specific conditions present at each site. Enrichment may be especially difficult in old regrowth forests where a canopy of pioneers is well established.

The advantage of using existing secondary forest is that the cost of retaining these and developing ways of managing them is likely to be much lower than clearing and replanting the site. Their retention also ensures many ecological services and socially important products are retained. The primary disadvantage is that the yields of commercially valuable products are often low (though yields of socially useful and domestic products may be high) and that the methods for enhancing the site productivity (e.g. by enrichment planting) can be difficult.

(b) Monocultures

Monocultures are attractive because trees of a commercially valuable species are planted at a high density. Fast-growing species have mostly been favoured in the past because the volume increments of these are greater and, consequently, they have shorter rotations. Besides, any tree cover, including that provided by exotic species, usually provides some ecological benefits (e.g. protecting soil erosion). But the commercial value of many of these fast-growing exotic species is now being questioned and the potential gains from using slower-growing but higher-value native species are looking rather more attractive. These changes are being prompted by the large areas of exotic plantations now established and because of the reduced areas of natural forest now left for commercial logging. Besides commonly having a higher market value, native species often provide some additional ecological benefits by being better adapted to local conditions and being more attractive to local wildlife. (On the other hand, they are also more prone to damage from their traditional pests and diseases than exotic species that may now have been separated from many of these.)

The ecological benefits of monocultures can be enhanced in two ways. One is to use buffer strips of natural vegetation, regrowth or ecologically restored vegetation along streams and rivers to protect these from any erosion. Similar buffer strips can be also used to separate compartments of the plantation and acts as firebreaks. That is, the extensive monoculture is broken into compartments embedded in a framework of buffers.

The other way ecological benefits might be enhanced is to use a mosaic of monocultures. That is, native species might be planted at particular sites depending on their site preferences. These, too, might be embedded in a matrix of buffer strips. Both approaches can add considerable structural complexity to the landscape and help the retention of many native plants and animals as well as facilitate their movement across the landscape (Lamb 1998).

These approaches might be more useful where large areas of cleared land are present. The advantage of these approaches is that the plantations can provide high timber yield per hectare (cf. the regrowth forests). High-value species can be used and the buffers help with watershed protection and biodiversity conservation. The main disadvantage of using native species is that the silviculture of most of these is comparatively poorly understood. Raising large numbers of most species in nurseries is difficult. Developing ways of establishing these in the field can also be problematic although promising results are now being obtained from quite different regions suggesting many of these difficulties will be overcome in time.

(c) Monocultures with understoreys

The main disadvantage of monocultures is their lack of biological diversity. This may not matter if industrial timber production is the sole objective but it may be a disadvantage if the local communities living in the surrounding areas need or expect to obtain resources such as foods and medicines or other ecological services from these new forests. In fact, many monoculture plantations acquire an understorey of other plant species over time as a result of colonisation by species from nearby intact native forests (Keenan *et al.* 1997). The extent to which this takes place depends very much on the distance to these forests and on the presence of wildlife such as birds and bats able to cross the landscape and disperse seeds. Such understoreys can also be deliberately planted (i.e. using the original plantation as a nurse crop).

The extent and diversity of these new understoreys can be large and many can contain a large variety of plant species. Over time many of these new colonists can grow up and join the forest canopy. One the one hand, this means the silvicultural opportunities increase because of the greater variety of tree species present. On the other hand, the increased tree density means that the growth of individual trees will slow unless some thinning takes place. A variety of options are available depending on the ecological, economic and social circumstances prevailing. These range from removing the new understorey to concentrate solely on the original plantation species, abandoning the plantation as a source of future timber and concentrating management on the fostering of the biodiversity values it now contains or perhaps managing the new, uneven-aged, multi-species forest as a selection forest. Some of these options are reviewed further in Keenan *et al.* (1997).

Fostering and managing understoreys as a means of increasing the value of plantations can improve the social value of plantation monocultures. These understoreys may also enhance the extent of watershed protection provided by the plantations. The primary disadvantage is they may necessitate a revision of the plantation management objectives from being simply to maximise timber production to trying to achieve something else. But this dilemma may be more common than is frquently supposed. Tree plantations are long lived and many social and economic situations can change during the time of a rotation, especially in plantations located near towns or cities. This means the opportunities to change may sometimes be a benefit rather than a problem.

(d) Multi-species plantations

Monoculture plantations offer very little in the way of biological diversity (although this may change over time as discussed above). In some situations there may be advantages in establishing mixtures of species rather than monocultures (Lamb 1998). These mixtures can have significant advantages over monocultures under certain circumstances (Montagnini *et al.* 1995) (Table 2). This may be because of enhanced production arising from improved use of the sites' above- or below-ground resources. Thus the mixture has a higher productivity than monocultures of its constituent species. Alternatively, the mixture may be less susceptible to pests or diseases because of microclimate changes or because the target trees are hidden in space (Keenan *et al.* 1995, Wazihuuah *et al.* 1996). Increased productivity may also arise from improved nutrition resulting from the use of a nitrogen fixing tree (de Bell *et al.* 1989, Binkley 1992). Or, finally, the mixture may be more financially secure because early maturing species can be harvested comparatively quickly and so provide a quicker financial return. The mixture can also act as an insurance policy at a time when it is difficult to estimate the market worth of species some time in the future.

Table 2. Mechanisms by which a plantation mixture might yield a greater benefit than plantation monocultures of the same species

Potential benefit	Mechanism
Reduced between-tree competition leading to increased productivity	From: • phenological separation in time • root separation in space (depth) • foliar separation in space (canopy architectural differences)
Reduced insect and pest damage leading to increased productivity	From: • microenvironment changes resulting from underplanting (e.g. red cedar) • target species being "hidden" in space or too distant for disease transfer
Improved nutrition—especially at degraded sites with infertile soils—leading to increased productivity	From: • inclusion of nitrogen fixing species in mixtures • faster litter decay and improved nutrient turnover
Improved financial returns	Early harvest of fast-growing and easily marketed species leaving slower-growing but more valuable species to develop over time. This harvest also acts as a thinning allowing improved growth of residual trees

The main problem with mixtures is that they are much more complicated to establish and manage. A variety of mixed species designs are available including permanent and temporary mixtures (i.e. temporal changes) as well as line plantings and random assemblages (i.e. spatial changes). But *ad hoc* plantings or assemblages are unlikely to work. Care needs to be taken to identify and match complementary species to ensure the theoretical advantages of mixtures are achieved in practice. This means that foresters have been reluctant to embark on large-scale mixed species plantings in the past because this knowledge is rarely available. However, evidence is beginning to develop from different regions suggesting that properly constructed mixtures can have significant advantages in particular circumstances (Keenan *et al*. 1995, Montagnini *et al*. 1995, Zhou *et al*. 2002).

In summary, there are a variety of approaches that might be used in tropical landscapes to overcome degradation. All require knowledge of the ecology and silviculture of native species, all require knowledge of the site preferences of these species and all require acceptance that native species may be rather slower growing, at least initially, than many well-known exotic species. On the other hand, all these approaches offer improvements in the ecological integrity of the new forest cover and in the benefits to human well-being that this reforest effort will provide.

THE SIGNIFICANCE OF SCALE

The forms of reforestation discussed above are necessarily concerned with changes at a site level. Many functional benefits (e.g. to biodiversity, to watershed protection) are only achieved when larger areas of landscape are reforested. The degree of ecological change can be measured at both scales. Thus diversity at a local scale is referred to as alpha diversity and is usually taken to mean the numbers of species present at a particular site. The gamma diversity, on the other hand, is the collective diversity of all species across a landscape. The beta diversity is the rate of change across the landscape in gamma diversity. Hence,

$$\text{Gamma diversity} = \text{alpha diversity} \times \text{beta diversity}$$

This means biological diversity might be achieved via complex mixtures across the whole landscape or, alterntively, by a mosaic of different monocultures (i.e. each monoculture has a low alpha diversity but, collectively, they generate a high landscape or gamma diversity).

The interesting question is—which approach yields the optimum functional outcome? Ecologists have not yet explored this question in sufficient detail to answer it with any confidence. Some things are reasonably clear. Most wildlife biodiversity is probably best conserved by reforestation that involves high numbers of plant species (i.e. using secondary forest, using mixed species plantations). These sites then have high levels of alpha diversity. Such sites are also probably better able to protect watersheds, sequester carbon and restore soil fertility lost during the degradation process. On the other hand, landscapes with high levels of gamma diversity may be equally suited for many wildlife species and equally effective at stabilizing hillsides or overcoming salinity problems. And such diversity may be much easier to establish (via mosaics of monocultures) than that involving mixed-species plantations. This topic is clearly one deserving much more attention in future.

CONCLUSION

The scale of the losses in tropical forest cover are now so great that new forms of reforestation must be found to provide more than just timber production. Without these new forms of reforestation the most biological diverse regions of the world will have been converted to impoverished and simplified landscapes unable to supply the diverse range of goods and services once supplied by the original forests. There is increasing evidence that this extensive loss of forest cover is likely to reduce the sustainability of much of the newly created agricultural landscapes (Hobbs & Morton 1999, Lefroy *et al*. 1999). This will leave the many people now living in poverty in even more desperate circumstances. What is needed, therefore, are ways of reforesting degraded lands that provide human benefits as well as biodiversity and functional improvements.

There are, in fact, a number of promising possibilities. No single alternative can be prescribed because each landscape has a different ecological and social situation. This means that the final outcome in any landscape will probably contain a number of alternative approaches to overcoming degradation including monocultures of exotic species as well as various versions of forest rehabilitation using some of the approaches outlined above and, in some particular situations, ecologically restored forests. The task for forest managers will then be to ensure that these options are combined in such a way as to maximize the overall ecosystem integrity across the landscape while also maximizing an improvement in human well-being.

REFERENCES

Adjers, G., Hadengganan, S., Kuusipalo, J., Nuryanto, K. & Vesa, L. 1995. Enrichment planting of dipterocarps in logged-over secondary forests—effect of width, direction and maintenance method of planting line on selected *Shorea* species. *Forest Ecology and Management* 73: 259–270.

Bebber, D., Brown, N., Speight, M., Moura-Costa, P. & Wai, Y.S. 2002. Spatial structure of light and dipterocarp seedling growth in a tropical secondary forest. *Forest Ecology and Management* 157: 65–75.

Binkley, D. 1992. Mixtures of nitrogen fixing and non-nitrogen fixing tree species. *In* M.G.R. Cannell, D.C. Malcolm, & P.A. Robertson, eds. *The ecology of mixed species stands of trees*, pp. 99–123. Blackwell Scientific.

Chokkalingam, U., Bhat, D.M. & von Gemmingen, G. 2001. Secondary forests associated with the rehabilitation of degraded lands in tropical Asia: a synthesis. *Journal of Tropical Forest Science* 13: 816–831.

De Bell, D.S., Whitesell, C.D. & Schubert, T.S. 1989. Using N^2 fixing *Albizia* to increase growth of *Eucalyptus* plantations in Hawaii. *Forest Science* 35: 64–75.

Dobson, A., Bradshaw, A. & Baker, A. 1997. Hopes for the future: restoration ecology and conservation biology. *Science* 277: 515–522.

Elliott, S., Kirby, J., Blakesley, D., Hardwick, K., Woods, K. & Anusarnsunthorn, V. (eds.) 2000. *Forest restoration for wildlife conservation*. Proceedings of a Workshop, January 30–February 4, 2000, Forest Restoration Research Unit, University of Chiang Mai, Thailand.

Finegan, B. 1992. The management potential of neotropical secondary lowland rainforest. *Forest Ecology and Management* 47: 295–321.

Goosem, S. & Tucker, N. 1995. *Repairing the rainforest: theory and practice of rainforest re-establishment in North Queensland's wet tropics*. Cairns, Australia, Wet Tropics Management Authority.

Hobbs, R.J. & Morton, S.R. 1999. Moving from descriptive to predictive ecology. *Agroforestry Systems* 45: 43–55.

Keenan, R., Lamb, D. & Sexton, G. 1995. Experience with mixed species rainforest plantings in North Queensland. *Commonwealth Forestry Review* 74: 315–321.

Keenan, R., Lamb, D., Woldring, O., Irvine, A. & Jensen, R. 1997. Restoration of plant diversity beneath tropical tree plantations in northern Australia. *Forest Ecology and Management* 99: 117–132.

Kelty, M.J. 1992. Comparative productivity of monocultures and mixed species stands. *In* M.J. Kelty, B.C. Larson, & C.D. Oliver, eds. *The ecology and silviculture of mixed species forests*, pp. 125–141. Dordrecht, Kluwer Academic Publishers.

Lamb, D. 1998. Large-scale ecological restoration of degraded tropical forest land: the potential role of timber plantations. *Restoration Ecology* 6: 271–279.

Lefroy, E.C., Hobbs, R., O'Connor, M.H. & Pate, J.S. 1999. What can agriculture learn from natural systems? *Agroforestry Systems* 45: 423–436.

Montagnini, F., Gonzalez, E., Porras, C. & Rheingans, R. 1995. Mixed and pure forest plantations in the humid neotropics: a comparison of early growth, pest damage and establishment costs. *Commonwealth Forestry Review* 74: 306–314.

Parrotta, J. & Knowles, H. 1999. Restoration of tropical moist forests on bauxite mined lands in the Brazillian Amazon. *Restoration Ecology* 7: 103–116.

Ramos, J. & Delamo, S. 1992. Enrichment planting in a tropical secondary forest in Veracruz, Mexico. *Forest Ecology and Management* 54: 289–304.

Tuomela, K., Kuusipalo, J., Vesa, L., Nuryanto, K., Sagala, A. & Adjers, G. 1995. Growth of dipterocarp seedlings in artificial gaps: an experiment in logged-over rainforest in South Kalimantan, Indonesia. *Forest Ecology and Management* 81: 95–100.

Wazihuuah, A.K.M., Islam, S.S., Rahman, F. & Das, S. 1996. Reduced attack of keora (*Sonneratia apetala*) by stem borer in mixed species plantations in Bangladesh. *Journal of Tropical Forest Science* 8: 476–48.

Wormald, T.J. 1992. *Mixed and pure forest plantations in the tropics and sub-tropics*. Rome, FAO.

Zhou, G.Y., Morris, J.D., Yan, J.H., Yu, Z.Y. & Peng, S.L. 2002. Hydrological impacts of reafforestation with eucalypts and indigenous species: a case study in southern China. *Forest Ecology and Management* 167: 209–222.

4 Bringing back the forests: by whom and for whom?

Stephanie Mansourian*, Geoffrey Davison** and Jeff Sayer***

ABSTRACT

WWF is moving beyond a purely site-based approach to conservation and is designing and managing its programmes at the landscape and regional levels. Forest Landscape Restoration (FLR) is an approach that considers the social, economic and environmental context and implications of forest loss and restoration. Partnerships are being developed between stakeholders, so as to operate across political and administrative boundaries. Our target is to not just restore forest cover but to ensure that the full range of forest goods and services are produced. An example is given of the Lower Kinabatangan River in Sabah, Malaysia, where WWF has been working together with government agencies, the private sector and local communities. The basis for this work is a project known as Partners for Wetlands, which has produced a vision for the area, now adopted by the government. Under this vision, the re-establishment of a forest corridor is intended to bring economic benefits to land-owners and communities. Model projects will demonstrate good practices, and if successful they should be scaled up by stakeholders who are not traditionally regarded as conservation actors.

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WHY BRING BACK THE FOREST?

Depending on who you are and where you live, the answer to the question “why bring back the forest?” will be very different. For some, restoring forests will be important for aesthetic reasons, while for others it will be a question of survival: forests provide them, for instance, with raw materials which they use to turn into goods they can sell. For others forests provide food and wood or medicine. In Tanzania, for example, it is estimated that over 70% of people obtain their medication from plants sourced from forests. For others still, forests will have some sacred value, or offer recreational opportunities. Forests are also home to over 50% of terrestrial plant and animal species. The genetic resources available for foods, medicines and adaptation to climate change, for instance, are vastly underestimated. In the dry forests of New Caledonia, as just one example, a species of wild rice, *Oryza neocaledonica*, may have genes that could improve domestic rice production worldwide.

Forests can also contribute to health. Ecuador’s *Epipedobates tricolor* (a frog) was discovered by medical researchers to produce chemicals that possess strong pain-killing effects. Or take a contrary example from Japan (WRM 2002) where pollen from fast growing conifers is affecting one out of six Japanese with hay fever. Twenty percent of Tokyo’s population now suffer from pollen allergies, as compared to 7% ten years ago. This can be traced back to the 10 million hectares of a single species of the conifer *Cryptomeria* that has been planted around the city.

In many cases, forests provide a safety net from which people can extract sufficient resources to ensure their livelihoods particularly during periods of famine, civil conflict, etc.

Despite their value to humanity, forests are under threat and half the world’s original tropical forests have been lost. Forest areas in most temperate countries are now stable, or even increasing. However, this often masks a loss in the quality of the forests, with diverse natural forests being replaced with plantations of a single species. In the last 50 years, deforestation and forest degradation have occurred at an unprecedented rate in the tropics. Recent estimates by the United Nations Food and Agriculture Organization put the annual natural forest loss at 14.6 million hectares, an area the size of Nepal. Sometimes the cleared forests are replaced by agriculture or tree crops, but often the forest soils are too poor to sustain crops and the result is degraded lands with little value for biodiversity conservation or economic development. The factors leading to forest loss and degradation are multiple and complex. They include misguided policies of governments and international agencies, illegal logging, fires, and lack of secure tenure for local communities. Forests are often seen by national governments as a reservoir of unoccupied and unproductive land. This attitude underestimates the market and non-market values of forests for both local communities and the world. It leads to ill-advised policies that encourage forest clearance. A few benefit from these policies; many suffer from them.

NEXUS BETWEEN CONSERVATION AND DEVELOPMENT

The World Bank has estimated that “forest resources directly contribute to the livelihoods of 90 percent of the 1.2 billion people living in extreme poverty and indirectly support the natural environment that nourishes agriculture and the food supplies of nearly half the population of the developing world.” The goods and services that forests provide include safe drinking water, supplies of water for agriculture, protection of soils, a wide range of raw materials, medicines, etc. Forest degradation leads notably to soil erosion and loss of arable land. According to Duraiappah (1996) an estimated 0.3 to 0.5 percent (5–7 million hectares) of the total world arable land is lost annually to land degradation.

Increasingly in a world facing massive social tragedies (from famines to diseases to dire poverty), attention is focussed on providing relief and a way out of such desperate situations. Forestry does not traditionally come to mind as such a solution. More immediate palliative solutions are usually sought. But short-term relief only addresses the symptoms of the problem. Long-term solutions must include restoring the natural resource base upon which people can build better livelihoods. Restoration can ensure that people have a healthy environment that can provide for their immediate needs and at the same time be sufficiently resilient to buffer them against future shocks.

"A study of 1 800 farm plots in 3 Central American countries hit by hurricane Mitch demonstrated that farms using "agro-ecological" methods to prevent soil and water runoff from hillsides lost far less topsoil, retained more moisture and were much less vulnerable to surface erosion than plots farmed using more conventional methods" (IFRC 2002).

Globally, the loss of forest cover is serious enough, but it is additionally compounded with a loss in forest quality. Degradation is much more difficult to measure, but the ITTO estimates that the total area of degraded and secondary forests is about 850 million hectares, corresponding to roughly 60% of the total area that is statistically classified as forests in the tropics. While it can be argued that deforestation itself is not a problem since it is in many cases a necessary pre-requisite to some form of economic development, the rate, type, location and the conditions under which it occurs are critical issues for biodiversity and human needs.

Restoration to an original or near original state is in most cases an unrealistic objective. Over time both the environmental context and the needs of people will have changed. Restoration to some hypothetical pre-intervention state may be neither realistic nor desirable. People have modified the landscape in ways that suit their immediate needs and reversing this trend is socially and economically problematic. Investments to restore a severely degraded forest are often not justified unless the pressures that have led to the degradation are removed.

WWF and IUCN are promoting the concept of Forest Landscape Restoration[1] (FLR) under their joint forest strategy. FLR seeks to restore the functions that forests provide within the landscape. It considers the landscape scale in order to have the "room" to balance and negotiate trade-offs between different land uses (and users) across the landscape. This would not be possible at a site level where one land use dominates. Thus, FLR provides a natural link between conservation and development. It is a way of restoring the goods and services that forested landscapes provide to both people and biodiversity.

The key elements of Forest Landscape Restoration are that it:

- is implemented at a landscape scale rather than a single site;
- has both a socio-economic and an ecological dimension;

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[1] The definition agreed by a group of people with diverse backgrounds and representing many different institutions and regions at a workshop in Segovia (Spain, in July 2000) is: *"A planned process that aims to regain ecological integrity and enhance human well-being in deforested or degraded landscapes."*

- implies addressing the root causes of degradation and poor forest quality (such as perverse incentives and inequitable land tenure);
- opts for a package of solutions, which may include practical techniques—such as agroforestry, enrichment planting and natural regenerations at a landscape scale—but also embraces policy analysis, training and research;
- involves a range of stakeholders in planning and decision-making to achieve a solution that is acceptable and therefore sustainable;
- involves identifying and negotiating trade-offs.

Forest Landscape Restoration focuses on re-establishing functions and key ecosystem processes at a large enough scale for this to be meaningful. Its aim is to recover close to the full range of functions provided by forests in the landscape (species habitats, hydrological cycles, soil protection, non-timber forest products, timber, etc.). FLR goes beyond establishing forest cover *per se*. Its aim is to achieve a landscape containing valuable forests, for instance partly to provide timber, partly mixed with subsistence crops to raise the yields and protect the soils, as well as partly improving biodiversity habitat and increasing the availability of raw materials and medicines. By balancing these within a landscape, it is possible to enhance the overall benefits to people and biodiversity at that scale. The functions of the overall landscape are more important than the functions of individual sites; the whole is greater than the sum of the parts. Thus a small protected area may not be viable in isolation but if nearby plantations are species rich or appropriate trees are planted in adjoining agricultural lands the biodiversity of the area may survive. Similarly, within a landscape, setting aside an area for production forestry might be relieving pressure on remaining natural forest and provide an opportunity for restoring these by enhancing connectivity. By looking at a larger scale, one can begin to identify the critical functions that need restoring and thus identify the right package of interventions. These will vary based on needs identified by key stakeholders and by resulting negotiations.

In 2001, the WWF network, with over 300 forest programmes/projects in over 70 countries, decided to adopt a target on Forest Landscape Restoration (FLR). This target is intended to act as a catalyst for FLR. It reflects the fact that the issues related to FLR are complex, apply at various scales and are multi-disciplinary. Therefore, the aim is to contribute to and promote 20 good examples, learn from them and disseminate these experiences and lessons widely. To achieve FLR it is important to bring in various partners, to look at issues from the international to the local level, to think long term and to remain flexible and adaptive. For this reason WWF's target reflects the recognition that each FLR initiative or programme will contribute to the overall knowledge base on FLR.

> WWF's FLR target is:
>
> *"By 2005, undertake at least 20 Forest Landscape Restoration initiatives in the world's most threatened, degraded or de-forested regions"*

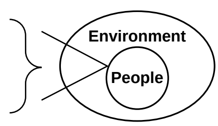
Multi-layered actions

In practical terms, a range of different interventions will be needed at many levels for FLR to become a reality. Once the agreed long-term vision for the landscape is established a series of tangible activities can be identified. These will range from ensuring the "environment" is right (i.e. institutions and economic incentives are appropriate, market pressures are addressed, etc.) to on the ground activities, such as fencing, tree planting, etc. At the international level, pressures on forests will still have to be addressed. Unless the root causes of forest degradation/loss are addressed, any intervention effort will be undermined. The policy and institutional framework at the national level are also essential to provide the right context for FLR and will sometimes have to be altered—for instance unsustainable incentives promoting large scale industrial plantations. The legislative (e.g. land tenure) framework might need addressing in some cases. At the landscape level, negotiations with key stakeholders will have to take place to identify the different goods, services and processes that are important and that need to be restored. Trade-offs will inevitably have to be addressed, as different stakeholders will have different needs. Stakeholders that need to be taken into account include future generations. Maintaining options for future generations and restoring key ecosystem functions in order to minimise risks for the future are important considerations in FLR. Finally, at the local level, a range of direct interventions will have to take place, based on the agreed priorities for the landscape.

Engaging stakeholders and partners

Traditional experiences in restoration, or indeed in any complex integrated development and/or conservation programme, have shown that no single actor can achieve ambitious goals.

Major actors in restoration include:
- government
- civil society and local communities
- the private sector
- society more broadly (including future generations)



Recognizing the need to mobilise different partners in support of conservation, The World Summit on Sustainable Development triggered the development of over 250 partnerships announced in Johannesburg in August.

FLR is a people-centred approach. It recognizes that achieving restoration needs for biodiversity requires engaging local populations and addressing their needs. This can be done through promoting a multi-functional landscape that reflects a diverse range of land uses with forest goods and services prominently recognized, restored and valued.

Previous involvement of local communities has often been confined to informing them of a programme. This is not sufficient. Active involvement throughout the process is needed to ensure success. The private sector also needs to be involved. With many private companies valued at more than some countries' entire output, there are strong reasons for engaging the private sector in restoration. And there are economic reasons for restoring forest functions. These range from ensuring a sustainable stream of specific marketable goods to responding to discerning consumers' concerns about sourcing of products. Increasingly, the private sector is becoming an active player in conservation as it faces more pressure from customers for more accountability in business practices.

Finally, the public sector needs to be engaged in any sustainable restoration initiative to ensure that the right supportive legislation and institutions are in place. Nonetheless this is not easy. It requires the ability to speak the same language as the private sector, as well as that of communities and of governments. These require different skills and often this is the stumbling block of many organisations that are specialised in one component. WWF suffers from the same problem. Nonetheless, over the years, one of WWF's strengths is to have developed key partnerships with different institutions. For instance in 1998, WWF engaged with the World Bank in an Alliance on the Conservation of Forests. While this has focussed exclusively on PAs and SFM, there has been some discussion on both sides to develop a third leg to this partnership, specifically on FLR.

Equally, in 1999 WWF engaged with the largest aggregates company, Lafarge, in a "Conservation Partnership" that is focussed partly on restoration but also on climate change and toxics. These two examples are global initiatives. At the regional/national level many other examples exist. One of these is discussed in more detail below.

FLR is an iterative process, and a feedback loop with a proper monitoring system in place is an essential pre-requisite.

KINABATANGAN (MALAYSIA): AN EXAMPLE OF AN INTEGRATED FLR PROGRAMME ENGAGING VARIOUS PARTNERS

Importance of the area

The Kinabatangan is the longest river in Sabah (560 km), N.E. Borneo, and the second longest in Malaysia, with a catchment area of 16 800 km^2. The catchment is approximately 60% forested, but less than 10% of the forest cover is in its pristine state. The river supplies water for 200 000 to 300 000 people, mostly through treated and piped supply to the town of Sandakan. The lower, mature phase river meanders over a floodplain of about 60 000 ha, within a lower catchment sector of about 300 000 ha. Within this floodplain, there are at least seven distinct vegetation types, including peat swamp forest, freshwater swamp forest, mangroves, forest over limestone, riparian forest on the river levees, and the aquatic plants of the various oxbow lakes.

The river floodplain is currently the focus of very active conservation efforts to preserve a riparian corridor that provides critical habitat for Asian elephants (*Elephus maximus*), orang-utans (*Pongo pygmaeus*), Sumatran rhinoceros (*Dicerorhinus sumatrensis*), proboscis monkeys (*Nasalis larvatus*), and a number of other focal species. Eight of Malaysia's threatened birds are found in the area, including Storm's stork (*Cicona stormi*) and a number of hornbills. The area is naturally diverse and intact enough to maintain species that have become rare in many other areas of Sabah.

Some 50 mammal species (including 10 primates) and approximately 200 bird species have been recorded in the area. Among these are several charismatic and keystone species. The forests of the lower Kinabatangan contain the largest concentration of orang-utans in Sabah and therefore one of the more important populations in the world.

Key environmental processes are associated with the river and its flooding. Inundation of the floodplain is a natural and, currently, a nearly annual event. This may or may not reflect prehistoric conditions on the river. Nevertheless, annual flooding is now the circumstance, with at least some areas submerged for between 2 and 32 days (Sooryanarayama 1995).

Current situation

The river has always been an exceptional resource for wildlife, but many species that are now restricted to the riparian corridor would normally have ranged much more widely when the area was contiguous forest. Land-use conversion, most recently and drastically for oil palm plantations, has reduced natural forest cover to a relatively narrow (or even nonexistent) strip. These plantations now form the matrix of the lower Kinabatangan water catchment. Currently, a relatively thin strip of forest borders the river, 27 000 ha of which have been gazetted as the Kinabatangan Wildlife Sanctuary thanks to the efforts of various bodies including the Sabah Wildlife Department. There are several gaps in the riparian buffer that will be a real challenge to connect with forest, including a village/ highway that crosses the river. These gaps are critical to close if the river is to remain an intact corridor for wildlife populations, especially elephants. This has encouraged the involvement of WWF through its Partners for Wetlands Programme as well as the Forests Reborn Programme, with financial inputs for forest landscape restoration.

The river's hydrology is naturally dynamic, and will further change because development many kilometres away in the upper watershed of the Kinabatangan is ongoing. This development has and will continue to alter the flood regime of the river, resulting in higher and more frequent peak flows. Indications are that flooding has indeed been occurring more frequently. Certain oil palm plantation owners have attempted to build levees based on previous flood events. This would not only exacerbate flooding downstream but could retard drainage when floods do eventually occur.

Unfortunately, elephants are also driven to higher ground by the floods, and conflicts between the elephants and the local populace increase temporarily at times of high water. This is a focus of efforts by Partners for Wetlands, AREAS, and other non-governmental organizations.

What is the problem?

- **loss of forest** –> conversion to oil palm plantations within flood-prone areas;
- **loss of habitat** –> many species restricted to the riparian corridor and under threat;
- **threatened habitat** –> several gaps in the riparian buffer.

Who are the stakeholders?

- Industry bodies such as the Malaysian Palm Oil Association.
- Government (local, state and national).
- Oil palm companies—Oil palm has been grown in the area since approximately the 1970s, but the swiftest expansion of estates in the vicinity was in the period 1985–1990. Oil palms require only three years after planting to become productive, reach peak productivity around year 15, and are productive for approximately 25 years before replanting.
- Buyers of oil palm on the international market—The oil is used in the production of margarine, soap, livestock feed, lubricants, and many other industrial and household products.
- Local communities—Orang Sungai the local river people—have depended on the river ecosystem for hundreds of years for fish, prawns, and forest products including rattan, beeswax, camphor, and edible swiftlet nests. There are five main settlements along the lower reaches of the river.
- Wildlife—It is still unclear whether the existing populations of elephants, orang-utans, and rhinoceros are viable (there are only 1–2 Sumatran rhinoceroses in the area) in the long term given the current land-use configuration. It is unlikely that certain species will persist at viable population levels and more forest habitats will need to be added.

- Ecotourism industry—There are currently six tourist lodges on the river providing lodging and wildlife cruises. It is clearly in their interest to maintain and enhance the habitat quality along the river. Further operations may begin in the near future on other stretches of the lower Kinabatangan.

What is the effect on the ground for the stakeholders?

- **Oil palm plantations** lose out as the younger trees are not resistant to floods. Severe flooding occurred in 1996, and in January–February 2000 water rose to 14.3 m above mean sea level. Damage to young oil palms on one plantation alone was estimated at US$10.6 million over 4 000 ha. Oil palm plants need to reach an age of 4–5 years before they can withstand flooding. The apparent increased frequency of flood events does not bode well for oil palm adjacent to the river.
- **Elephant/human** conflict as elephants have to trample through villages and feed in plantations as they migrate along the river.
- **Local communities** see their livelihoods from fishing reduced as poor water quality reduces fish stock, and access to forest products is reduced.

Conflict

Conflict has been noted between:

- the oil palm industry and local people (fewer local people are employed in the plantations, all could potentially suffer due to soil or chemical runoff into the river, and local forest users have suffered when plantations replace the forest);
- the oil palm industry and wildlife (significant areas have been converted from forest to oil palm—destroying important wildlife habitat, and elephants raid the plantations, eating the shoots of young palms and destroying fences);
- wildlife and local people (the elephants, again, attempting to continue their natural movements along a sometimes converted river corridor, trample human crops and cause general mayhem).

Forest Landscape Restoration: building partnerships and negotiating trade-offs between key stakeholders

Contrary to what might have been expected in a conflict situation, the various stakeholders in the Lower Kinabatangan have been able to establish a constructive, workable partnership to try to reduce the environmental and economic problems. Some of the more significant steps in this process have included:–

- Memoranda of Understanding between WWF, the Forestry Research Centre and two oil palm companies to re-establish forest on flood-prone fragments within privately owned land;
- a “land-use forum” to set out the various options for the best use of land, through discussion between government agencies, plantation companies, smallholders, and non-governmental organisations;
- the launch of a vision statement for “The Kinabatangan–A Corridor of Life” by the Chief Minister of Sabah;

- the preparation of a District Development Plan for the Kinabatangan district, with the formation of six sub-commmittees, including those on agriculture and forestry, and on tourism and industry, as well as socio-economic development, including representation by non-governmental organisations and some private sector companies;
- the establishment of a Forest Restoration Committee, jointly chaired by the District Officer and a staff member of WWF Malaysia, intended to help fulfil the vision statement for the area.

An important point throughout these developments is that government agencies, non-governmental organizations and the private sector have consistently adopted a fact-led approach whereby all discussions must be supported by facts, and technical studies are the basis for all conservation and development activities directed towards the restoration of forests. This approach has been adopted in:–

- working with **industry bodies** (Malaysian Palm Oil Association MPOA, East Malaysia Planters' Association EMPA) to develop a common view;
- working with **oil palm companies** to improve their standards;
- working with **buyers** of palm oil to encourage selective buying (e.g. Unilever, Sustainable Agriculture Initiative);
- working with **decision-makers** at a national level through legal and policy measures to reduce the rate of conversion, and identify high conservation value forest (HCVF);
- working with **tourist lodges** to enhance riverbank scenery;
- working with **communities** on ways to reduce human–wildlife conflicts;
- working with both **oil palm companies** and local **communities** to identify important areas for on the ground restoration and engage them in the process.

CONCLUSION

WWF's approach to forest conservation has broadened to include Forest Landscape Restoration. This is an important shift which allows a realistic approach to restoration. While in some areas full restoration of original forest cover might be feasible and desirable, in many instances this is not the case. Yet at the same time, land devoid of any forest is not only a great loss to biodiversity but also to people that depend on it. To ensure a sustainable approach to restoration, we need to take a larger and longer-term view of the term "restoration". This signifies bringing in the people that need the forests together in strategic partnerships that will allow the definition of a forested landscape in which other necessary land uses, including agriculture, can be optimally achieved.

RECOMMENDATIONS

1. Carefully engage with different sectors.
2. Develop strategic partnerships with different stakeholders.
3. Manage information in a transparent way so as to provide a basis for negotiations and decision-making.

4. Agree on long-term goals and establish indicators to determine progress, adapt management if indicators are not met or if they need to be changed.
5. The people who benefit from restoration measures should compensate those who incur any costs.

BIBLIOGRAPHY

Brooks *et al*. 2002. Habitat loss and extinction in the hotspots of biodiversity. *Conservation biology*, Vol. 16, No. 4.

Duraiappah, A. 1996. *Poverty and environmental degradation: a literature review and analysis*. CREED Working Paper Series No. 8.

FAO. 2001. *State of the world's forests*. Rome.

Gobster, P.H. & Hill, R.B. (eds.). 2000. *Restoring nature, perspectives from the social sciences and humanities*. Washington, DC, Island Press.

IFRC. 2002. *World disasters report.*

ITTO. 2002**.** DRAFT *guidelines for the restoration, management and rehabilitation of degraded and secondary tropical forests.* In collaboration with FAO, CIFOR, IUCN, WWF and IUFRO.

Kaale, B. 2001. *Forest landscape restoration in East Africa: Tanzania report*. IUCN/ WWF (Draft).

Lamb, D. & Gilmour, D. *Rehabilitation and restoration of degraded forests*. "Issues in conservation" Series. WWF and IUCN. (in print).

McKie, R. 2002. The end of the world is nigh, starting with him. *The Observer.*

UNDP. 2001. *Human development report*.

World Bank. 2001. *DRAFT forest strategy.*

WRM. 2002. *Japan: sick from monoculture tree plantations*.

WWF and IUCN. 2000. *FLR regional workshop*. Segovia, WWF and IUCN.

WWF and IUCN. 2001. *FLR regional workshop report*. Mombasa, WWF and IUCN.

WWF. 2002. *Forest landscape restoration: working examples from five ecoregions.*

SESSION II

5 The use of forest succession for establishment of production forest in northeastern Viet Nam

First Experiences from the Afforestation Project Bac Giang, Quang Ninh and Lang Son Provinces Co-financed by Kreditanstalt für Wiederaufbau (KfW)

Ulrich Apel* and Knut Sturm**

ABSTRACT

The economic potential of secondary forest established by means of forest succession is underestimated and has been neglected in practical forest management as well as in research causing a lack of concepts and management approaches. The authors present first experiences from an afforestation project in northeastern Viet Nam where forest succession is used to establish so-called Production Forest on a larger scale. The economic potential of eight stands between three and eight years of age was examined by measuring the number of target trees according to three classes. The paper concludes that forest succession has a great potential to establish multifunctional forests with a high economic value. A concept is proposed with the ultimate objective to establish a permanent forest estate resembling natural forest with a broad mixture of species, products and services. Medium-term objectives are set along four stages of forest succession: (i) establishment, (ii) qualification, (iii) selection, and (iv) permanent forest. Training of smallholders is crucial to make full use of the potential of forest succession. During the first and second stages forest owners need to be trained in particular in the marking and determining of target trees according to three classes.

INTRODUCTION

The use of forest succession[1] for the establishment of productive forest is not an introduced approach and has been neglected in practical forest management (e.g. Lamprecht 1989,

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[1] In Viet Nam, forest succession is usually referred to as natural regeneration.

Evans 1992). The usual approach is planting of fast-growing tree species in monocultures or in mixed stands with very few species. Forest succession is tolerated only where the objectives of forest management are not primarily economic, e.g. in protected areas or in protection forest for environmental purposes. Over the past decade, forest succession on degraded forest land or abandoned agricultural fields has become an increasingly accepted approach for the establishment of protection forest in environmentally important areas such as watersheds within the framework of large-scale national projects in Viet Nam and elsewhere. However, it is hardly used for the establishment of multifunctional forests with the main objective production. Often early stages of forest succession are completely removed and fast-growing plantations established instead.

The economic potential of secondary forest resulting from succession is not only neglected in the practice of afforestation projects but in scientific research as well. Patterns of forest succession have been documented by many studies in the past several decades. Most of the studies describe patterns of forest succession across longer chronosequences and compare the development of the secondary forest with mature primary forest in terms of species composition, species richness, and stand structure (e.g. Kappelle *et al.* 1996, Kennard 2002). The main focus of these studies has been the comparison of the secondary forest to mature primary forests in terms of ecological value.

The reason for this negligence in practice and research seems to be the common view that secondary forest has a lower economic and ecological value than mature primary forest. Consequently, management concepts and silvicultural methods are lacking on how to use forest succession for the establishment of forest stands with a high economic value. This situation is regrettable since the relevance of the topic is immense: if sustainable forest management is to be achieved on a significant scale, the re-establishment of secondary forests with multiple functions through forest succession is a sheer necessity (Ewel 1979, GTZ 2000).

Since 1999, an afforestation project (hereafter referred to as the Project) in three northeastern provinces in Viet Nam has been supporting local smallholders in using forest succession for the establishment of so-called Production Forest[2] . The approach of the Project includes land-use planning, site-mapping and, on approximately 5 000 ha of better sites, the use of forest succession with the long-term goal of creating permanent forest estates with multiple functions.

The paper begins with introducing the concept of the Project by defining the long-term management objectives for these stands and the main silvicultural treatments applied in the different stages of succession. After that, it presents first experiences on how smallholders apply the concept and gives examples of the current value and future potential of different young stands. Finally, these experiences are discussed and conclusions are made on how to advance the use of forest succession for the establishment of productive forests in afforestation projects.

[2] Forest land in Viet Nam is classified either as protection forest, special use forest (nature reserves, etc.), or production forest. The latter has the main objective of production of timber and non-timber forest products; however, in many cases it has also protective functions.

A CONCEPT FOR THE USE OF FOREST SUCCESSION FOR THE ESTABLISHMENT OF PRODUCTIVE FORESTS

The long-term management objectives

Reforestation concepts require long-term objectives for future management and utilization of the forest stands to be established. These management objectives guide all technical measures; thus silvicultural treatments are the means of implementation of the defined objectives. However, a brief look into the history of forest management reveals that management objectives defined centuries or decades ago have often been altered completely[3]. Long-term objectives have to be able to respond to changing markets, ecological conditions, social requirements, and economic framework conditions[4].

In view of this, efficient forest management calls for dynamic and flexible objectives in particular in terms of species composition. Natural processes and changes of species composition have to be accepted as the natural production potential of forest management. The ultimate objective of the presented concept is a permanent forest estate resembling natural forest with a broad mixture of species, products and services. The management focuses on the individual tree rather than on whole stands. Consequently, there are no fixed rotational periods but an optimized utilization of trees according to a minimum harvestable diameter. This form of management leads to forest stands rich in species and structure. The permanent forest estate is able to fulfil economic requirements and other forest functions as well (e.g. watershed protection, erosion control, biodiversity, etc.). Furthermore, it is particularly suited to smallholder forest management on small area units. Because of its uneven-aged structure, usable volumes and products are permanently available.

Stages of forest succession

Forest succession has a great potential to achieve the long-term goal of a permanent forest estate for natural and sustainable management with high economic benefits. In order to set intermediate management objectives which take the changing tree species composition, structure and quality of the stand into account, four stages of forest succession are distinguished:

I: establishment stage
II: qualification stage
III: selection stage
IV: permanent forest stage

The recognition of stages is a matter of practical convenience to define silvicultural measures and treatments accordingly. Actually, the developing stands on a given site are continuously changing as new species invade the site and already occurring species reproduce or disappear through failure to reproduce. The actual occurrence of the successional stages is hardly evident in the field (Spurr & Barnes 1980).

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[3] For example, oak trees in Germany now used for veneer production were planted more than two centuries ago with the objective to produce wood for shipbuilding.

[4] For example, the tapping of pine for resin production as well as the production of fuelwood in coppice forests in Viet Nam is presently profitable because of the low labour costs.

This paper describes the successional sequence of species and the structural characteristics of the different stages only briefly because they have been described in detail by many authors (e.g. Spurr & Barnes 1980, Richards 1996). The focus is on the silvicultural measures prescribed for the different stages.

I: Establishment stage

Characteristics

- Trees occur in groups and patches in varying density and from different origin (seeds, coppice, root shoots).
- There are patches without trees.
- Forest microclimates are not yet developed, climatic extremes are prevalent.

Species composition

Light-demanding and fast-growing (pioneer) species dominate (e.g. *Liquidambar formosana*, *Wendlandia glabrata*, *Cratoxylon* sp., *Mallotus* sp., *Macaranga adenantha*, *Schima wallichii*, *Trema orientalis*, *Aporusa* sp., *Alangium chinense*, *Pithecellobium clypearia*, *Litsea cubeba*, *Wrigthia annamensis*, *Ficus* sp.). The species composition in the Project area varies according to many factors, such as site conditions, availability of seeds, and the disturbance history of the site. Homogeneous site conditions favour the occurrence of pioneer species, whereas heterogeneous microconditions lead to recruitment of long-lived pioneer species (e.g. *Engelhardtia spicata*, *Canarium album*, *Machilus bonii*) and shade-tolerant species *Erythrophleum fordii*) from the very beginning together with the early pioneers (also described by Horn 1981).

Intermediate management objective

To facilitate succession towards complete vegetation coverage and the quick development of an interior forest microclimate.

Silvicultural measures

(1) <u>Forest protection</u> The emphasis of the silvicultural treatments is on forest protection:

- There is no removal of trees or shrubs.
- There is no cutting of trees, bark or branches.
- Ground vegetation is to be fully protected.
- Grazing is to be completely prevented.
- Fire has to be extinguished immediately.
- Harvest of fuelwood has to be avoided.

(2) Marking of target trees At the end of the pioneer stage (from approximately 3 m of height of the dominating trees) the target trees are marked with a ring of red colour according to the following basic principles:

- The target trees are selected according to their quality.
- The target trees belong to a species with economic value.
- The number of the target trees per hectare and the distance between them are unimportant for their selection.
- Lianas are to be removed *from the target trees that have been marked*.

The marking of the target trees is to be repeated annually to include newly arriving target trees in later stages of the succession. At the same time it serves as a practical training of the Project participants in the determination of quality of individual trees and for a measure to observe the qualitative development of the stand.

(3) Defining a technical goal for each individual target tree The determination of the quality of the target trees will be the basis for the application of silvicultural measures in the future. Three classes of target trees are distinguished considering specific future utilization:

Class 1: All target trees with high quality with the following characteristics: the trees must be vital, with a straight stem, have a seed origin and belong to an economically useful target tree species. The target trees must be able to develop a straight, faultless bole of 6 to 8 m in the qualification stage, for high-quality industrial wood processing.

Class 2: This class contains target tree species, which produce industrial relevant non-timber forest products (e.g. resins, fruits, nuts). Only trees which are vital, with big crowns and a stable stem foot are selected (seed origin or low coppices). This class includes rare tree species as future seed trees which are of great importance for the future development of the forests. Quality standards might be lower for rare tree species.

Class 3: Trees which do not fulfil the requirements of classes 1 and 2 might be selected for class 3. These trees will be utilized for subsistence purposes including sawn timber, fruits, nuts and medical purposes. However, trees have to meet minimum quality standards; firewood trees, shrubs, crooked and branched trees—even if they belong to the target tree species are not selected.

(4) Enrichment planting Additional planting of economic valuable trees should be done in stands with less than 30 target trees of classes 1 and 2 per ha and is optional in stands with 30–70 target trees of classes 1 and 2 per ha. These low numbers take account of the fact that the succession is ongoing and more target trees are likely to arrive in this process. The following basic principles are applied:

- Tree species selection for enrichment planting has to avoid the selection of pioneer species or species with predominantly pioneer character.
- Enrichment planting is limited to gaps in the natural succession. In those gaps the density of planted trees is at least 2 x 2 m. Gaps smaller than 100 m^2 are not to be enriched.
- Fixed planting schemes are avoided and gap planting favoured instead. Microsite conditions and heterogeneous site conditions are taken into account in species selection.

II: Qualification stage

Characteristics

- Dominating trees have about 5 m height and 8 cm diameter at breast height (DBH).
- Tree density and height development is heterogeneous, but the soil is completely. covered by a canopy composed of different vegetation storeys.
- Development of a typical forest microclimate which evens out climatic extremes.

Species composition

Light-demanding species are still dominating. First shade-tolerant species are occurring under the pioneer trees (e.g. *Machilus bonii*, *Castanopsis* sp., *Horsfieldia glabra*, *Erythrophleum fordii*, *Pygeum arboreum*, *Pometia tomentosa*, *Cryptocarya lenticellata*, *Garcinia* sp., *Canarium nigrum*). First pioneers and shrubs disappear due to failure to regenerate and competition for light.

Intermediate management objective

To facilitate the qualitative development of the stand.

Silvicultural measures

Since the qualitative development of the stand is not yet complete and trees often change their sociological classes in this stage, activities such as thinning, pruning, or singling are not yet appropriate. Usually, the further development of target trees is facilitated by biological automation. Competition between trees and fast height increment facilitate the development of straight and branchless boles with the desired height of 6–8 m. Silvicultural treatments are only required if the qualitative development of the stand is hampered by frequent occurrence of bad and branchy forms, or if non-target trees replace target trees. If silvicultural treatments are applied, they are limited to the upper storey. Treatments in the middle or understorey would only lead to an undesired homogenization of the stand and thus need to be avoided.

Measures for forest protection and marking of target trees are still applied as in the previous establishment stage.

III: Selection stage

Characteristics

- Dominating trees have about 12 m height and 20 cm DBH.
- Further differentiation of height and development of a vertical structure of the stand.
- Canopy layer dominated by individual and small groups of trees.
- Presence of middle-storey and understorey trees.
- Ground vegetation disappearing.

Species composition

Species composition is in transition to shade-tolerant climax tree species (e.g. *Erythrophleum fordii*, *Pygeum arboreum*, *Pometia tomentosa*, *Vatica tonkinensis*, *Litsea* spp.).

Intermediate management objective

To facilitate growth of selected target trees of classes 1 and 2.

Silvicultural measures:

The qualitative development of the trees in the upper storey is complete. Target trees in the upper storey are now easily recognizable and can be permanently marked. The target trees to be finally selected need to fulfil certain vitality (healthy, upper storey tree with long and well-formed crown) and quality criteria (straight bole with 6–8 m piece of high quality, no damage or diseases). The number of target trees per hectare will vary between 50 and 200. Again, the distance between the target trees is of no importance. Selective thinnings are applied to enhance the development of the target trees of classes 1 and 2. The focus is on the individual target trees and not on the stand. It implies that patches of low quality without target trees of classes 1 and 2 do not receive any treatment. Thinnings are applied to the upper storey and only trees which compete and put pressure on target trees in the canopy layer are removed. Trees to be removed might include target trees of class 3. In the middle storey, thinnings are only necessary to foster the crown development of target trees of class 2 (e.g. fruit trees).

IV: Permanent forest stage

Characteristics

- Stand is vertically and horizontally structured.
- Previous qualification and selection stages prevail or are newly formed in small gaps.
- Larger gaps might exist as a result of disturbances where the establishment phase starts again.

Species composition

The tree species richness is highest in this stage. Shade-tolerant species and long-lived pioneers dominate the upper storey. Species typical for earlier successional stages prevail in gaps. Early pioneers might be present in larger gaps where disturbances have occurred.

Management objectives

- To harvest timber according to minimum harvestable diameters (MHD)[5] for species and/or groups of species
- To ensure permanent usability of the forest estate through keeping a certain growing stock

[5] MHD is the DBH of a tree species or group of species where – according to present knowledge and market conditions – the optimum value is achieved.

Silvicultural measures

The forest has developed into a stage where harvest of timber products can start. Permanent utilization of products (depending on the area of the estate and market conditions annually or in periods of a few years) is possible. The target trees of class 1 are harvested according to minimum harvestable diameters (MHD). Target trees of class 2 are harvested for non-timber forest products. Utilization of target trees of class 3 can be considered also in the middle storey to provide products for subsistence use.

In order to keep the forest estate permanently usable, the forest must not fall back into previous successional stages at a larger scale. A suitable level of harvest is estimated with 10 percent of the stock per storey within five years. The removal of 25 percent of the stock set as a maximum, however, would require longer phases of recovery of the forest.

FIRST EXPERIENCES APPLYING THE CONCEPT

Future potential of forest succession

To examine the future economic potential of forest established by means of succession, eight young stands of site class A_1 (according to the site mapping of the Project A_1—sites have > 800 trees/ha^{-1} of 1 m height belonging to economically useful species) have been randomly selected. In these stands the number of target trees and their distribution in the three classes were measured. The results are presented in Figure 1.

The total number of target trees varies between 180 and 372 trees/ha^{-1} depending on the age and history of the stand. The stands are 3- to 8-year-old successions either after shifting cultivation or clear cut of the original stand. Some stands have been influenced by fuelwood harvest (No. 1, 2, 3, 8) and have a high number of coppices. All stands are still in the establishment stage except stand No. 4 with an age of 8 years in transition to the qualification stage. The number of target trees of classes 1 and 2 per ha varies between 15 (No. 8) and 160 (No. 4).

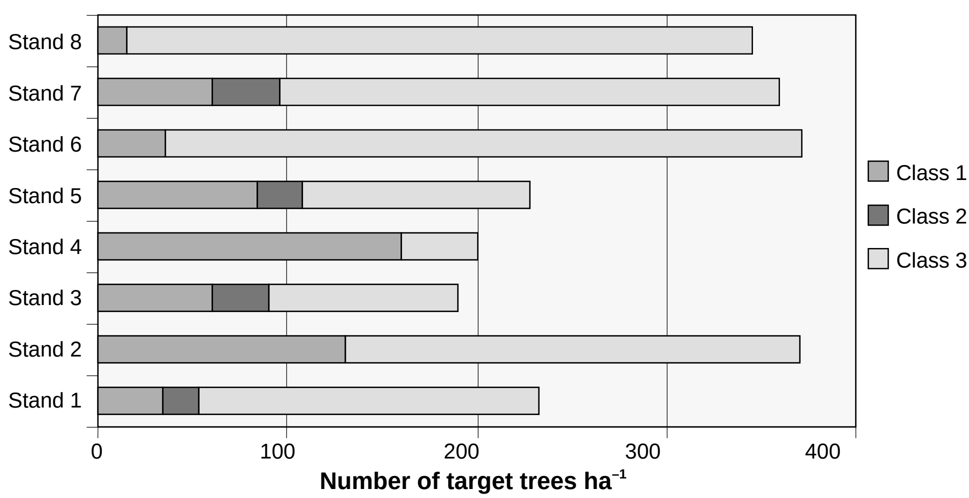

Figure 1. Number of target trees per hectare by class in eight randomly selected stands

The economic potential is estimated as:

- **high** in stands with > 70 target trees of classes 1 and 2 per hectare (stands No. 4, 2, 5, 7, 3). These stands will probably reach a standing stock of more than 350 m ha^{-1} in the permanent forest stage. These 70 or more target trees will almost entirely dominate the upper storey. In the middle and understoreys enough young target trees of classes 1 and 2 will develop.
- **medium** in stands with 30–70 target trees (stands No. 1, 6). These stands will probably reach a standing stock between 150 and 350 m ha^{-1} in the permanent stage. The further development has to be observed until the end of the establishment stage. Enrichment planting with shade-tolerant species might be considered.
- **low** in stands with < 30 target trees of classes 1 and 2 (stand No. 8). These stands will probably reach a standing stock of less than 150 m ha^{-1} in the permanent stage. Enrichment planting in gaps is recommended.

Determination of target trees by smallholders

Crucial to the application and success of the concept is the proper selection of target trees and the determination of its class, which is actually a definition of a technical goal for the individual tree according to its quality and expected products. Consequently, silvicultural measures can only be properly applied if the definition of the technical goal for each individual tree fully exploits its potential.

To examine the marking and structuring of target trees according to the three classes by Project participants the following exercise has been conducted: 80 trees were numbered and a reference established through a judgement of target trees and its classes by the authors. Fourteen project participants were asked to determine for each of the 80 trees if it is a target tree and to which class it belongs. The results are presented in Figure 2.

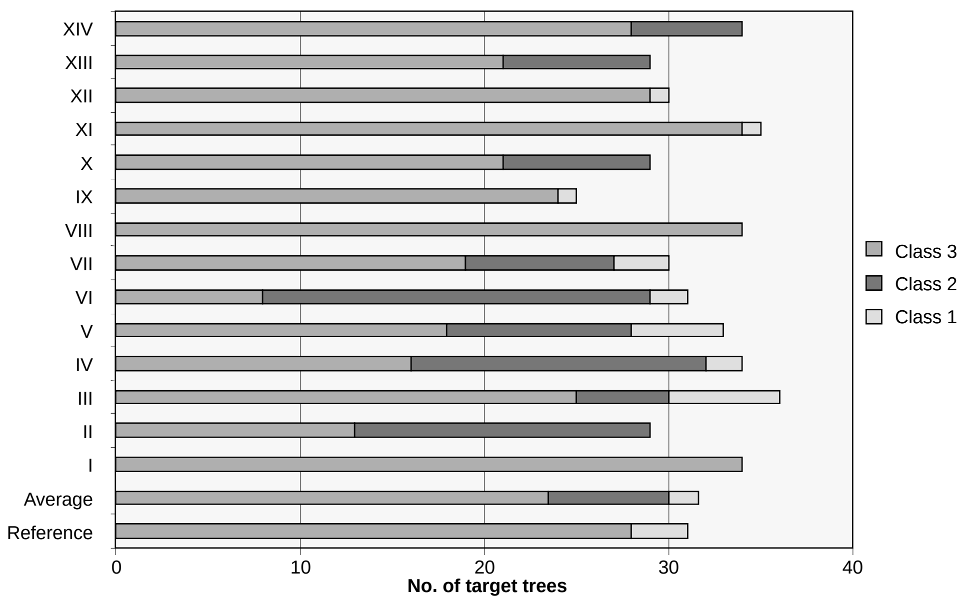

Figure 2. Determination of target trees by class. By 14 project participants (1–XIV)

Out of the 80 trees the smallholders marked between 25 and 36 target trees rather corresponding to the reference of 31. However, the determination of the class differs. No target tree was picked for the same class by all smallholders. The highest correspondence was achieved for two well-formed and vital target trees of class 1, which were selected by 12 out of the 14 participants. On average, the smallholders selected target trees for class 1 more cautiously than the authors did. However, target trees of class 1 chosen by the authors were selected by 75 percent of the smallholders as a target tree (classes 1–3). The lowest correspondence of results shows class 2. Smallholders tend to classify trees which are in quality between classes 1 and 3 in this group, although class 2 is actually defined as target trees for production of industrial relevant non-timber products.

DISCUSSION AND CONCLUSION

Studies on the economic potential of forest succession are rare. Nguyen van Sinh (2000) examined the share of economically valuable tree species in 3- to 11-year-old forest succession in northern Viet Nam. The study reports between 32 and 287 stems of 7–23 economic useful species, making up 23–60 percent of the total stems and 25–32 percent of the total species per hectare. The study concludes that forest succession close to natural forest can substitute forest plantations and that enrichment planting is unnecessary. Finegan (1991) found 184 economic useful tree species > 10 cm BHD in a 15-year-old secondary forest area in Costa Rica. Fedlmeier (1996) investigated not only the percentage of economically useful species in forest succession in Costa Rica, but also structured the individual trees according to quality criteria, such as the form of the stem. This study recorded a high number of 135–378 trees ha^{-1} with high quality in 2.5- to 9-year-old stands, making up 16–30 percent of the basal area of the stand. The percentage of the valuable trees on the total basal area of the stands increased with their age.

In the Project area in northeastern Viet Nam, the future economic potential of forest stands established by means of forest succession is relatively high. This estimation is based on the actual number of target trees taking account of the quality of the individual trees rather than of the share of economic valuable tree species. For five out of eight examined stands the economic potential looks quite promising. Only one out of eight stands requires enrichment planting. This result matches with the actual area of enrichment planting compared to pure forest succession in the Project: only 375 ha out of 2 230 ha established have been enriched (17 percent). However, the prognosis, which is based on only eight young stands, is far from representative. With this paper the authors would like to contribute to a discussion of this topic and to encourage more surveys on the economic potential of secondary forest.

Training of forest owners is crucial to fully exploit the potential of forest succession. This is especially important for rather new silvicultural methods that focus on the use of natural processes and biological automation. Training needs to convey the long-term management objective of a permanent forest estate with multiple functions and its advantages. In the establishment and qualification stages of succession an observation and assessment of the developing forest oriented at the long-term objective are necessary. As presented in one example, the marking of target trees revealed differences between individual smallholders which are not yet satisfactory. The selection of target trees and the determination of a technical goal for each individual tree are important for an appropriate silvicultural treatment of such stands in the selection stage of succession.

This paper also outlines a practical management approach towards the establishment of a permanent forest estate through forest succession. It is structured along the stages of forest succession and includes medium-term management objectives and tries to use natural processes (biological automation) as much as possible. Although this management concept needs to be further elaborated in the course of implementation, it provides principles to guide the management of forest succession.

Forest succession for the establishment of forest with multiple functions, and in particular with economic function, can only be advanced if its economic potential is brought to more attention. This requires more surveys and research into this topic as well as more examples in the praxis of afforestation projects and more openness in practical forest management.

REFERENCES

Evans, J. 1992. *Plantation forestry in the tropics*. 2nd edition. Oxford University Press.

Ewel, J.J. 1979. Secondary forests: the tropical wood resource of the future. *In* M. Chavarria, ed. *Simposio internacional sobre las ciencias dorestales y su contibucion al desarrollo de la America tropical*, pp. 53–60 . Costa Rica, UNED.

Fedlmeier, C. 1996. Sekundärwaldentwicklung auf aufgegebenen Weideflächen im Norden Costa Ricas. *Göttinger Beiträge zur Land- und Forstwirtschaft in den Tropen und Subtropen*, No. 109.

Finegan, B. 1991. The productive potential of neotropical secondary lowland rain forest. *Proc. of the Humid Tropical Lowlands Conference*. Panama City.

GTZ (Gesellschaft für Technische Zusammenarbeit GmbH) (ed.) 2000. *Die entwicklungspolitische Relevanz der Sekundärwaldbewirtschaftung*. Eschborn, GTZ.

Horn, H.S. 1981. Some cases of variety in patterns of secondary succession. *In* D.C. West, H.H. Shugart & D.B. Botkin, eds. *Forest succession: concepts and application*, pp. 24–35. Berlin & New York, Springer.

Kappelle, M., Geuze, T., Leal, M.E. & Cleef, M. 1996. Successional age and forest structure in a Costa Rican upper montane *Quercus* forest. *Journal of Tropical Ecology* 12: 681–698.

Kennard, D.K. 2002. Secondary forest succession in a tropical dry forest: patterns of development across a 50-year chronosequence in lowland Bolivia. *Journal of Tropical Ecology* 18: 53–66.

Lamprecht, H. 1989. *Silviculture in the tropics*. Eschborn, Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH.

Nguyen Van Sinh. 2000. Sukzessionsuntersuchungen in Sekundärwäldern auf aufgegebenen Reisanbau- und Siedlungsflächen im Norden Viet Nams. *Göttinger Beiträge zur Land- und Forstwirtschaft in den Tropen und Subtropen*, No. 109.

Richards, P.W. 1996. *The tropical rain forest*. 2nd edition. Cambridge University Press.

Spurr, S.H. & Barnes, B.V. 1980. *Forest ecology*. 3rd edition. New York, Wiley & Sons.

6 Variable success of native trees planted on degraded pasture in Costa Rica

F. Lynn Carpenter* and J. Doland Nichols**

ABSTRACT

Native trees planted across a degraded 25-ha farm in southern Costa Rica in several experiments since 1993 varied at least 12-fold in success (growth and mortality). Depending on the experiment, our results showed that success can be affected by the tree species, seed mother tree, topography, and whether legume trees were part of the species mix. Historical use of each area on the farm during the 40 years after its deforestation also affected success. For example, areas that were bulldozed or heavily tracked by cattle exhibited poor success at reforestation. However, much of the variability depended on specific site and is still unexplained. Patchy occurrence of mycorrhizal fungi is a possible explanation for some of the variability in tree success. In the tree nursery, inoculation of mycorrhizal fungi into pot soil increased performance of native tree seedlings. One of our working hypotheses for the future is that improvement of mycorrhizal status in recalcitrant areas might increase re-establishment of trees and soil fertility to extremely degraded tropical soil.

INTRODUCTION

Foresters in Costa Rica began incorporating native tropical timber trees in reforestation schemes almost 20 years ago (Nichols & Gonzalez 1992, Haggar *et al*. 1998). More recently, experimental trials of various native species have produced preliminary results (Gonzalez & Fisher 1994). These results and continuing studies are important because tropical woods are becoming scarce, yet remain in demand. Also, many native trees are adapted to the environmental conditions of abandoned land and may perform better than

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exotics under such circumstances (Gonzalez & Fisher 1994). Furthermore, the tropical natives can serve many purposes other than timber production. Examples are restoration of wildlife habitat, erosion reduction, regeneration of soil fertility and improvement of watersheds.

This paper reports preliminary results of several experiments established between 1993 and 2000 on a degraded, eroded cattle pasture in southern Costa Rica. Tree growth and survival have varied greatly across the 25-ha farm. Although the pasture seemed homogeneously degraded when the experiments first began, experience revealed substantial underlying environmental heterogeneity. This heterogeneity explains some but not all of the variance in tree performance. Intentionally manipulated factors in our experimental designs also accounted for some of the variance. Such factors included tree species, seed mother, proximity of legume nurse trees, degree of erosion, topography, land-use history, and the nature of the soil mycorrhizal community. We report here our information to date on several of the factors explaining variability in tree performance. Understanding the factors affecting tree performance on tropical degraded land will help future restoration efforts as well as tropical plantation forestry.

MATERIAL AND METHODS

Our study site is a 25-ha farm in southwestern Costa Rica, 83°W, 9°N. Elevation is 1 050 m on the south Pacific slope. Mean annual temperature is 20°C, with 4 400 mm annual rainfall mostly between April and December. The site was "tropical premontane rainforest" (Holdridge 1967) before being cleared for agriculture in the 1950s. Much of the region is steep, subject to erosion, and inappropriate for annual crops or pasture. The Ultisols of the farm range from Typic Hapludults to Humic or Andic Hapludults (USDA system). Soils at the beginning of our experiments in 1993 were not compacted, bulk densities never exceeding 1.1 of cmg^{-3} even in the bottoms of cattle trails. Initial pHs before restoration ranged between 4.4 and 5.8, averaging 5.2. The soils of the region are acid, phosphorus-fixing and infertile—more so after erosion removes topsoil (Carpenter *et al*. 2001).

After growing coffee for about 20 years, approximately 20 ha of the 25 ha farm were converted to pasture in 1978 by planting exotic grasses for grazing. For the first experiment described below, 5 ha were fenced from cattle in 1993. Over the succeeding years, fences were built around each new experiment to exclude cattle. By the year 2000 about 15 ha had been planted in experimental plots.

Experiment 1—1993. *Terminalia amazonia* interplanted with legumes

We planted a native timber tree, *Terminalia amazonia* (Combretaceae), in eight experimental treatments to determine methods to improve growth and survival (Nichols *et al*. 2001). We planted tree seedlings in 3 × 3 m hexagonal arrays. Besides the unmanipulated control, treatments included:

- 10–30–10 fertilizer upon outplanting;
- *T. amazonia* interplanted with herbaceous legumes, either *Phaseolus vulgaris* or a mix of *Mucuna pruriens/Canavalia ensiformis* (Fabaceae);
- *T. amazonia* interplanted with arboreal legumes, either *Inga edulis* or *Gliricida sepium* (Fabaceae);
- *T. amazonia* interplanted with an equal mixture of the two legume trees to form three-species plots.

The experiment was a randomized block design with five replications of each treatment. Two of the five blocks were steep, one was flat at the foot of steep slopes, one was flat but cut by deep cattle trails and the fifth consisted of rolling hills. Each block contained eight experimental plots (one replication of each treatment), and each plot measured 24 × 26 m and contained 93 *T. amazonia*. The entire experiment consisted of 40 plots and over 3 700 *T. amazonia*.

At the beginning of the experiment in 1993 we took soil samples at 0–15 and 15–30 cm depth for each of the 40 plots and analysed pH, Olsen P, SOM, % Al saturation, CEC, NO_3, NH_4 and Ca to determine the initial soil fertility. We estimated the degree of erosion in each of the 40 plots based on depth of cattle trails and remaining topsoil. We characterised the topography of each plot as predominantly one of the following categories: ridge, slope, valley between slopes, or flat.

We collected *T. amazonia* seeds from 14 seed mother trees in the region around our site. We raised the seedlings in an on-site tree nursery till they reached 5 cm height and then outplanted them during September 1993. Seedlings were kept clear of weeds for the first two to three years.

Each year between 1993 and 2001 we measured the height to the tip of the tallest leader and diameter at breast height. In 2001 we also noted each death and scored each living tree along a rank of health: 1=very sick or dying, 2=sick, 3=normal, 4=exceptionally healthy.

We analysed height and DBH after four years (Nichols *et al*. 2001) and, here, after eight years in 2001, with Two-way ANOVA using SPSS. Here we also analyse survival and health data from 2001.

Experiment 2—1994. Tree species trials

We tested the relative abilities of seven tropical tree species to establish in our degraded pasture with no special treatment, only weeding when necessary during the first two or three years. In this experiment we included five natives as well as two exotics recommended by local foresters for our elevation. For each native species, we collected seeds during 1993–1994 from various provenances, and raised the seedlings in our nursery for several months. We purchased seedlings of the two exotics. The native species were *T. amazonia*, *Tabebuia ochracea* (Bignoniaceae), *Calophylum brasiliense* (Clusiaceae), *Cedrela odorata* (Meliaceae), and *Vochysia hondurensis* (Vochysiaceae). The exotics were *Pinus tecunumanii* (Pinaceae) and *Eucalyptus deglupta* (Myrtaceae).

From July to September 1994 we planted the seedlings in a randomized block design, 30 blocks across the entire farm, three individuals per species in each block. Each species was represented by a total of 90 trees. Planting pattern was a hexagonal array, each block measuring 18 × 9 m. We measured height annually and analysed growth and survivorship after five years (Bhasin 2000).

Experiment 3—1995. Fertilization of *Terminalia amazonia*

To determine if N, P, or K individually affects the growth of *T. amazonia*, we planted seedlings across a range of terrain in three randomized blocks with three levels of each mineral, for a total of nine treatments. We replicated each treatment three times in each block, giving 27 experimental plots per block (81 total plots). Each plot contained two experimental trees surrounded by six barrier trees, yielding 162 experimental trees and 486 barrier trees. The forms of fertilizer were ammonium nitrate for N (33 percent N), triple super phosphate for P (46% P_2O_5), and potassium chloride for K (60% K_2O). The concentrations were 0, 1×, and 2× the amount of each mineral recommended for trees.

We analysed growth annually for four years (Henriquez & Carpenter, ms in preparation). In 1999 we also took data on topography of each plot.

Experiment 4—1996. Mycorrhizal potential

As heterogeneity of tree growth and survival emerged in the above experiments, we suspected that mycorrhizal fungi might vary across the farm and cause some of this variability in success. Mycorrhizal communities are known to be related to history of land use and degree of erosion (Carpenter *et al*. 2001). We analysed soil fertility and mycorrhiza over a gradient of land mismanagement, ranging from the worst areas that had been bulldozed or especially heavily used by cattle, through moderately eroded areas, to secondary forest with 20 years of recuperation since the 1970s. In 1996 we selected eight sites that represented this gradient of land use and took three 1 kg soil samples from each site. A small subsample of this soil was used to measure pH, soil humidity, SOM (Walkley-Black method), and available P (Bray method). The remainder was used to culture mycorrhizal fungi to determine mycorrhizal inoculum potential. We harvested the cultures after two months, and counted and identified spores produced from each soil sample (Carpenter *et al*. 2001).

Experiment 5—2000. Mycorrhizal inoculation of six native species

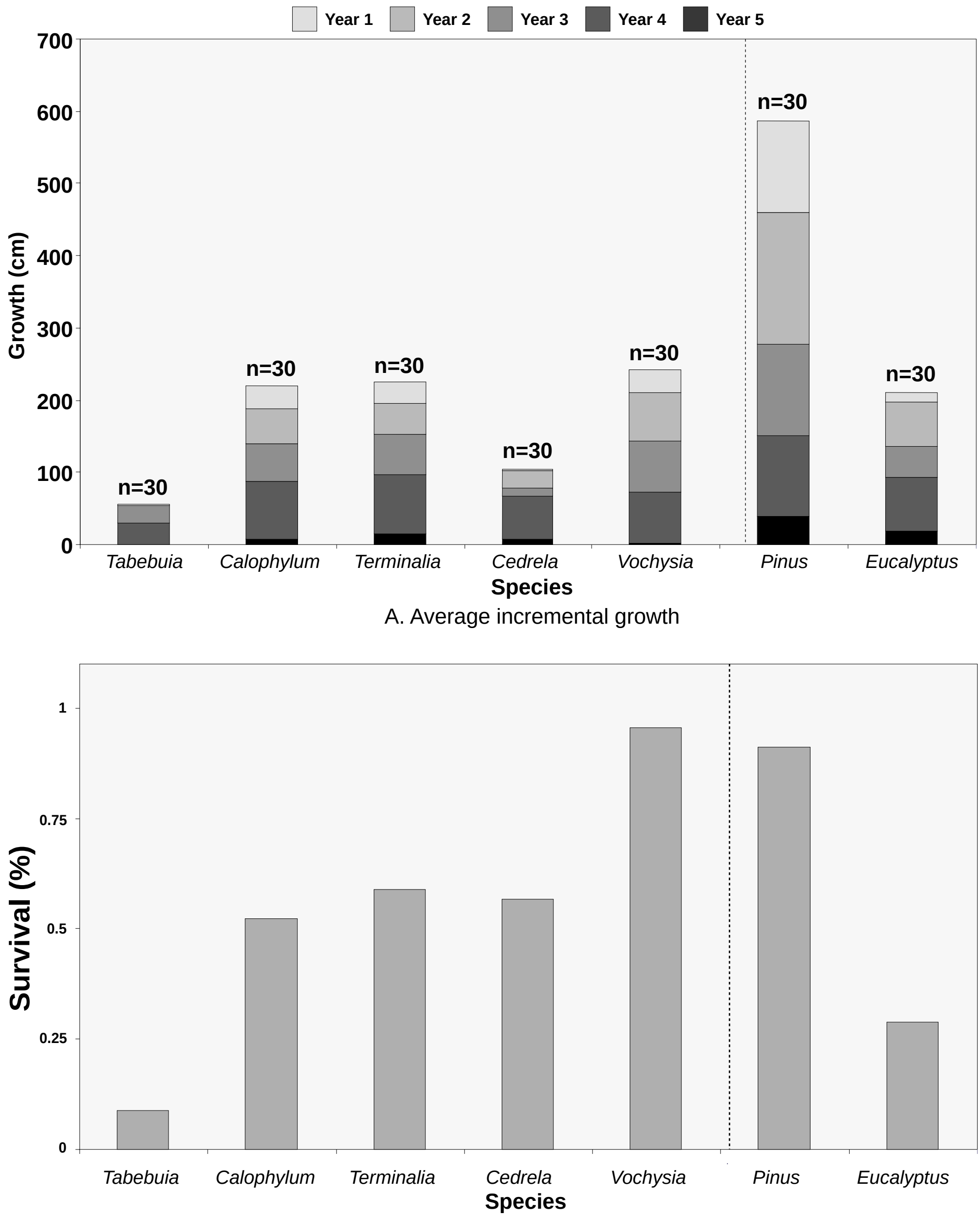
To determine the effect of mycorrhiza on six of the native trees with which we work, we selected three legume species and three non-legume species to raise from seed in 10 × 20 cm black plastic nursery bags in the tree nursery. The legume species were *Inga edulis*, *Dyphysa robinioides* and *Calliandra calothyrsus*; the non-legumes were *T. amazonia*, *C. odorata* and *Hieronyma oblonga* (family Euphorbiaceae). We established three blocks with 100 seedlings of each species in each block (one seedling per bag), half of which we inoculated with live mycorrhizal inoculum and half of which we inoculated with killed inoculum for controls. The entire experiment consisted, therefore, of 1 800 seedlings. We analysed growth at 3.5 and 6 months (Andonian 2001), and both growth and survival after 13 months (Zakhor unpublished ms, 2002).

RESULTS

We present results not in chronological order but in the order in which they relate to one another.

Tree species trials (Experiment 2)

The different species included in our 1994 tree trial showed large differences in growth and survival, as expected (Figure 1). Survival was best in *P. tecunumanii* and *V. hondurensis* (above 90%) whereas almost all *T. ochracea* died. Spatial patterns of growth across the farm differed among species. Two species, *P. tecunumanii* and *C. brasiliense*, showed almost no spatial variation in growth across the farm, growing equally well in all areas. The only exception was that *C. brasiliense* died in one of the 30 blocks. In contrast, *T. amazonia* and *V. hondurensis* showed 4- to 5-fold differences in growth rates between their best and worst blocks. Mortality of *C. odorata* and *E. deglupta* was high in the same places where *T. amazonia* and *V. hondurensis* grew the worst, showing that these areas were stressful for four of the six surviving species.



B. Average survival

Figure 1. Growth from 1994 to 1999 and survival in 1999 of five native species of trees (left of vertical line) and two exotics (right of vertical line). A. Means of three trees per block averaged over 30 blocks for each species. B. Percent of the initial 90 trees of each species still alive in 1999. Species from left to right are *T. ochracea, C. brasiliense, T. amazonia, C. odorata, V. hondurensis, P. tecunumanii, E. deglupta.*

Two widely separated areas, totalling eight of the 30 blocks, showed the poorest tree growth and survival. One of these areas, consisting of four blocks, had been bulldozed early in the history of the farm, according to its previous manager. The other area, also represented by four blocks, was an extremely steep slope where some of the cattle trails had eroded as much as 2 m deep.

Two widely separated areas showed the best tree growth. One of these areas, consisting of four blocks, occurred on gentle slopes or at the foot of a steep slope. The other area, represented by two blocks, was a valley.

Terminalia amazonia interplanted with legumes (Experiment 1)

All response variables in *T. amazonia* were highly correlated after eight years of growth: height with diameter ($r = .92$, $p = .000$), height with survival ($r = .73$, $p = .003$), and height with health rank ($r = .78$, $p = .001$). We therefore report primarily height and survival as our response variables.

Although few differences occurred between treatments four years after planting (Nichols *et al*. 2001), by eight years large differences had emerged (Two-way ANOVA, treatment $F = 13.6$, $p < .000$;). The best treatment for increasing growth of *T. amazonia* was to interplant it with the legume tree *I. edulis* (Table 1). After four years of growth, *T. amazonia* in this treatment grew only 27% taller than those in the worst treatment. However, after eight years these trees had grown 43% faster than those in the worst treatment.

Table 1. Treatment effect on growth of *Terminalia amazonia,* shown by three significant post-hoc Tukey subgroups (p<.05). Heights of *T. amazonia* are in cm. Results for legume trees are bolded.

Treatment	Mean tree heights		
Beans	327		
Fertilizer	350		
Herbaceous legumes	352		
Control	368	368	
Mixed legumes	371	371	
Gliricidia sepium		**412**	
Mixed legume trees		**414**	**414**
Inga edulis			**467**

The two factors in the Two-way ANOVA above were block and treatment. The difference between blocks in mean growth rates of *T. amazonia* was also highly significant (Two-way ANOVA, block $F = 23.1$, $p < .000$). Several environmental factors varied between blocks. The most important were degree of erosion and terrain. Trees on flat or gently hilly terrain grew up to 35% taller than those in the eroded block (Table 2). Degree of erosion accounted for some of the difference between blocks. Across all 40 plots, degree of erosion accounted for about half of the variance in growth rate ($p = 0.001$). Additionally, topography played an important role: growth tended to be poor on ridge tops and best in small valleys between slopes. Although the steep slopes were deeply eroded, patches of good growth occurred in depressions on these slopes. Surprisingly, growth was unrelated to any of the soil chemical factors measured at the beginning of the experiment (Nichols *et al*. 2001).

Table 2. Block effect on growth of *Terminalia amazonia,* shown by three significant Tukey subgroups ($p < .05$)

Block	Mean tree heights		
Eroded	326		
Steep 2	357	357	
Steep 1		373	
Hilly			422
Flat			440

Another important factor influencing performance of *T. amazonia* was seed mother, or provenance from which came the seeds. Seed mother affected height growth of progeny (14 different mothers, Two way ANOVA, mother $F = 13.1$, $p < .000$, no significant interaction between mother and block). The offspring of the best seed mother averaged 70% taller than those of the worst seed mother. We ranked the 14 seed mothers from worst to best performance of their offspring as represented by average height, survival and health rank. All three variables correlated positively with each other (Table 3), meaning that the mothers with the tallest offspring also produced offspring with higher survival and better health than those with the smaller offspring.

Table 3. Pearson correlation tests on performance ranks of offspring from 14 seed mothers of *Terminalia amazonia.* The rank order of all variables representing success correlated positively.

Comparison	Pearson correlation	Two-tailed p
Height rank vs. survival rank	.73	.003
Height rank vs. health rank	.78	.001
Height rank vs. survival rank	.86	.000

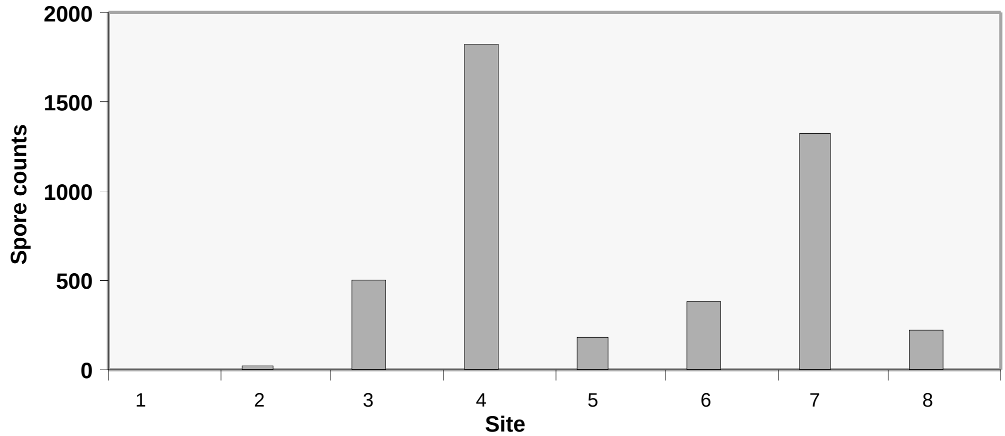
Fertilization of *Terminalia amazonia* (Experiment 3)

The experiment (#3) in which we fertilized *T. amazonia* with N, P, and K separately showed that none of these inorganic fertilizers had any significant effect on growth in any year. The first year's growth, 1995–1996, showed only a slight trend for effect of N ($p = .08$) but the overall analysis was not significant (GLM $F = 1.15$, $p > .33$). The trend disappeared in subsequent years. However, topography conspicuously affected growth. This experiment occupied three undulating ridges and valleys, with steep slopes between. Growth was best in the valleys and worst on the ridges.

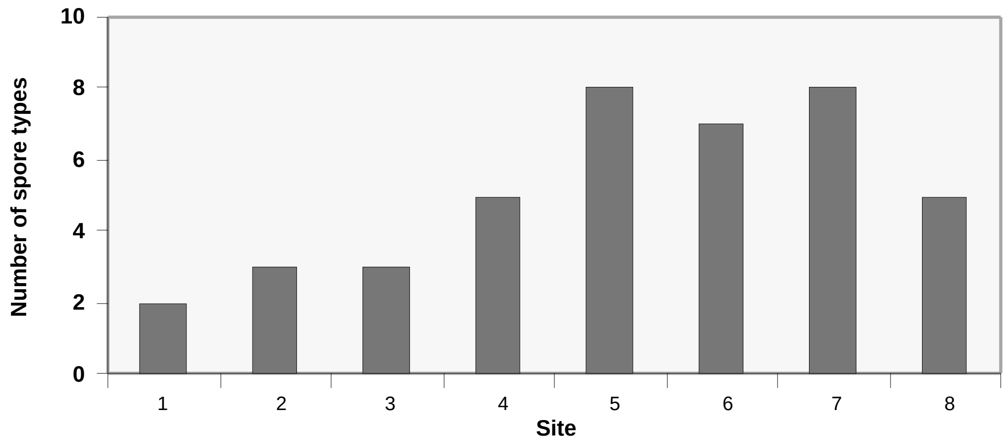
Mycorrhizal potential (Experiment 4)

Mycorrhizal inoculum potential did not correlate with degree of erosion except to approach zero in the two most deeply eroded sites (Figure 2A). One of these sites was the bulldozed site mentioned above. The other site was an area where cattle always had congregated when being herded off the farm, and was deeply cut by cattle trails. Neither of these sites contained rhizospheres of plants.

However, the *diversity* of mycorrhizal spore types was inversely related to degree of erosion ($p < .01$, Figure 2B), which in turn was negatively correlated with growth in Experiment 1.



A. Mycorrhizal inoculum potential



B. Spore diversity

Figure 2. Relationship between land management and mycorrhiza. Sites range from the most deeply eroded (1 and 2) to the least (8). A. mean mycorrhizal inoculum potential of soils from each site (n=3 samples per site). B. mean number of types of mycorrhizal spores cultured from these samples.

Mycorrhizal inoculation of six native species (Experiment 5)

Five of the six species inoculated with arbuscular mycorrhizal fungi in the nursery responded positively to inoculation (Table 4). All three species of legumes showed positive responses, either in growth (*I. edulis, D. robinioides*) or in survival (*C. calothyrsus*). Two of the three non-legumes showed increased growth (*H. oblonga*) or survival *C. odorata*) when inoculated. The other non-legume, *T. amazonia*, showed no response up to 13 months.

Table 4. Effect of inoculating six native species of trees in the nursery with inoculum of arbuscular mycorrhizal fungi. Data are the Two-way ANOVA p values for: I. Total biomass after four months of growth, based on sums of above- and below-ground biomass on a sacrificed subset of trees; II. Height growth in the remaining trees after six months; III. Survival after 13 months; IV. Height growth in the remaining trees after 13 months.

Type of tree	Species	I.	II.	III.	IV.
Legume	*Inga edulis*	.07*	ns	**ns**	.02
Legume	*Calliandra calothrysis*	ns	ns	**.01**	ns
Legume	*Diphysa robinioides*	ns	.00	**ns**	.01
Non-legume	*Terminalia amazonia*	ns	ns	**ns**	ns
Non-legume	*Cedrela oblonga*	.05	.04	**.00**	ns
Non-legume	*Hyeronima oblonga*	.00	ns	**ns**	ns

*Below-ground biomass responded positively (p=.02).

DISCUSSION

Clearly, many factors determined the success of our reforestation efforts.

Importance of species

Tree species was crucial. We performed several experiments with *T. amazonia*, which showed good survival throughout most areas and in all experiments. However, this species grew poorly in many areas. This species was intermediate in success across the farm, proving inferior to pine and *V. hondurensis* but superior to four other species, at least in the first years of growth.

Although almost all *T. ochracea* died, experiments established in 2001 on its shade requirements are suggesting so far that this species needs shade. We also have noticed that *C. brasiliense* has begun to grow more rapidly now that neighboring trees offer some shade. Both of these species are members of primary forest and might not be obvious to use in reforestation schemes. However, both are valuable tropical hardwoods and worth further study.

One possible technique to improve the performance of both of these species would be to interplant them with a fast-growing species that can quickly provide shade, or to plant them in second growth. In fact, since both pine and *C. brasiliense* performed well in some of the worst areas on the farm, a mixture of these two species might be a good way to begin reforesting the most degraded areas in a region.

Spatial patterns of growth across the farm differed among species. Two species, the pine and *C. brasiliense*, showed predictable growth regardless of area, which is a desirable characteristic of species to be used in reforestation projects. The pine species we used, *P. tecunumanni*, is a middle-elevation species that is native as far south as Nicaragua. A different tropical pine, *P. caribaea*, is a lowland species that has been used in forestry in Central America and to jump-start succession in Puerto Rico (Lugo). It also can do well on degraded sites. Pines in general may hold promise as a first species to plant to help moderate the extreme conditions of some degraded lands.

Results for *Terminalia amazonia*

Although *T. amazonia* did not perform the best in the tree trial experiment, it produces valuable wood and does grow well under some circumstances. What are those circumstances, and how can we grow it better?

First, to date, no evidence exists that would recommend fertilizing this species with inorganic fertilizer. Addition of P did not improve performance of 15 species of native trees on a P-fixing volcanic soil in Ecuador (Davidson *et al*. 1998). The lack of effect of 10-30-10 fertilizer in our 1993 experiment on *T. amazonia* was supported by our 1995 experiment in which we applied each mineral separately in two concentrations. Growth of this species was unrelated to any of the soil chemical factors measured at the beginning of the 1993 experiment, including N (Nichols *et al*. 2001). These negative results may also explain why this tree species does not seem to respond to inoculation with mycorrhizal fungi since the mutualism primarily helps plants obtain phosphorus. Perhaps this tree species simply has very low requirements for the macronutrients.

On the other hand, Nichols *et al*. (1997) found that performance of *T. amazonia* in plantations improved with soil nitrogen availability. Consistent with this result was the fact that we found interplanting *T. amazonia* with certain legume trees, especially *I. edulis*, improved performance of the former. The effect increased with time, which is not surprising as the impact of the nitrogen fixation of a legume tree probably increases as its biomass increases. We are now testing the impact of an organic form of nitrogen fertilizer, urea. The practice of interplanting this species with legume trees needs to be studied in more detail, including determining legume species to be used as well as optimal spacing of both timber tree and legume. The practice of using legume trees to “nurse” timber trees is not new. Various studies have shown their value (e.g. Kumar 1998).

Seed mother strongly affected performance, so plantations should definitely include a variety of provenances until genetic superiority can be selected.

Spatial heterogeneity of tree performance

Tree performance varied spatially in all field experiments. In tree trials, four of the six species that survived showed much greater growth in some areas than in others. In the fertilization experiment on *T. amazonia*, topographical effects may have swamped any fertilizer effects. And in the experiment testing the effect of legumes on *T. amazonia*, block effect explained twice as much variance in tree growth as did the experimental treatments. Blocking had originally been based upon topography and degree of erosion.

The very worst growth and survival occurred in areas that had been bulldozed or deeply cut by cattle trails in the past. Bulldozing has been shown to arrest succession in Brazil (Nepstad *et al*. 1991). In general, we found that growth was poor on ridges and on exceptionally steep and eroded slopes. Particularly problematic was poor performance on ridges, not just in *T. amazonia* but in all species except pine; yet ridges are not deeply eroded. Lack of moisture could explain this result in many regions of the world, but rainfall and humidity are so high in our site that this factor is unlikely to explain our patterns. We are currently examining the possibilities that ridges could be unusually compacted or devoid of mycorrhiza.

Growth was best on gentle slopes or in shallow valleys between slopes, which are both areas subject to less erosion. Also, valleys can capture runoff from steep slopes that might contain both nutrients and mycorrhizal inoculum. However, since many of our results showed no relationship between growth and availability of mineral nutrients,

nutrients may not be the most important factor. Topographical effects could instead be partly explained by heterogeneous occurrence of mycorrhizal communities.

Possible importance of arbuscular mycorrhizal fungi

In some studies, mycorrhizal fungi have been shown to aid regeneration of tropical forest trees (Alexander *et al*. 1992). Most neotropical trees are symbiotic with arbuscular mycorrhizal fungi rather than with ectomycorrhizal fungi. Tree species differ in their dependency on the relationship (Janos 1996). In some ecosystems the diversity of mycorrhizal fungi is an experimentally demonstrated factor increasing plant species diversity and plant productivity (van der Heijden *et al*. 1998).

In the most deeply eroded areas on our study site, both mycorrhizal inoculum potential and diversity of spore types are low. Even in less deeply eroded areas, spore type diversity decreases linearly with degree of erosion. Both mycorrhizal factors, diversity and density, could be important in tree growth, since most of the tree species that we tested showed positive reactions in the nursery to inoculation with a diverse inoculum. The lack of response of the one species (*T. amazonia*) may reflect premature testing. In other words, the relationship is a mutualism costing plants photosynthate in exchange for nutrients. In early growth, sometimes this cost exceeds or equals the benefit to seedlings, and no positive response in the trees can be detected for several months or even years (Ricardo Herrera, personal communication).

Alternatively, *T. amazonia* may need types of mycorrhizal fungi not included in our inoculum. Some plants are known to perform better with some types than with others (van der Heijden *et al*. 1998). Or, this tree species may simply not need the mutualism to do as well as it does in degraded land.

Still to be determined is the impact of inoculation in the field, and whether mycorrhizal communities destroyed by land mismanagement can be restored. The areas of exceptionally poor tree growth that had been bulldozed in the past or eroded to bedrock probably had their soil community completely removed. These sites contained no rhizospheres of any plants, so the fungi lacked any host material for colonization and subsequent propagule formation. These two sites also have subsequently failed to produce reasonable tree growth by any of the species we have so far tried. We currently have several experiments testing if mycorrhiza can be re-established in such areas, and if so, whether this feat results in improved tree growth.

CONCLUSION

At this point, we can make some recommendations for restoration practices as well as for future research:

- Choose your species carefully. Experiment with different possibilities for your site. Some species that would seem unsuitable, such as slow-growing late successional species, might actually do well in the most degraded areas.
- Consider planting pine in the most difficult areas to provide shade for other trees planted simultaneously or subsequently.
- Determine which nitrogen-fixing legumes can establish, because legumes can not only increase soil nitrogen but are also usually mycorrhizal and may re-establish soil communities.

- Inorganic fertilizer may be a waste of money and effort. Experiment with organics.
- Seed provenances of native species show variable performance; if the species you are using has not been selected for genetic superiority, use seedlings from several mother trees.
- Investigate nursery practices that yield superior performance once trees are outplanted. Examples might be to determine if collecting seeds at the peak of seed production in the field could improve later performance. Experiment with mycorrhizal inoculation in the tree nursery.
- Ridge tops may be recalcitrant. Try your hardiest tree species, perhaps pines. Investigate which characteristics of ridges differ from slopes and valleys and cause reduction in tree performance.
- The key to improving performance in extremely degraded areas in high rainfall areas is probably to slow erosion and increase soil organic matter. Increased SOM is associated with more mycorrhizal fungi as well as with organic forms of nutrients. Mulch if at all feasible.
- Research on the role of mycorrhizal fungi in reforestation of degraded lands is needed.

In sum, one should expect great spatial heteogeneity in tree performance, even if using a single hardy species. Improving the recalcitrant areas within the overall degraded landscape is one of our primary challenges.

REFERENCES

Alexander, I., Ahmad, N. & Lee, S.S. 1992. The role of mycorrhizas in the regeneration of some Malaysian forest trees. *Philosophical Transactions Royal Society London* B, 335: 379–388.

Bhasin, K. 2000. Performance of native and non-native tropical trees in reforestation of degraded pasture. *Journal of Undergraduate Research in the Biological Sciences*. Irvine, USA, University of California.

Carpenter, F. L., Mayorga, S. P., Quintero, E. G. & Schroeder, M. 2001. Land-use and erosion of a Costa Rican Ultisol affect soil chemistry, mycorrhizal fungi and early regeneration. *Forest Ecology and Management* 144: 1–17.

Davidson, R., Gagnon, D., Mauffette, Y. & Hernandez, H. 1998. Early survival, growth and foliar nutrients in native Ecuadorian trees planted on degraded volcanic soil. *Forest Ecology and Management* 105: 1–19.

Gonzalez, E.J. & Fisher, R.F. 1994. Growth of native forest species planted on abandoned pasture land in Costa Rica. *Forest Ecology and Management* 70: 159–167

Haggar, J.P., Briscoe, C.B. & Butterfield, R.P. 1998. Native species: a resource for the diversification of forestry production in the lowland humid tropics. *Forest Ecology and Management* 106: 195–203.

Holdridge, L.R. 1967. *Life zone ecology*. Rev. edn. San Jose, Tropical Science Center.

Janos, D.P. 1996. Mycorrhizas, succession, and the rehabilitation of deforested lands in the humid tropics. *In* J.C. Frankland, N. Megan & G.M. Gadd, eds. *Fungi and environmental change*, pp. 129–162. Cambridge, UK, Cambridge University Press.

Kumar, B.M. 1998. Intercropping teak with *Leucaena* increases tree growth and modifies soil characteristics. *Agroforestry Systems* 42: 81–89.

Nepstad, D.C., Uhl, C. & Serrao, E.A.S. 1991. Recuperation of a degraded Amazonian landscape: forest recovery and agricultural restoration. *Ambio* 20: 248–255.

Nichols, J.D., Gillespie, A.R. & Richter, D.D. 1997. Growth and foliar nutrient status of *Terminalia amazonia* in 25 plantations in Costa Rica. *Journal of Tropical Forest Science* 10: 233–248.

Nichols, J.D. & González, J.E. (eds.). 1992. *Especies nativas y exóticas para la reforestación en la Zona Sur de Costa Rica*. San Jose, Costa Rica. Organización para Estudios Tropicales y Dirección General Forestal, Editorial Universidad Estatal a Distancia. 73 pp.

Nichols, J.D., Rosemeyer, M.E., Carpenter, F.L. & Kettler, J. 2001. Intercropping legume trees with native timber rapidly restores cover to eroded tropical pasture without fertilization. *Forest Ecology and Management* 152: 195–209.

van der Heijden, M.G.A., Klironomos, J.N., Ursic, M., Moutoglis, P., Streitwolf-Engel, R., Boller, T., Wiemken, A. & Sanders, I.R. 1998. Mycorrhizal fungal diversity determines plant biodiversity, ecosystem variability and productivity. *Nature* 396: 69–72.

7 Growth of subtropical rain forest trees planted on degraded farmland in eastern Australia

Kevin Glencross* and J. Doland Nichols**

ABSTRACT

Before European settlement, subtropical rain forests were found on moist volcanic landscapes along the coast of eastern Australia. These complex forests contained high value timbers that were rapidly exploited. Much of these forests were then cleared for agriculture, resulting in significant degradation of land and water resources. Australian rain forest trees are now being re-established on cleared agricultural land for environmental and economic benefits. The assessment of the early growth of young rain forest trees in plantation has been carried over a five-year period by the Subtropical Farm Forestry Association (SFFA). The plantings are located across fourteen ex-rain forest sites in northeastern New South Wales (NSW). Data were collected initially in 1996–97, and the same trees were measured again in September 2000. The plantations contain a mixture of over twenty species; from the data nine species have been selected for analysis of growth performance. Each of the nine species produces very highly sought-after timber, and has a long history of high value utilization. The growth performance of 1 265 trees has been assessed with regard to survival, tree height, stem diameter, bole length, canopy diameter and qualitative assessments of the stem form. The preliminary analysis of these data has identified four species with good survival and growth rates from these early stages, on well managed sites. Among the more successful species are Elaeocarpis grandis (2.0 m y^{-1} mean annual height increase), Flindersia brayleyana (1.7 m y^{-1}), Grevillea robusta (1.5 m y^{-1}) and Flindersia schottiana (1.4 m y^{-1}).

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INTRODUCTION

Subtropical rain forests occur in patches along the coast of eastern Australian from southern New South Wales (NSW) to the uplands of far north Queensland (36°S to 17°S) (Floyd 1989). Subtropical rain forests are regarded as rich and complex, in terms of species diversity and structure (Kooyman 1996). The moist, volcanic landscapes of eastern Australia have served as a refuge for these dense, closed forests for the last 100 million years. It was in these ancient rain forests that the unique flowering plants of the southern continent evolved and flourished (White 1994).

Subtropical rain forests grew on landforms created by the volcanic activity during the mid- to late-Tertiary, about twenty million years ago. The weathered basalt lava produces a krasnozem soil of good fertility and water holding capacity. These rich basalt derived soils supported complex forests characterised by trees with plank buttressing, compound leaves, and dense canopies often covered with epiphytes and woody vines (Webb 1978).

Subtropical rain forests are defined as ecologically diverse in terms of species and life forms they support (Floyd 1989). Specht *et al.* (1995) suggest that the lowland subtropical forests contained around 90 species of plants per ha. The loss of species resulting from clearance of subtropical rain forests has been significant, with over 110 rare and endangered rain forest plants in NSW alone (Allworth 1985). Subtropical rain forests grew in relatively small areas that were unique across the dry, harsh Australian landscape. The high rainfall (over 1 300 mm) and deep soils that supported these rain forests were of great interest to the earliest European settlers (Webb 1985). On subtropical sites, removal of the forest cover and high rainfall have resulted in nutrient leaching and very high rates of soil loss, up to 300 tonnes $ha^{-1}y^{-1}$ (Bird *et al.* 1992). The soils, especially on the slopes, where the tallest trees grew, soon lost their fertility and became infested with weeds (Webb 1985). Unfortunately, this situation is common across the rain forest lands of the world.

The largest area of subtropical rain forests in Australia, referred to as the "Big scrub", originally occupied 75 000 ha on the rich coastal plateau's and river valleys of north eastern NSW (NPWS 1997). Much of the original rain forests was cleared and burned to make way for agriculture from 1860 to 1900; now only 100 ha or 0.13% of the "Big Scrub" remain in small, isolated and vulnerable relics (NPWS 1997).

Increasing community interest in rain forest regeneration has stimulated a number of trial plantings on cleared ex-rain forest land in eastern Australia (Kooyman 1996, Herbohn *et al.* 1999), particularly in the Big Scrub area. In northern NSW, investigations into the commercial farm forestry sector indicate that a small number of innovative landowners are planting trees for both environmental and economic reasons (Emtage & Specht 1998). These plantings are generally small areas (less than 5 ha), usually containing a range of species in intimate mixtures.

In northeastern NSW and Queensland the rain forests contained some of the finest furniture species found anywhere in the world. Despite this very high value and market demand, rain forest cabinet timber trees have been largely ignored as potential plantation species (Russell *et al.* 1993). From the 150 commercial rain forest timber species (Sewell 1997), only two species have been widely planted to date, hoop pine (*Araucaria cunninghamii)* and silky oak (*Grevillea robusta)* (Borshmann & Lamb 1998). A relatively small number of forestry research papers have been published on the potential of rain forest trees for timber production and ecological regeneration (Cameron & Jermyl 1991, Russell *et al.* 1993, Harrison 1996, Keenan 1996, Applegate & Borough 1998, Lamb

1998, Ibell *et al.* 2001). Research on lesser known subtropical rain forest species is essential if growers are to design successful restoration or agroforestry timber production systems.

A key research focus for Southern Cross University (SCU) and Subtropical Farm Forestry Association (SFFA) has been on developing commercially viable, high value, mixed-species systems on private land. Our understanding of the dynamics of these complex, mixed species rain forest plantation systems remains underdeveloped at present (Borshmann & Lamb 1996). Growers still lack sound scientific data from which to base planning and management decisions. Southern Cross University and the SFFA have been developing a database which seeks to assess early growth from mixed species rain forest plantations (Specht *et al.* 1999, Glencross *et al*. 2001) The objective of this study is to assess the survival and early growth of nine rain forest species across a variety of sites and conditions. The aim is to determine which species are most suitable for plantation and reafforestation programmes on degraded subtropical sites.

METHODS

Fourteen sites were included in this assessment, planted between 1994 and 1996, chosen from a total of 19 sites monitored by the SFFA. The selection of the 14 study sites was made on the basis of adequate replication of target species and suitability of the sites for establishment of rain forest species. The monitoring programme was conducted over two separate rounds by SFFA extension staff and university students. Initial measurements were undertaken in October 1996 and December 1997, with a further round of measurement carried out in August and September 2000.

The sampling strategy was designed to sample across any environmental gradients that may influence growth across the site (e.g. changes in soil type, slope, aspect and management). Measurement of individual trees along the permanent plots was carried out by the SFFA using standard forestry measurements of diameter of the stem at breast height (DBHOB (cm)—1.3 m above ground), height (m), and height to lowest live branch (free bole height) were recorded. Additional measurements of the diameter of the canopy, and a qualitative assessment of the form of the tree were also collected. The form of the tree stem was classified into one of three categories: 1—poor (crooked or multi-stemmed), 2—fair (slightly curved), 3—good (straight–very straight).

The analysis of growth was carried out on nine subtropical rain forest species. Each of the species assessed required a minimum of 100 individuals to be measured (Table 1). This requirement reduced the number of species assessed from the 24 total species present to 9 species. In all 1 265 individual trees were measured.

Tree survival was recorded for each species and shown as a percentage of total individuals planted (Table 1). Age differences between individual trees was standardised by calculating a mean annual increment in height (m y^{-1}), canopy growth (m y^{-1}) and diameter (DBHOB) (cm y^{-1}) for each of the nine species.

RESULTS

The number of trees from each species that survived to five years is given as a survival percentage (Table 1). Those species with highest survival rates were Queensland maple (*Flindersia brayleyana)* 97.5%, silver quandong (*Elaeocarpis grandis*) 94.7%, cudgerie (*F. schottiana)* 93.0%, and white beech (*Gmelina leichhardtii)* 90.4%.

Table 1. Species total number, distribution across sites and survival

Species	Common name	Total no. individuals (n)	No. sites	Dead	Survival %
Araucaria cunninghamii	Hoop pine	135	10	13	90.2
Elaeocarpis grandis	Silver quandong	151	11	8	94.7
Flindersia australis	Crows ash / teak	135	11	22	83.7
F. brayleyana	Queensland maple	120	8	3	97.5
F. schottiana	Silver ash / cudgerie	172	12	12	93.0
Gmelina leichhardtii	White beech	104	8	10	90.4
Grevillia robusta	Southern silky oak	181	13	18	90.0
Melia azedarach	White cedar	117	7	28	76.0
Rhodoshphaera rhodanthema	Deep yellowwood	150	11	25	83.3

Mean annual height increment (MAHI m y^{-1})

Mean annual height increase was calculated for each of the nine rain forest tree species across the 14 sites (Table 2). The better performing species, across all sites, were silver quandong with just over 2 m mean height increase per year (my^{-1}) to year five, Queensland maple with 1.7 m y^{-1} and silky oak 1.55 m y^{-1}.

Table 2. Growth increment in height (m y^{-1}), diameter (cm y^{-1}), canopy (m y^{-1}) and form

Species (MAHI m y^{-1})	Species code	Mean annual height increment-metres/year (m y^{-1})				Diameter DBHOB (cm y^{-1})	Canopy Dia (m y^{-1})	Form
		Mean (m y^{-1})	St. Dev.	Worst site	Best site			
Araucaria cunninghamii	Ac	0.97	0.52	0.24	1.51	0.9	0.6	good
Elaeocarpis grandis	Eg	2.01	0.86	1.02	3.51	1.8	1.3	good
Flindersia australis	Fa	0.6	0.31	0.52	0.71	0.5	0.3	poor
F. brayleyana	Fb	1.71	0.73	0.72	2.31	1.2	0.7	fair
F. schottiana	Fs	1.41	0.76	0.44	2.09	1	0.7	fair
Gmelina leichhardtii	Gl	1.08	0.54	0.42	1.42	0.9	0.7	good
Grevillia robusta	Gr	1.55	0.64	0.91	2.26	1.4	0.7	fair
Melia azedarach	Ma	0.61	0.36	0.13	0.84	0.7	0.5	poor
Rhodoshphaera rhodanthema	Rr	1.08	0.49	0.41	1.65	1.3	0.9	poor

The annual height increases at the best and worst sites are also shown (Figure 1) to give an indication of the variation in growth performance for each species. *Eleaeocarpis grandis* (silver quandong) grew the fastest across all sites with over 1 my^{-1} on the worst site, a mean height increment of 2 my^{-1} across all sites, and on the best site grew 3.5 m y^{-1}. *Flindersia australis* generally grew slowly, and early growth does not seem to be affected by increases in site quality. Mean tree heights for all species at five years of age are presented in Figure 2. Four species, *E. grandis* (10.1 m), *F. brayleyana* (8.55 m), *Grevillea robusta* (7.75 m) and *F. schottiana* (7.05 m) showed good early height growth.

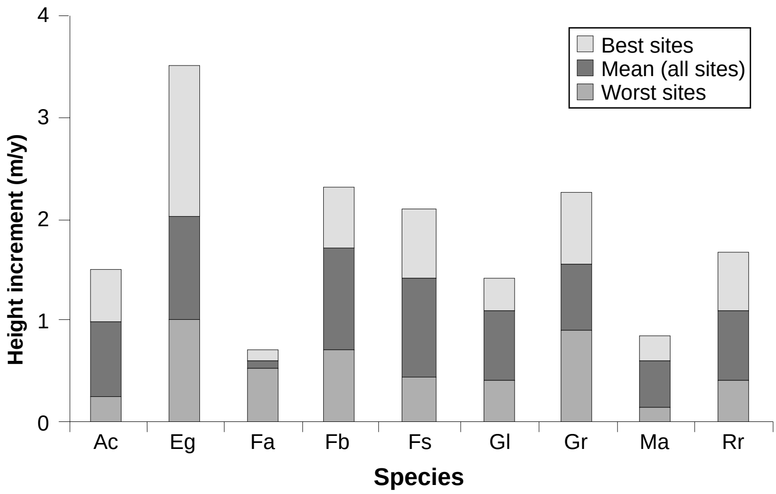

Figure 1. Mean annual height increments (my^{-1})

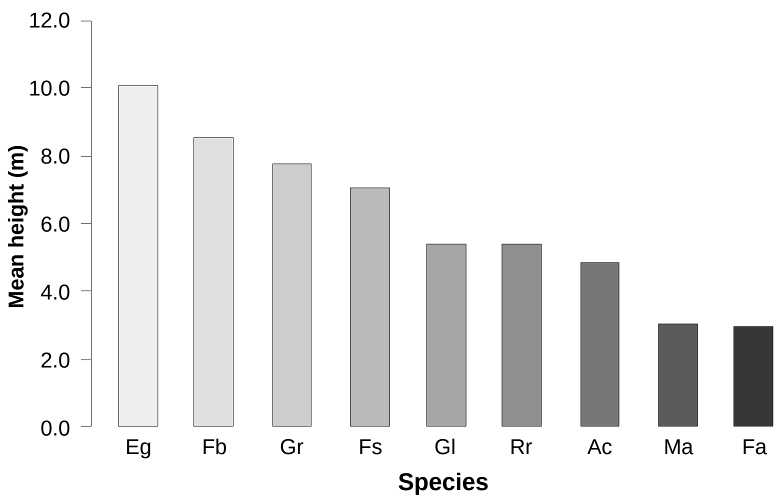

Figure 2. Mean heights at five years (m)

Mean annual diameter increment (DBHOB cm y^{-1})

The mean annual increase in the mean stem diameter (cm y^{-1}) at breast height (DBHOB 1.3 m) for each species was calculated across all sites and is shown in Table 2. Mean stem diameter for each species at five years of age is shown in Figure 3. Again, silver quandong had the largest mean diameter of 9 cm at five years, *G. robusta* 7 cm, *Rhodoshpaera rhodanthema* 6.5 cm and *F. brayleyana* 6 cm. The poorest performing species in diameter at five years was *F. australis* with only 3 cm.

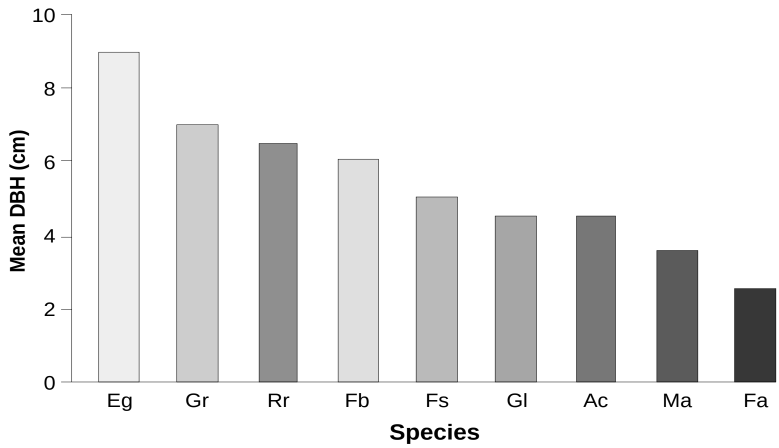

Figure 3. Mean stem diameters at breast height (cm) at five years

Canopy growth

Growth in the diameter of the canopy was measured for each species over the five- year period and has been shown as an annual increase (m y^{-1}) (Table 2). The species with the most rapid canopy growth were *E. grandis* (1.3 m y^{-1}), *R. rhodanthema* (0.9 m y^{-1}) and *F. brayleyana* (0.75 m y^{-1}). The mean canopy radius for each species at five years of age is shown (Figure 4).

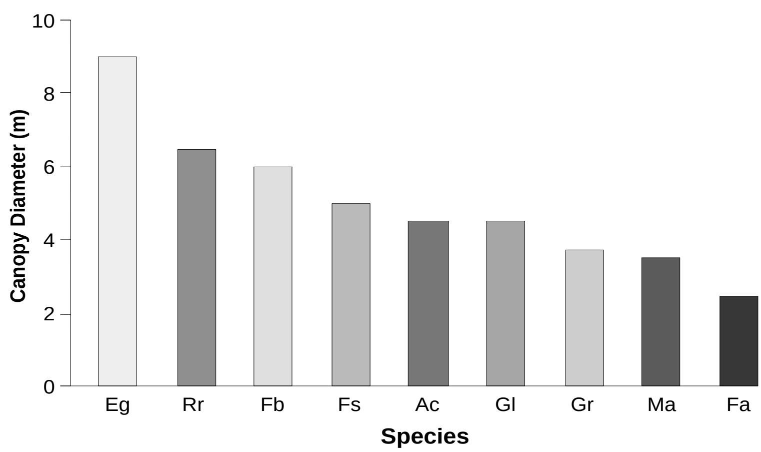

Figure 4. Mean canopy diameters (m) at five years

Form

A qualitative assessment of tree form indicates stem straightness and degree of low branching, both of which will influence timber production potential. Individuals from each species has been classified into one of three classes: poor, fair or good (Figure 6). The species with the best form were *Araucaria cunninghamii* (64% good), *G. leichhardtii* (55% good), and *E. grandis* (54% good). The species with the poorest form was *Melia azedarach* (2% good).

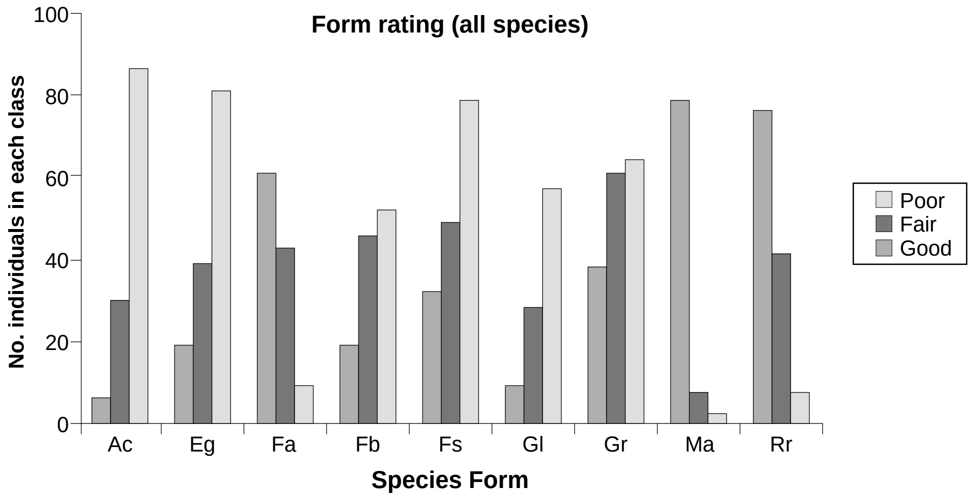

Figure 5. Form classification for each species

DISCUSSION

The planting of a range of native rain forest trees on cleared agricultural land in subtropical areas of eastern Australia has the potential to provide environmental and economic benefits (Keenan 1998). If growers are to design and manage successful restoration or agroforestry timber production systems it is essential that they receive research support to assist in the decision-making process. Unfortunately, research on lesser-known subtropical rain forest species is not well developed at present. Concerns over the large-scale clearance of rain forests has created interest in replanting suitable species on these degraded sites. This assessment of nine rain forest species growing across northeastern NSW may provide some indication of suitable species for plantation and reafforestation projects on ex-rain forest sites.

The inputs required to re-establish trees are very significant in terms of capital, labour, and on-going maintenance and opportunity costs. Therefore, it is critical to ensure that planted trees will have the ability to survive and grow well in the early stages after establishment. When planting rain forest trees on cleared, degraded farmland, care needs to be taken to ensure the species selected are able to tolerate the often harsh conditions. Of the nine species assessed, six had survival rates over 90%, and three species have shown very good survival rates, most notably *F. brayleyana* (97.5%), *E. grandis* (94.7%) and *F. schottiana* (93.0). The species with the poorest survival was *M. azadarach* (76%).

Four species have performed well in terms of tree height and diameter growth at five years of age. The best performers at this stage were *E. grandis* (10 m tall and 9 cm DBH), *F. brayleyana* (8.4 m tall and 6.5 cm DBH), *G. robusta* (7.7 m tall and 7 cm DBH) and *F. schottiana* (7 m tall and 5 cm DBH). Rapid early growth is very important for both successful restoration and timber production. However, timber production potential is also influenced by the form of the stem, and when this is taken into consideration, *E. grandis* combines good growth with good form.

Hoop pine (*A. cunninghamii*) is the only native Australian rain forest tree to be planted commercially and in this assessment it performed very well in terms of form. The sample trees experienced slow early growth to five years of age, with a mean tree height of only 5 m across all sites and 1.5 m y^{-1} on the best site. Slow early growth is characteristic of this species; however, the growth performance over the medium to long term of this species has been generally good (Russell *et al.* 1993).

The diameter growth of *G. robusta* and *R. rhodanthema* is relatively good, and these species may be desirable for restoration plantings. The poor form of these species, especially *R. rhodanthema*, reduces the suitability for timber production unless significant management (pruning), is to be carried out.

When good site preparation and plantation management are applied to rain forest species, the growth response can be very promising. On the best site *E. grandis* was able to record a mean height increase of 3.5 m y^{-1} at five years. *Elaeocarpis grandis* was also the fastest-growing species on poor sites with height increment of 1 m y^{-1}. The strong growth across the range of site conditions indicates this species is very promising. The growth of the canopy diameter of *E. grandis* on the well managed sites was over 1.5 m y^{-1}. This rapid growth of the canopy is highly desirable if managers wish to achieve site capture (canopy closure) early in the plantation cycle.

Site capture reduces weed competition and provides improvements in microclimate, that in turn facilitates growth (Kooyman 1996). Shading and root development provide environmental benefits through the protection of the soil and drainage features from erosion. Rapid early growth and site capture also generate ecological benefits by providing suitable habitat and resources such as flowers, fruit and nesting sites in the shortest possible time. The creation of shade and perches for seed vectors facilitates the recruitment of other rain forest species.

Over the period of the study, the eastern Australian coast has experienced difficult climatic conditions, with a very severe drought (1993–94) in the period leading up to the planting and historically low rainfall for a number of years (1998, 2000). The deep red soils of the 'Big Scrub' are well drained and soil moisture levels may have reduced early growth and survival.

CONCLUSION

The growth data give an indication of the performance of the nine rain forest species across fourteen sites, and over a number of environmental gradients. The growth, survival rates and canopy structure of the various species are useful in assisting in plantation design and management decisions. The growth rates in combination with good stem form are of particular interest to farm foresters who would like to engage in commercial timber production. The most promising species was *Elaeocarpis grandis*, with rapid early growth, good form and survival rates.

REFERENCES

Allworth, D. 1985. *In* L. Meier, *Rain forests of Australia.* Sydney, Australia, Weldon Press.

Applegate, G. & Borough, C. 1998. *Silvicultural management of rainforest plantations*. Australian Forest Growers Conference. Lismore, NSW, Australia.

Bird, P.R., Bicknell, D., Bulman, P.A., Burke, S.J.A., Leys, J.F., Parker, J.N., Van der Sommen, F.J. & Voller, P. 1992. The role of shelter in Australia for protecting soils, plants and livestock. *In* R.T. Prinsley, ed. 1993. *The role of trees in sustainable agriculture*, pp. 59–86. Dordrecht, Kluwer Academic. Reprinted from *Agroforestry Systems* 20: 1992.

Borschmann, G. & Lamb, D. 1996. Plantation performance of 16 rain forest cabinet timber trees grown in polyculture. *The Australian Forest Grower*. Vic, Australia.

Cameron, D.M. & Jermyl, D. 1991. *Review of plantation performance of high value rain forest tree species*. Brisbane, Australia, CSIRO Division of Forestry and Queensland Forest Service.

Emtage, N. & Specht, A. 1998. *Landholders' perceptions of farm forestry in the Northern Rivers region of NSW*. Australian Forest Growers Conference. Lismore, NSW, Australia.

Floyd, A.G. 1989. *Rain forest trees of mainland south-eastern Australia,* Sydney. INKATA Press.

Glencross, K.S., Nichols, J.D. & Bailey, M. 2001. Comparative early growth rates of some subtropical rainforest tree species and assessment of potential economic returns. *Subtropical Farm Forestry Association Newsletter*. November 2001. Corndale, NSW.

Harrison, S.R. 1996. Small scale farm forestry of native cabinet timbers in North Queensland. *Managing and Growing Trees Training Conference*. Vol. 1: 45–56.

Herbohn, J.L., Harrision, S.F. & Emtage, N.F. 1999. Potential performance of rainforest and eucalypt cabinet timber plantations in North Queensland. *Australian Forestry.* Vol. 62, No. 1.

Ibell, P., Glencross, K., Palmer, G. & Atyeo, B. 2001. *A preliminary study of the timber properties of Elaeocarpis grandis thinnings from an eight-year-old, mixed species plantation*. 27th CSIRO Forest and Wood Products Conference, Melbourne, November 2001.

Keenan, R. 1996. *Mixed species rain forest plantations in North Queensland: operational experience and research results*. Managing and Growing Trees Training Conference. QLD, Australia.

Keenan, R. 1998. *Farm forestry in the tropics: potential and pitfalls*. Australian Forest Growers Conference. Lismore, NSW, Australia.

Kooyman, R. 1996 *Growing rain forest: rain forest restoration and regeneration.* Brisbane, Greening Australia.

Lamb, D. 1998. Large-scale ecological restoration of degraded tropical forest lands: the potential role of timber plantations. *Restoration Ecology* 6(3): 271–279.

NPWS. 1997. *The 'Big Scrub' management strategy.* Alstonville, New South Wales, National Parks and Wildlife Service.

Russell, J.S., Cameron, D.M., Whan, I.F., Beech, D.F., Prestwidge, D.B. & Rance, S.J. 1993. Rain forest trees as a new crop for Australia. *Forest Ecology and Management* 60: 41–58.

Sewell, A.J. 1997. *Australian timbers, Volume one. Commercial timber species of eastern subtropical Australia*. Brisbane, QLD, Department of Natural Resources.

Specht, A., Nichols, J.D., Vanclay, J., Parkes, A., Luxford, D., Luxford, J., O'Brien, J. & Glencross, K. 1999. *Assessment of mixed-species plantings on the north coast of New South Wales*. Presented at Meeting of Institute of Foresters of Australia, Hobart, Tasmania, Oct 4–8, 1999.

Specht, R.L., Specht, A., Whelan, M.B. & Hegarty, E.E. 1995. *Conservation atlas of plant communities in Australia.* Lismore, Centre for Coastal Management, Southern Cross University Press.

Webb, L.J. 1978. A general classification of Australian rainforests. *Australian Plants* 9: 349–63.

Webb, L.J. 1985. In L. Meier, *Rain forests of Australia.* Sydney, Australia, Weldon Press.

White, M.E. 1994. *After the greening.* Sydney, Australia, Kangaroo Press. 47 pp.

8 Local knowledge on indigenous trees: towards expanding options for smallholder timber tree planting and improved farm forestry in the Philippine uplands

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ABSTRACT

Tree domestication initiatives, aimed at conserving natural resources as well as providing small-scale farmers with more options for income generation, need to be based on a thorough study of existing knowledge of the range of available tree species. Since previous public and private research has almost entirely focused on improving production of a small number of exotic species, local peoples' needs, priorities, knowledge and practices on indigenous trees need to be further evaluated. These new initiatives are seeking to integrate indigenous trees, which have been traditionally harvested from natural forest, into tropical agricultural systems. The study conducted in eight municipalities in the islands of Leyte and Bohol, Central Philippines, aimed to identify the topmost promising indigenous species for smallholder tree domestication based on the knowledge of farmers as well as suppliers of tree products. The eight study sites were purposively selected to include areas with both existing and non-existing natural forest. Knowledgeable farmers, wood processors and market dealers of tree products were interviewed using a semi-structured questionnaire, followed by focused group discussions. In addition, we collected information on the veneering potential and marketability of farm-grown indigenous tree species among timber industries of

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northern Mindanao. One important component of this approach was the utilization of the Local Ecological Knowledge–Knowledge Base Systems (LEK–KBS), using a computer software application called WinAkt to store and retrieve the information gathered from the local people. This paper emphasises the importance of considering the socio-economic conditions of farmers and the local ecological knowledge in the identification of tree species options with potential for farm forestry and in the development of a farmer-driven tree domestication process.

INTRODUCTION

During the past two decades, the rapid decline of timber supply from natural forests and an increasing domestic demand for wood products have caused a steady increase of timber prices in the Philippines (PCARRD 1994). At the same time, with the widespread adoption of people's oriented forestry programmes, reforestation and tree planting have been promoted as a way to alleviate poverty, increase domestic supply of wood and rehabilitate degraded upland environments. As a result, smallholder farmers have become major timber producers in many parts of the country (Garrity & Mercado 1993).

The farm forestry industry in the Philippines is mostly based on the well-known *Gmelina arborea*, *Paraseriantes falcataria*, and to a lesser extent, *Acacia* sp. and *Eucalyptus deglupta*. Because of their excellent growth rates and the favourable market conditions, these species were promoted as "the million-Peso trees" and farmers were promised high economic returns in short periods. However, in recent years as more trees become mature, prices for farm-grown timber have decreased due to market saturation. Consequently, many farmers, not able to realize the expected economic benefits, have discontinued tree production after the first rotation. Similar experiences have been also reported in other parts of the Philippines (Caluza 2002) and elsewhere (Saxena 1991).

Market instability and other risks faced by timber tree farming (e.g. poor growth rates) can be ultimately attributed to the promotion of "undifferentiated tree planting" (Raintree 1991). As in traditional plantation forestry, species selection for smallholder farm forestry has been determined only by the tree's attributes (e.g. fast growth), without due consideration to other biophysical, socio-economic and cultural factors that condition tree planting in the smallholder context. Therefore, to avoid further disappointments and realize the full economic and environmental benefits derived from tree farming, there is a need to develop a range of tree options that considers the needs, priorities and knowledge of planters, manufacturers and consumers.

Recently, research and development institutions in the Philippines recognized the ecological and economical value of indigenous tree species (Roshetko & Evans 1999), and have emphasized the importance of their future production on private smallholder farms rather than in large plantations. Smallholder tree planting systems are generally more successful than large-scale reforestation schemes, because these small-scale tree growing activities benefit from intensive management over a limited area and suit farmers' desire to profit from the investment of time and resources. Field evidence also suggests that there is a great potential to expand and promote a wider range of alternative tree species that are more appropriate to the smallholder context. On degraded landscapes indigenous trees are deliberately protected and nurtured on farms. Farmers manage their number and value the tree products for household consumption, the market and environmental benefits (e.g. soil fertility, shade). Farmers are also showing an increasing interest on indigenous tree planting, if provided with the right incentives and some support.

In several upland municipalities of northern and central Mindanao, a farmer-led movement, known as Landcare, that initially focused on the dissemination of soil and water conservation practices, is becoming increasingly active in the collection, propagation and planting of high-value indigenous tree species. Farmer's motivation and initiative to test tree resources and diversify their farming systems are supported by the local government through financial and policy initiatives (Laotoco *et al*. 2002).

In the Philippines, there is a lot of information on recommended indigenous tree species for reforestation, their propagation and management (PCARR 1982, Margraf & Milan 1996a, DENR–ERDB 1998). However, very few tree planting programmes have promoted native trees. Many of these initiatives have failed because they have been based on technical aspects rather than local people's knowledge and necessities. Even in those few encouraging initiatives like the GTZ–VISCA "Rainforestation Farming" (Margraf & Milan 1996b) that have succeeded, there has been a long process in the promotion, propagation, planting and utilization of indigenous tree species on farms.

As suggested by Simons *et al*. (2000) the integration and improvement of trees on farms could be done through a participatory farmer-driven domestication process. The first step of this process should be to determine farmers' and users' priorities, preferences and needs (Franzel *et al*. 1996). As forestry science has traditionally overlooked existing trees of importance to farmers in deforested landscapes, local knowledge on these indigenous trees can be a very useful resource in the development of options that complement the current scientific knowledge focused on a few plantation species (Walker *et al*. 1995). By starting with what farmers already know and practise, it is highly probable that the consequent action or any intervention to be implemented will be acceptable by the users (Joshi *et al*. 2001). Walker *et al*. (1995), as cited by Joshi (2002), indicated that a rigorous analysis of the detailed articulation of farmers' understanding of the ecosystem functioning is one of the ways by which local knowledge is integrated into the scientific knowledge systems. Local ecological knowledge as a method in qualitative research requires depth in the understanding and at the same time the knowledge produced can be systematically stored, formally represented and generalized.

This paper reports the results of research activities aimed at identifying and expanding tree options for smallholder farm forestry by creating a knowledge database on indigenous tree species with high potential for tree farming. We firstly conducted a study on the islands of Bohol and Leyte to determine farmers' perceptions on constraints to indigenous tree planting and to elicit local knowledge on native tree species. Secondly, we collected information from technicians at a plywood company in northern Mindanao on the veneering properties and potential uses of several indigenous tree species commonly grown on farms. Consideration of local knowledge on indigenous tree species may enhance involvement of individuals and farmers' groups in a participatory tree domestication strategy that can realistically provide more appropriate tree options to upland farmers for farm forestry and the re-vegetation of degraded lands.

MATERIALS AND METHODS

The study focused on selected upland villages in eight municipalities of Leyte and Bohol. These islands in the central Philippines are characterized by generally shallow degraded soils and little remaining forest cover (i.e. below the national average of about 20%). The site selection was based on two variables: the existence of remaining natural forest (presence of natural forest as opposed to without natural forest), and the type of soil as characterized by the soil pH (acidic vs. calcareous) (Table 1).

Table 1. Final sites selected for the study

Selection Criteria	Leyte		Bohol	
	Municipality	Village selected	Municipality	Village selected
Calcareous soil—with forest	Hinunangan	Calag-itan	Valencia	Omjon
Calcareous soil—without forest	Tabango	Manlawaan	San Isidro	Baryong Daan
Acidic soil—with forest	Inopacan	Cabulisan & Caminto	Guindulman	Biabas
Acidic soil—without forest	Tomas Oppus	Mapgap	Inabanga	Ilaya

The Darwin Database on Local Knowledge and Biodiversity Conservation (DOF 1998) was used as an initial source of information about identified indigenous trees with economic and ecological importance. The ALICE computer software was used previously as a database tool and will be used to store collected information from the present study, i.e. the existing database will be complemented and amended.

Collection of primary data for the study was done mainly through individual interviews using a semi-structured interview schedule and by conducting focus group discussions (FGD) in selected sites. Actual field observations and collection of herbarium specimens were also done to supplement the interview and FGD data. All of the processors and market dealers within or nearby each focus village or municipality were included in the interview. Processors included chainsaw owners/operators, furniture-makers, lumber-makers, firewood gatherers, charcoal-makers and others. Market dealers were those selling tree-based products in small or commercial quantities (Mangaoang & Lawrence 1998).

In addition, two workshops were held with two experienced technicians from a plywood manufacturing company of northern Mindanao to discuss and collate information on potential uses and marketability of farm-grown indigenous tree species. In an effort to reduce their dependence on imported veneer, the company has tested over the years the veneering properties of some 30 exotic and indigenous lesser-known[1] and lesser-used[2] timber species commonly found on farms. Results from these tests are only observational as there has not been neither proper sampling nor experimental design. However, the results presented are validated by the many years of experience of the key informants in timber processing and marketing.

The LEK study on indigenous trees in Manlawaan and Tabango, Leyte, was a validation of the earlier study by ICRAF. As sketched out by the authors of the LEK—KBS method (Thapa *et al*. 1995), there are four stages in the knowledge acquisition

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[1]According to (Sosef *et al*. 1998):

The term lesser-known indicates that the producers and consumers are unfamiliar with these timbers as sources of veneer.

[2]The term lesser-used denote those species which generally lack market acceptance and utilization though occasionally are used and even traded.

strategy, namely scooping, definition, compilation and generalization. In scooping, the aims of the study were set out, the parameters to be studied were clarified and identification made of who would be interviewed. The definition of the terms to be used was the second stage. Actual knowledge acquisition strategy was carried out in the compilation stage. This was mainly done through the use of participatory rural appraisal tools, such as the focus group discussion (FGD), timeline, species ranking, and key informant interviews. AKT 5 computer software was used to store the knowledge base. The last stage of LEK–KBS was the generalization phase to find out how representative the knowledge base was.

A sample of the population was surveyed to determine the representativeness of the generated knowledge base. In addition, the study utilized field validation to pinpoint where the existing indigenous trees are found and characterized them. It should be noted, however, that the study was focused on those people in the selected sites who were most knowledgeable about indigenous trees and thus, they were not a representative sample of the community they belonged to. On the other hand, according to Joshi (2002), the representation of local people's knowledge as concise, unitary statements:

- reduces ambiguity and misinterpretation
- allows easy access to information
- allows explicit analysis and synthesis of information on related topics
- facilitates rigorous analysis of these unitary statements using techniques of automated reasoning and artificial intelligence
- enables quick updating of knowledge bases in an electronic form by modifying existing statements and by adding relevant new statements

RESULTS

Knowledge, uses and preferences

Around 100 to 200 indigenous timber and fruit tree species were identified in each of the study areas. However, an estimated 10–15% of the species listed by farmers are not truly indigenous. For instance, mango (*Mangifera indica*) and raintree (*Samanea saman*) are considered indigenous because they have been known and used by local people for decades and even centuries (Margraf & Milan 1996a).

Most of the identified indigenous timber species are currently confined to forested areas. Only very few are found in the farms and as such, oftentimes limited to peripheral or roadside planting. The confinement of the premium timber species in natural forested lands could be indicative of their non-domestication for a good number of years.

Economic benefit is the foremost value ascribed to trees/forests. But interestingly, people also duly recognize their ecological values, such as for the hydrologic cycle, microclimatic conditions, soil conservation, as food and habitat for wildlife.

In addition to house construction, post, furniture, boat keel, charcoal and firewood as the main uses of timber trees, farmers have indicated a multitude of other uses such as medicine, beverage, spice, vegetable, forage, organic fertilizer and insect repellent. Specific utility values were associated with particular tree species, notably the medicinal values of trees.

Knowledge on indigenous trees, particularly on tree identification, is affected by the state of the forest resource in the area. It is therefore observed that there is a direct relation between the knowledge base and the stage of degradation of the remaining forest. Farmers' knowledge about indigenous trees is considered as a motivating factor for them to conserve biodiversity.

Molave (*Vitex parviflora*) stood out as the topmost preferred indigenous timber species for cultivation on farm. It is also the most preferred species for furniture-makers, processors and buyers. Its durability and magnificent wood finish were cited as the main reasons for preference. Farmers also favor it because seed is readily available from existing mature trees, and it has medicinal value.

Other top indigenous species selected by farmers include santol (*Sandoricum koetjape*), snislag (*Securinega flexusa),* samod (*Shorea contorta*), sagimsiman (*Syzygium brevistylum*), bayong (*Afzelia rhomboidea*), dalingdingan (*Hopea manquilingensis),* narra (*Pterocarpus indicus),* tagibokbok (*Stemonurus luzonienses),* mayapis (*Shorea palosapis),* hagakhak (*Dipterocarpus warbugii*), toog (*Combretodendrom quadrialatum*) and almon (*Shorea almon).*

The respondents in all sites readily recognized the superior wood quality and durability of indigenous species. The choice for indigenous instead of exotic species had been based on the indigenous trees' durability, wood finishing quality, their medicinal and high economic values. On the other hand, short rotation and availability of planting material were cited as the advantages of exotics.

Constraints to growing indigenous trees

Farmers in all study sites have encountered the following constraints in growing indigenous trees:

- Lack of financial resources to start and maintain tree farming. In the early growing years trees need periodic brushing and weeding around them, which the respondents perceived to be very laborious.
- Lack of technical skills and knowledge about collection and seed germination of indigenous trees. The respondents find it difficult to identify fallen seeds and/ or wildings.
- Long period before trees provide harvestable products. This is also coupled with tenure insecurity since people have no confidence that they are allowed to harvest. In most cases the landlords do not encourage planting of trees on their lands.
- Lack of area that could be devoted to tree cultivation alone due to farmers' concern about tree-crop competition.
- Long or complicated bureaucratic procedures to obtain harvest permits. This may have contributed to the negative impression of farmers about tree farming and plantation establishment programmes of the government.

Processing and marketing aspects

A decreasing trend in the supply of raw materials, especially for premium timber (e.g. molave and marra), is acknowledged in all sites, while the demand for quality furniture products is very high. The strict implementation of the Department of Environment and Natural Resources (DENR) policies against those who illegally cut timber has made it difficult for wood processors to procure raw materials. Hassles in the processing of papers and legalities involved in timber cutting, processing and transport (e.g. high payment for the issuance of a cutting permit involving indigenous trees) had significantly decreased woodcraft production while the demand for its finished products had apparently increased over time (PAWB 1998).

Special arrangements between furniture processors and buyers are often made due to scarcity of available preferred raw materials for a particular product. The buyer himself brings his own raw material for the product that he wants to have manufactured. In this manner the processor avoids the legalities of buying and transporting raw materials from the timber sources. Chainsaw owners are usually paid cash in terms of wood volume by tree owners.

Indigenous trees commonly grown on farms identified as suitable for veneer and sawn timber by technicians at a plywood industry in northern Mindanao are presented in Table 2. Recommendations are based on observations on the wood's peeling, drying and gluing properties, surface finishing and colour qualities.

Table 2. Tree species commonly found on farms that can be used for veneer and sawn timber

Veneer		**Sawn timber**
Face & back	**Core**	
Hinagdong (*Trema orientalis*)	Marrang (*Artocarpus odoratissima*)	Mangolinaw (*Melia dubia*)
Gubas (*Endospermum peltatum*)	Durian (*Durio zibethinus*)	
Antipolo (*Artocarpus blancoi*)	Santol (*Sandoricum koetjape*)	
Binuang (*Octomeles sumatrana*)	Kamansi (*Artocarpus camansi*)	
Loktob (*Duabanga moluccana*)	Balete (*Ficus* sp.)	
Dita (*Alstonia scholaris*)		
Bakan (*Litsea philippinensis*)		
Baono (*Mangifera caesia*)		

DISCUSSION

The findings of the study showed that farmers in rural upland communities in the Philippines have a remarkable knowledge about indigenous trees. This wide range of knowledge is usually associated with the utility value of the tree species, which are more often than not economic in nature. The results also indicated that resource knowledge goes with resource state of degradation, and therefore, without good documentation this knowledge will be lost together with the resource base. Biodiversity loss and ultimately the extinction of germplasm is a serious threat given the continued confinement of the main timber resources in natural forests, their non-domestication and rising population pressure.

Although most of the identified indigenous timber species are currently confined to forested land in the study areas of Bohol and Leyte, an inventory of farm-grown trees conducted on 217 farm plots in Claveria, northern Mindanao, found that 21% of the on-farm timber trees are established as natural regeneration of indigenous species (Bertomeu, forthcoming paper). This could be due to either earlier deforestation in the Visayas than in Mindanao, or to spontaneous tree domestication initiatives in the latter for some reasons that would be worth exploring.

The respondents indicated preferences especially for indigenous timber tree species for on-farm domestication. People consider wood quality as their foremost basis for preference and, accordingly, value the "premium" indigenous species for their domestic use, as well as for their high market value. Despite the introduced bias in the respondent selection, the results of the study still provide a solid springboard for future research and development efforts. Local people undoubtedly acknowledge the ecological and economic superiority of indigenous over exotic species. The fact that farmers commonly associate fast growth and early harvest of products with exotic trees points to the important intermediate role that exotics play in the provision of valuable products and environmental benefits, especially as long as skills and knowledge on indigenous trees are lacking (i.e. in the short term).

To support farmers' tree domestication initiatives, a small-sized local Trust Fund has been recently established with support from the Spanish Agency for International Co-operation (AECI). The Fund is providing incentives in the form of small grants for community-based projects like the collection and distribution of seed and germplasm, nursery establishment and tree planting initiatives. It also provides support to local governments for proper land use and community capacity for forest management planning and incentives for conservation of native vegetation on private lands. The minimal financial support provided by incentive schemes like these could prove appropriate in involving farmers' groups and local communities in the integration of indigenous trees on farms, land restoration and forest conservation. Through such mechanisms the cost of restoration and forest biodiversity conservation can be justly shared among the individual farmers, local communities and society as a whole.

Existing policies and regulations on planting, transportation and harvesting of indigenous trees play a crucial role in tree planting and the development of farm forestry. As farmers' responses show this proves to be a strong disincentive for native tree planting. Therefore, it would prove unrealistic to expect spontaneous planting and use of indigenous trees on farms. However, if policies change and farmers are provided with appropriate incentives and support, faster and wider integration of trees on farms and degraded uplands can be expected as it has occurred with exotic and unregulated tree species.

CONCLUSION

Based on the above discussion, the following conclusions can be made:

- There is a need to thoroughly assess the potential of promising and traditionally preferred indigenous tree species for on-farm domestication. Important aspects include the production of planting materials through seed and wildings collection, suitability and/or growth performance (including resistance to pests and diseases) in varying site conditions (mostly in cultivated and degraded lands which are not suitable for the more delicate dipterocarp species). Observations suggest that some pioneer species grow at least as fast as exotics, and are better adapted to degraded soil conditions.
- Research also needs to support the identification of established schemes/patterns and silvicultural practices as well as wood processing techniques for smallholders. The above will provide the necessary basis for small-scale farmers to effectively incorporate indigenous trees into their farming systems and maintain them to produce desirable timber and other products.
- There is a great potential for farm forestry in the Philippines to supply markets with farm-grown indigenous timber trees. But to increase the number and diversity of indigenous trees under cultivation there is a need to:

- Review and/or evaluate existing government policies and arrangements related to the cultivation, processing and marketing of indigenous tree products as these were perceived to be creating disincentives to farmers' engagement to on-farm domestication of promising indigenous trees.
- Intensify information, education and communication needed for the production of quality planting material, silvicultural practices, and processing and marketing aspects of promising indigenous trees. Information also needs to raise awareness on the environmental benefits of indigenous trees (including biodiversity conservation) and effectively articulate their value for the community. It should also include the relevant policies and arrangements related to tree farming.
- Provide good documentation and data storage of the rich local knowledge on indigenous trees, tree farming, wood processing, and marketing. This will serve as a major reference for future research and development activities related to indigenous trees, particularly in their promotion for on-farm domestication.
- Provide institutional arrangements that can effectively support farm forestry development. Local government support, small incentive schemes and establishment of mechanisms for farmers to make informed choices (e.g. tailored training, tree growing manuals, exchange visits with other farmers) can prove to be an effective approach to farm forestry development and rehabilitation of degraded lands.

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REFERENCES

Caluza, D. 2002. Farmers quit planting gmelina in Apayao, women's study says. *Philippine Daily Inquirer*. Manila.

DENR–ERDB. 1998. *Development and management of forest plantations. A guidebook*. Laguna, Philippines.

DOF. 1998. *Darwin database report I: economically important plants of Leyte, Western Samar and Bohol*. Leyte State University, Department of Forestry (DOF).

Franzel, S. *et al*. 1996. *Choosing the right trees: setting priorities for multipurpose tree improvement*. The Hague, International Service for National Agricultural Research.

Garrity, D. & Mercado, A. 1993. *Reforestation through agroforestry: market driven small-holder timber production on the frontier*. Marketing of multipurpose tree products in Asia. Baguio City, Philippines, Multipurpose Tree Species Research Network for Asia.

Joshi, L. 2002. *A knowledge-base systems approach for systematic acquistion and use of local ecological knowledge*. Notes prepared for the LEK Training Workshop, Los Baños, Philippines.

Joshi, L. *et al*. 2001. Recognising local knowledge and giving farmers a voice in the policy development debate. *In* M.v. Noordwijk, S. William, & B. Verbist, eds. *Towards integrated natural resource management in forest margins of the humid tropics: local action and global concerns*. Bogor, Indonesia, International Center for Research in Agroforestry.

Laotoco, A. *et al*. 2002. *The landcare approach: enhancing partnerships for sustainable upland development*. First Southern Mindanao Upland Development Congress, Davao City, Philippines, International Center for Research in Agroforestry (ICRAF).

Mangaoang, E.O. & Lawrence, A. 1998. *Economically important plants in Leyte, Western Samar, and Bohol*. A Darwin database report I.

Margraf, J. & Milan, P.P. 1996a. Ecology of dipterocarp forests and its relevance for island rehabilitation in Leyte, Philippines. *In* A. Schulte, & D. Schone, eds. *Dipterocarp forest ecosystems: towards sustainable management*. Singapore, World Scientific Publishing Co. Pte. Ltd.

Margraf, J. & Milan, P.P. 1996b. *Rainforestation farming: a farmers guide to biodiversity management for the Philippines*. Baybay, Leyte, VISCA-GTZ.

PAWB. 1998. *The first Philippine national report to the convention on biological diversity*. Manila, Philippines, Protected Area and Wildlife Bureau (PAWB)–DENR.

PCARR. 1982. *The Philippines recommends for reforestation*. Los Baños, Laguna.

PCARRD. 1994. *Status of industrial timber in the Philippines*. Los Baños, Laguna, Philippine Council for Agriculture, Forestry and Natural Resources Research and Development.

Raintree, J.B. 1991. *Socio-economic attributes of trees and tree planting practices*. FAO, Rome.

Roshetko, J.M. & Evans, D.O. 1999. *Domestication of agroforestry trees in Southeast Asia*. Domestication of Agroforestry Trees in Southeast Asia, Yogyakarta, Indonesia; Taiwan Forestry Research Institute and Council of Agriculture, Taiwan, Republic of China; Winrock International, Morrilton, Arkansas, USA; International Centre for Research in Agroforestry, Nairobi, Kenya.

Saxena, N.C. 1991. Crop losses and their economic implications due to growing of *Eucalyptus* on field bunds—a pilot study. *Agroforestry Systems* 16: 231–245.

Simons, A.J., Jaenicke, H. *et al*. 2000. *The future of trees is on farm: tree domestication in Africa*. XXI IUFRO World Congress, Kuala Lumpur.

Sosef, M.S.M. *et al*. (eds.) 1998. *Plant resources of South-East Asia. Timber trees: lesser-known timbers*. Plant Resources of South-East Asia. Bogor, Prosea Foundation.

Thapa, B. *et al*. 1995. Incorporation of indigenous knowledge and perspectives in agroforestry development. Part 2: Case-study on the impact of explicit representation of farmers' knowledge. *Agroforestry Systems* 30(1-2): 249–261.

Walker, D. *et al*. 1995. Incorporation of indigenous knowledge and perspectives in agroforestry development. Part One: Review of methods and their application. *Agroforestry Systems* 30: 235–248.

9 Forest rehabilitation on post-mining landscapes—a German case study

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ABSTRACT

Worldwide Germany is the leading lignite mining nation. Most of the lignite is produced in opencast operations. However, opencast mining causes enormous impacts on natural ecosystems and even on entire landscapes. The extensive production of lignite particularly in eastern Germany resulted in large completely devastated areas which so far have only been partially reclaimed. For the restoration of the post-mining area of more than 80 000 ha the major land use option is the re-establishment of forest ecosystems. However, extreme site conditions resulting from mining activities such as extreme soil acidification and very high salt concentrations call for specific recultivation practices. Therefore, after the German reunification new reclamation and reforestation concepts have been developed. The Collaborative Research Center (SFB 565) at the Brandenburg University of Technology at Cottbus (Germany) investigates new approaches for sustainable forestal reclamation. Different aspects of forest rehabilitation such as the role of mycorhizal function for the establishment of new forests on terra nova are subjects of these research projects. As a case study our comprehensive investigations into forest ecosystem development on terra novae in the Lusatian lignite mining district, southeast of Berlin, will be presented.

INTRODUCTION

In Germany most of the lignite is produced in three mining districts. These are the Rhenish, the Central German and the Lusatian lignite districts. The geological conditions in all three districts are favorable for large-scale opencast mining. Especially in Lusatia, a region about 100 km southeast of Berlin, the conveyor bridge technology is used predominantly. This technology allows very efficient lignite production. Up to 60 m thick sandy overburden sediments can be excavated in one step. The sediments are dumped immediately into the exploited mining

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area. In Lusatia an area of about 80 000 ha has been affected directly by mining activities. Winning of 1 million tonnes lignite causes the devastation of about 10-ha land in Lusatia. Additionally, opencast mining implies also large-scale groundwater lowering. Thus, about 2 100 km^2 of land in Lusatia have been disturbed additionally by mining-related groundwater lowering. Therefore, the impacts of lignite mining are especially serious in this mining district.

In addition, the recultivation of the post-mining landscapes is hampered by the sediment properties. The Tertiary and Quaternary overburden sediments in Lusatia consist mainly of poor sandy material with low silicate and base contents. Fertile sediments like loess are missing. Only poor soils with very low nutrient contents develop on these spoil dumps. Furthermore, during the dumping procedure, the various Quaternary and Tertiary overburden substrates are mixed and aerated resulting in oxidation processes, particularly in the oxidation of pyrite (FeS_2). This mineral is a typical component of Tertiary sediments. As a consequence of oxidation, extremely acidified spoil dumps are generated.

If the production of acidity resulting from pyrite oxidation is not buffered, pyrite-containing substrates may not be colonized by vegetation for many decades. Therefore, based on extensive practical experience, these substrates are commonly ameliorated with the application of limestone or alkaline fly ash stemming from brown coal combustion in power plants (Pflug 1998). A critical step in this approach was and is the assessment of the required quantity of buffering materials. This is commonly determined by applying the so-called acid-base budget method established by Illner and Katzur (1964). A number of specific amelioration practices have been developed since the 1950s (Pflug 1998). In fact, establishment of forest stands on these minesites after adequate amelioration has been surprisingly successful, even on originally extremely acidic, i.e. phytotoxic, spoil substrate (Böcker *et al*. 1999). But experience with these various rehabilitation methods in the Lusatian mining area is still much shorter than the general rotation period of a forest stand.

The dumps are rehabilitated with the aim of constructing sustainable ecosystems. In the Lusatian mining district about 60% of the land was covered by forests before the mining activities. About 30% of the area has been agricultural land and only 1% was in use for water resource management (Figure 1). The post-mining land use is regulated by the federal mining law. The mining area has to be recultivated subsequently after mining. “Recultivation” means the establishment of land for conventional or innovative land use. The term includes surface engineering, amelioration measurements and the establishment of vegetation (e.g. forest stands, agricultural sites or agroforestry). If compared to pre-mining conditions, the proportion of land use sectors is changed after mining (Figure 1). Nevertheless, forests represent the dominant land use after mining, too. Therefore, the development of typical forest ecosystems in the post-mining landscape of Lusatia is the focus of the following discussion.

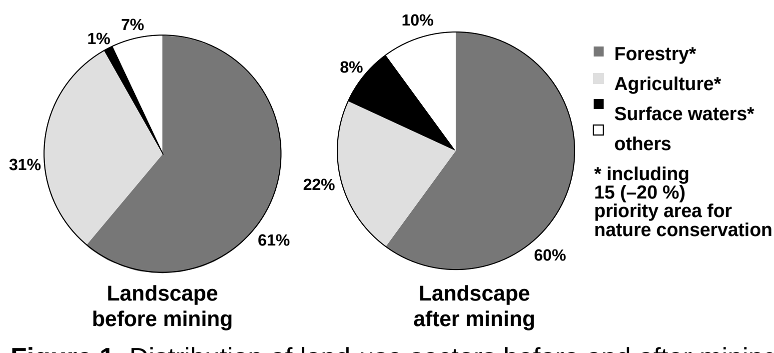

Figure 1. Distribution of land-use sectors before and after mining (Pflug 1998; modified)

Large-scale surface mining represents an ecological disaster at the landscape level. At the same time, the ecological restoration of post-mining areas offers the rare opportunity to examine the development of ecosystems starting at "point zero". To investigate the initial phases of ecosystem development under these minesite conditions, comprehensive studies were carried out in Lusatia. Results concerning agricultural systems, mining lakes and succession sites are detailed by Hüttl *et al*. (1999), Hüttl *et al*. (2000) and Wiegleb *et al*. (2000).

METHODOLOGICAL APPROACH

At the Brandenburg University of Technology (BTU), research into restoration ecology is presently carried out by the Collaborative Research Center "Development and Evaluation of Disturbed Landscapes, Case Study Lusatian Post-Mining Landscape" (SFB 565) funded by the Deutsche Forschungsgemeinschaft since the beginning of 2001. Research into restoration ecology started already between 1994 and 1999 by the Center of Excellence "Ecological Development of Post-Mining Landscapes in the Lusatian Lignite Mining District" (BTU Innovationskolleg Bergbaufolgelandschaften). This paper presents results achieved by the Collaborative Research Center, as well as by the Center of Excellence.

One central methodological approach is chronosequence studies of pine (and oak) ecosystems established on ameliorated minesites with sandy substrates containing geogenic carbon and pyrite typical of Tertiary overburden material, as well as on pyrite-free substrates typical of Quaternary strata (Figure 2).

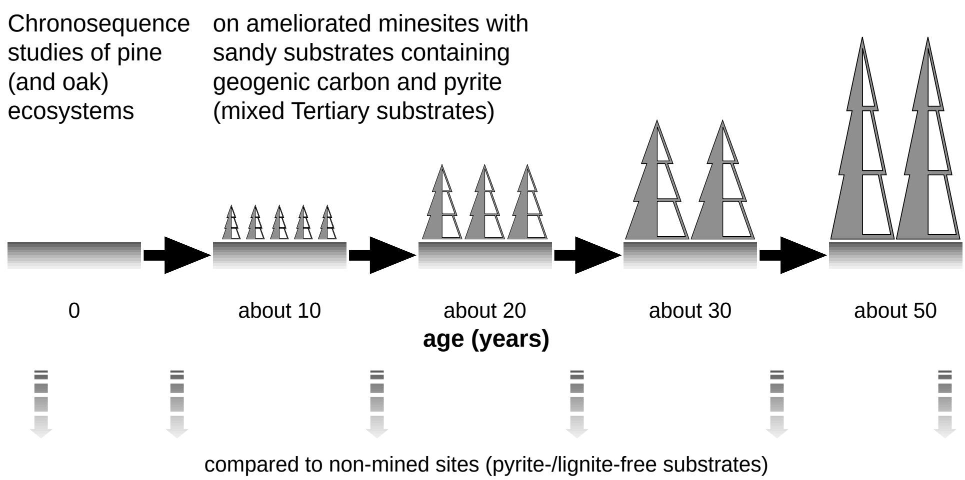

Figure 2. Chronosequence studies of pine ecosystems (schematically)

Hypotheses deducted from results of the chronosequence analysis were tested in manipulation experiments under controlled conditions (e.g. mycorrhiza inoculation). Alternatively, they were used to formulate conceptual models (e.g. on succession), process models (for ecosystem compartments) and dynamic ecosystem models. Finally, long-term monitoring data such as on groundwater levels were integrated into the research concept. In this context the findings of our chronosequence approach were interpreted with much care as chronosequence studies are generally marked by the problem of trying to compare conditions that are in fact not fully comparable.

RESULTS AND DISCUSSION

Superficially, the selected chronosequence of pine forest stands on ameliorated, pyrite- and geogenic carbon-containing substrates does not differ from pine stands on non-mined sandy sites of the general region. Biomass production of the minesite stands tends to be even higher than of comparable stands on non-mined sites (Bungart *et al*. 1998, Böcker *et al*. 1999).

With regard to the chemical soil conditions, extremely high concentrations of soluble salts in the soil solution, particularly of the early chronosequence stages and low pH values in the deeper soil layers are typical for these minesites (e.g. Knoche *et al*. 1999). In the older chronosequence stands, average pH values were not only clearly elevated in the top soil, but to some degree also in the subsoil (down to about 100 cm soil depth). With regard to the subsoil, this improvement appears to be due to the seepage of water rich in buffering capacity, percolating down into unameliorated soil layers and resulting in consumption of protons (Schaaf *et al*. 2000a,b).

During the early stages of ecosystem development, this process results in a spatial separation of the solum, leading to relatively fertile topsoils, but still rather phytotoxic subsoil conditions. Nevertheless, in about 30-year-old pine stands, roots were found below the amelioration horizon. However, the root length density was well below what is known from pine stands on non-mined sandy sites for the same soil depths (Hüttl 2000, Schneider, pers. comm.). This finding shows that it is possible for pine roots to grow even under extremely acidic soil conditions.

It is hypothesized that preferential flow of dissolved buffering chemicals used for amelioration of the top soil could result in microcompartments with higher pH in the subsoil, where root growth would be favored, while roots would cease to grow in the extremely acidic bulk soil (Gerke *et al*. 2000). Tracer experiments revealed that the spatial distribution of drainage structures is extremely heterogeneous (Figure 3). Obviously seepage water is limited to some specific areas of the subsoil. In addition, preliminary results of investigations into the three dimensional structure of a typical ameliorated dump

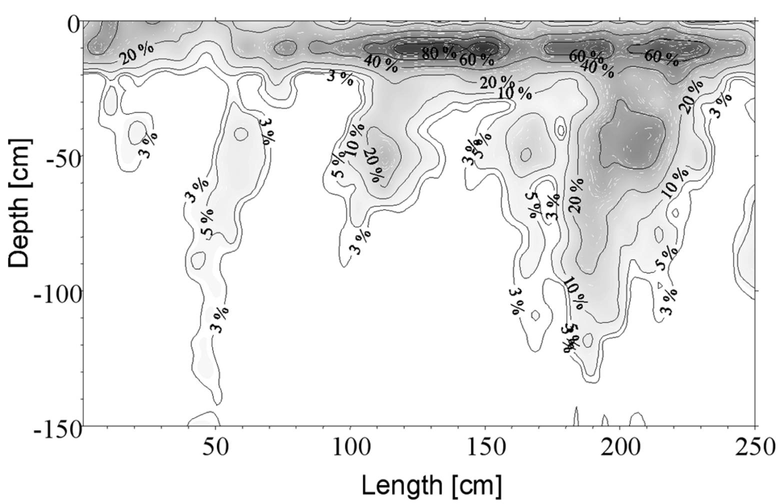

Figure 3. Spatial heterogeneity of dumps soils: results of a jodid-tracer study at Bärenbrück (distribution in %) (Gerke *et al*. 2000)

soil down to a depth of 2 m illustrate the extremely heterogeneous physical and chemical conditions of subsoils of these post-mining sites (Schaaf, pers. comm.). Small-scale spatial variability of soil chemistry is possibly the key for understanding the unexpectedly successful establishment of forest stands on these extreme sites.

Pedogenesis

Soil development of typical sandy substrates free of geogenic carbon and pyrite is similar to pedogenesis of comparable natural sites, such as sand dunes (cf. Ellenberg 1996). In contrast, soil development of substrates containing highly reactive minerals such as pyrite is significantly different from pedogenesis of non-mined soils of the test region (Hüttl 2000). In young mine soils developing from Tertiary strata, oxidation of pyrite and/or marcasite is the dominating process. This can be seen from very high values of electric conductivity and S content in the mineral soil of minesites, particularly when these sites are of young age as presented in Table 1. Even after more than 10 years of soil development, unweathered pyrite can still be found, particularly in the subsoil (Heinkele *et al*. 1999), presenting a high potential for further soil acidification (Table 1). However, after about 20 years of soil development pyrite was completely weathered in the investigated soil depths down to about 100 cm (Heinkele *et al*. 1999). Extremely high concentrations of ions such as SO_4^{2-}, $Fe^{2+}/^{3+}$, Ca^{2+} and Al^{3+} in the solution of subsoils could be correlated with intensive weathering of feldspars and phyllosilicates (Hüttl 2000). At the same time, secondary mineral phases were formed (Schaaf *et al*. 2000a). For example, large amounts of gypsum could be detected. The formation of different phases of aluminum and iron sulfates as well as of aluminum and iron hydroxides is very likely (Neumann *et al*. 1997) and in fact is indicated by geochemical modelling (Schaaf *et al*. 2000b). So far, goethite, jarosite and schwertmannite have been detected by micromorphological investigations (Neumann 1999).

Table 1. Chemical characteristics (median) of a mine soil chronosequence on Tertiary substrate and of a non-mined forest site of the general test region (Vetterlein, pers. comm.; Heinkele *et al*. 1995; Puhlmann, pers. comm.)

Site	Weissagker Berg			Bärenbrücker Höhe			Domsdorf			Taura		
Substrate	Tertairy spoil			Tertiary spoil			Tertiary spoil			Non-mined, forest soil		
Age	Just planted			14 years			32 years			48 years		
Depth (cm)	0–30	30–60	>60	0–30	30–60	>60	0–10	30–60	>70	0–5	45–60	75–94
pH (H_2O)	3.9	3.8	3.1	5.5	5.4	3.1	5.1	4.5	3.3	3,8	4.3	4.9
EC (mS cm^{-1})	2.3	2.2	2.5	0.1	1.4	2.2	0.1	0.6	1.1	n.d.	n.d.	n.d.
C (%)	2.3	2.4	2.3	4.0	5.0	4.5	8.9	7.3	5.8	1.6	0.1	<0.1
S (%)	0.4	0.4	0.5	0.2	0.7	0.7	0.2	0.2	0.2	0.01	0.01	<0.01

Changes in soil solution along depth gradients in the investigated, originally pyrite-containing chronosequence, indicate that with time sulphur is translocated along the profile into deeper soil layers via dissolution and precipitation processes (Knoche *et al*. 1999). However, studies on sandy substrates of the region show that it takes a relatively long time, until sulphur concentrations are close to values known from originally pyrite-free substrates (Thum *et al*. 1992).

Soil water and nutrients

Lusatian mine spoils are typically sandy substrates with only very small nutrient pools. Therefore, young forest stands need nutrient additions, particularly of N, P and K. In this context, it is of both scientific and practical interest to find out whether from this initial situation relatively closed nutrient cycles develop, or if nutrient budgets are deficient over longer time periods. In the latter case, these systems would need continuous nutrient amendments as indicated by studies from Heinsdorf (1992). Furthermore, it is also important to know, whether eventually the "nutrient budget types" that develop under these specific site conditions are similar to those for comparable forest ecosystems on non-mined sites.

Our comprehensive element cycling studies illustrate that matter budget types of forest ecosystems on minesites are quite different from non-mined sites of the test region. This was expected given the findings of soil development. For example, elements like S, Ca (Figure 4) or Fe, that dominated soil solution concentrations, showed enormous output rates (Knoche *et al*. 1999, Schaaf *et al*. 2000a). In contrast, P and K are not leached out of the forest ecosystems (Wilden *et al*. 1999, Embacher 2000, Wilden 2000). The high Ca concentrations in young dump soils stem from marine Tertiary sediments which were dumped to the surface. Weathering and leaching out of Ca from the topsoil decrease with increasing age of the dump soil.

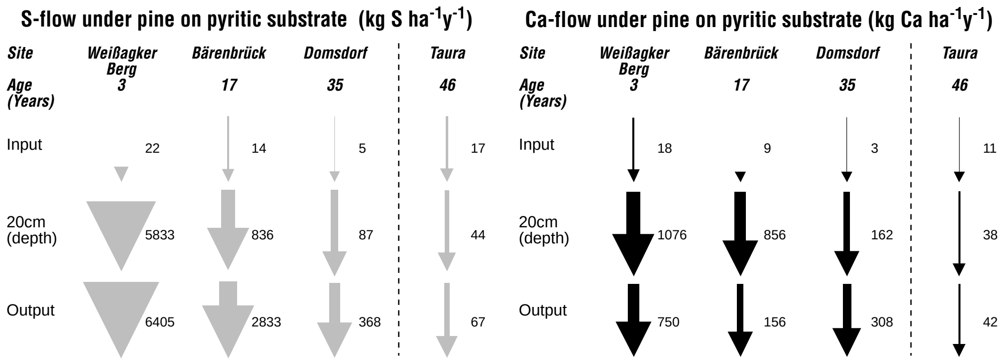

Figure 4. Sulphur- and calcium-flows under pine on pyritic, i.e. Tertiary substrate (Gast *et al.* 2000, modified)

Soil carbon and mesofauna

In forest stands on young minesites that have already developed an organic topsoil layer, a considerable proportion of the nutrients added via fertilizers is stored in this layer (e.g. Heinsdorf 1992). Accordingly, processes such as decomposition and in particular mineralization of the organic layer are critical for understanding nutrient cycling in these young ecosystems.

A study of soil fauna revealed increasing biological activity along the pine chronosequence investigated on Tertiary strata (Keplin 1997). In the oldest stand (30 years), soil mesofauna activity showed a depth profile typical for pine forest soils of comparable, but non-mined sites of the same general area (Keplin 1997).

With regard to soil micro-organisms there were signs of highly dynamic changes of biomass, composition and activity over the time period studied via the chronosequence. Development of the humus layer starts with an extremely high abundance of soil fungi, which is generally much lower on comparable but undisturbed sites ("Pilzförna"; Kobel-Lamparski & Lamparski 2001). Later in the development of the humus layer, a relatively sudden increase of nitrogen mineralization activity occurs—again on a much higher level than would be typical for comparable N-poor non-mined sites (Kolk & Bungart 2000). This may be a consequence of qualitative changes in decomposition caused by immigration of earthworms to the test sites after about 20 years of ecosystem development (Dageförde *et al*. 2000).

After the dumping of minespoil, the substrate is initially free of pedogenic organic carbon, i.e. organic carbon recently accumulated by biomass production. Since a functional carbon cycle is essential for forest ecosystems sustainability, accumulation of pedogenic organic carbon must be considered as a critical process in system development on these “terrae novae”. In general, pedogenic organic carbon can be estimated without problems as total soil organic carbon. However, there is a carbon component in most Tertiary minespoils that is not present in non-mined soils, namely geogenic organic carbon, i.e. fossil (“lignite”) carbon. Quantitative information on the contribution of this geogenic carbon to the total soil carbon pool can be obtained by radiocarbon dating (Rumpel *et al*. 2000). In turn, this method allows an estimation of the proportion of recently produced organic carbon. In the soils of the pine chronosequence, an increase in the content of pedogenic carbon as related to the total soil carbon storage was observed with increasing stand age (Rumpel 1999), as was expected.

Lignite carbon is not an inert soil component. Katzur and Hanschke (1990), Laves *et al*. (1993), and Waschkies and Hüttl (1999) showed that geogenic carbon can be subject to microbial decomposition. Results of Rumpel and Kögel-Knabner (2000) further proved that lignitecarbon is incorporated into microbial biomass in young mine soils. Also, as mentioned above, considerable amounts of nitrogen are suggested to be released from this geogenic carbon fraction. This appears to be particularly true for subsoils of newly established afforestation areas on pyritic spoil material (Wilden *et al*. 1999). The relevance of this N-pool for the nutrition of the developing pine stands is still not clear.

Furthermore, the geogenic carbon fraction may increase the soil water holding capacity (Thum *et al*. 1992, Embacher 2000). An improvement of the soil water holding capacity represents an important advantage for forest stand development on sandy soils in a region with relatively low precipitation.

Colonization

Spontaneous, natural colonization of minesites by flora, fauna and micro-organisms can be observed within the first year after rehabilitation. This colonization also includes symbiotic micro-organisms such as mycorrhizal fungi or N-fixing bacteria (Kolk & Bungart 2000). A number of species that invade these minesites are extremely rare at non-mined sites in the general region (e.g. previously undescribed mycorrhizal fungi, cf. Golldack *et al*. 2000).

In this context, a very interesting question is whether species, groups of species, or strategy types become established on these sites according to a particular pattern, i.e. whether there exists a typical minesite succession of flora and fauna in re-established forest ecosystems (cf. Dunger 1978, Dunger 1989, Dunger 1991, Broll *et al*. 2000).

Observations in the pine chronosequence indicate a trend from species of open habitats in very young stands towards species typical for forest understoreys in older and closed forest stands (Dunger 1997). This development is probably “forced” by pine planting, as under the prevailing site conditions in plantation stands, the planted tree species becomes the dominating organism within a rather short time period (Wulf *et al*. 1999).

Plants and animals can be used as bioindicators. When this concept is applied to the test stands on the minesites though discrepancies appear. The floristic composition of the understorey of the pine chronosequence indicates an ecosystem development not differing from non-mined sites (Wulf *et al*. 1999) although—as shown above—soil conditions are in many ways different from non-mined soils of adjacent sites. Also, when using understorey flora of the pine chronosequence as an indicator of nitrogen availability misleading results would be obtained. Indicator values of understorey plant species did reflect actual nitrogen availability in the mine soil as determined by both bioassays and chemical extraction methods (Schmincke & Weber, pers. comm.). Finally, Schötz and Pietsch (2000) found that classical bioindication of soil parameters by plants is not applicable for natural succession flora on unameliorated minesites (cf. Ellenberg *et al*. 1992). The causes of these discrepancies are not yet well understood and need further investigation.

On the other hand, Kielhorn *et al*. (1999) showed that—when using selected taxonomic groups of the soil fauna, e.g. carabids, as indicators—the indicated system development is in accordance with typical forest ecosystem succession with the exception of the very first year after minesite rehabilitation. At the same time, utilizing enchytraeids as indicators of soil fauna activity (cf. Graefe 1997), it was indicated that the soil conditions of the minesites differ compared to non-mined sites. Both rapid colonization and establishment of soil fauna typical for comparable undisturbed habitats are hampered (Keplin *et al*. 2000).

INCOMPLETE KNOWLEDGE

Space for time substitution, i.e. the study of chronosequences, if interpreted carefully, is a useful method to create sound hypotheses on how ecosystems or parts of ecosystems function and develop over time. However, in using this methodology, definite answers to questions on cause–effect relations cannot be obtained. For this purpose, well designed process studies are much better suited and are therefore needed.

With regard to the development of ecosystems on minesites, the major focus should be on pedogenesis since soil is the compartment most dramatically altered by open-cast mining. A conceptual model of pedogenesis on sites with pyritic spoil was developed by Neumann (1999). This model though, is not completely explicit on processes and conditions at the microscale level of these minesite soils. Due to the relevance of i) spatial heterogeneity in root distribution, ii) root activity, and iii) mycorrhiza fungi, ongoing research is concentrating on these aspects (cf. Hüttl 2000).

Nutrient cycling, particularly of N, in pine forests on minesites containing Tertiary sediments is not well understood (Hüttl & Bradshaw 2001a). Nitrogen availability from lignitic material, low N-availability in young stands, but high N-mineralization and N-availability in older stands are empirical observations, for which the causes are still unknown (Schaaf *et al*. 2000b). There are, however, indications of improved nutrient (N and P) availability for pine trees due to mycorrhization, which might be a key factor in the survival of trees on young mine soils (e.g. Grote 1999).

To integrate our comprehensive research results, a forest ecosystem model created for pine forests on non-mined sites is currently adapted for minesites. One important objective is to generate quantitative data on stand development as well as on water, carbon, nitrogen and sulphur cycling as related to realistic ecological scenarios. Another objective is to use this model to help focus on critical questions considering the system context. And a third objective will be to determine the processes relevant for explaining forest ecosystem functions on minesites at the landscape scale and finally to integrate this information into a GIS-based model at landscape scale.

SYNOPSIS

In Europe, ecosystems on minesites present a rare example for "de novo" ecosystem development. Therefore, a comprehensive research project was carried out on the development of forest ecosystems established in the post-mining landscape of the Lusatian lignite district. As was expected, ecosystems on minesites do not function entirely differently from comparable ecosystems on non-mined sites of the general test region. Major discrepancies, however, occur on sites with extreme substrate conditions such as spoil material containing pyrite and/or geogenic, i.e. lignitic, carbon. But, when these extreme sites are ameliorated and rehabilitated with forest trees, pedogenesis and overall water and element budgets could be viewed as pointing towards "normal" development as known from adjacent non-mined forest areas. This conclusion might be postulated from our chronosequence approach with pine forest ecosystems on typical Lusatian minesites (cf. Hüttl 2000).

However, this concept remains a hypothesis. For example, root system and mycorrhiza development is distinctly different from what is known for non-mined sites apparently due to enormous small-scale heterogeneity of the mine soil chemical conditions. On the other hand, forest stand growth on these minesites is not retarded—at least during the early stages of development. Also, organic matter cycling is influenced by fractions of organic carbon unique to these sites. To better understand cause–effect relations under such extreme conditions, well-designed process studies need to be carried out. By combining the results of these studies with specific monitoring data, integrated forest ecosystem models are adapted to shed more light on the future development of these man-made ecosystems.

From the experience gathered so far we can state that ecosystem development in the post-mining landscape of the Lusatian lignite district can be used as a rather ideal "field laboratory" to eventually establish general findings on the ecological development of disturbed sites and even of entire disturbed landscapes.

REFERENCES

Abresch, A., Gassner, E. & v. Korff, J. 2000. Naturschutz und Braunkohlesanierung. *Angewandte Landschaftsökologie*. Heft 27.

Böcker, L., Katzur, J. & Stähr, F. 1999. Bodenkennwerte und Waldwachstum der Kippen-Erstaufforstungen. *AFZ/Der Wald* 25: 1336–1338.

Broll, G., Dunger, W., Keplin, B. & Topp, W. 2000. *Rekultivierung in Bergbaufolgelandschaften. Bodenorganismen, bodenökologische Prozesse und Standortentwicklung*. Berlin, Springer.

Bungart, R., Ende, P. & Hüttl, R.F. 1998. N-Dynamik und Holzzuwachs von Kiefernbeständen auf rekultivierungsstandorten des Lausitzer Braunkohlereviers. *Forum der Forschung* 7: 97–100.

Bungart, R. & Hüttl, R.F. (eds.). 1998. *Landnutzung auf Kippenflächen*. Cottbuser Schriften zu Bodenschutz und Rekultivierung. Band 2. Cottbus, BTU.

Bungart, R. & Hüttl, R.F. (eds.). 2000. *Praxisbegleitende Forschung zur Rekultivierung von Kippenflächen im Lausitzer Braunkohlerevier*. Cottbuser Schriften zu Bodenschutz und Rekultivierung, Band 14. Cottbus, BTU.

Dageförde, A., Düker, C., Keplin, B., Kielhorn, K.H., Wagner, A. & Wulf, M. 2000. Eintrag und Abbau organischer Substanz auf forstlich rekultivierten Kippsubstraten und Reaktion der Bodenfauna (Carabidae und Enchytraeidae). *In* G. Broll, W. Dunger, B. Keplin & W. Topp, eds. *Rekultivierung in Bergbaufolgelandschaften. Bodenorganismen, bodenökologische Prozesse und Standortentwicklung*, pp. 101–130. Berlin, Springer.

Dunger, W. 1978. Bodenzoologische Untersuchungen an rekultivierten Kippböden der Niederlausitz. *Abh. Ber. Naturkundemus*. Görlitz 52, 11: 1–19.

Dunger, W. 1989. The return of soil fauna to coal mine areas in the German Democratic Republic. *In* J.D. Majer, ed. *Animals in primary succession. The role of fauna in reclaimed land*, pp. 307–333. Cambridge, Cambridge University Press.

Dunger, W. 1991. Zur Primärsukzession humiphager Tiergruppen auf Bergbauflächen. *Zool. Jb. Syst.* 118, 423–447.

Dunger, W. 1997. *Untersuchungen zur Fauna 35-jähiger aschemeliorierter Kippböden*. Final Report. BTUC Innovationskolleg Bergbaufolgelandschaften. (unpublished)

Ellenberg, H. 1996. *Vegetation Mitteleuropas mit den Alpen*. 5. Auflage, Stuttgart, Ulmer.

Ellenberg, H., Weber, H.E., Düll, R., Wirth, V., Werner, W. & Paulissen, D. 1992. *Zeigerwerte von Pflanzen in Mitteleuropa*. 2nd edition. Scripta Geobot., 18.

Embacher, A. 2000. *Wasser- und Stoffhaushalt einer Eichenchrononsequenz auf kohle- und schwefelhaltigen Kippsubstraten der Niederlausitz*. Cottbuser Schriften zu Bodenschutz und Rekultivierung. Band 10. Cottbus, BTU.

Gast, M., Schaaf, W., Wilden, R. & Scherzer, J. 2000. Entwicklung von Wasserhaushalt und Stoffkreisläufen in Kiefernökosystemen auf tertiären Kippenstandorten des Lausitzer Braunkohlereviers—steuernde Prozesse und beteiligte Pools. *In* R.F. Hüttl, E. Weber & D. Klem, eds. *Ökologisches Entwicklungspotential der Bergbaufolgelandschaften im Niederlausitzer Braunkohlerevier*, pp. 38–54. Stuttgart, Leipzig, Wiesbaden, B.G. Teubner.

Gerke., H. H., Schaaf, W., Hangen, E. & Hüttl, R.F. 2000. Präferenzielle Wasser- und Luftbewegung in heterogenen aufgeforsteten Kippenböden im Lausitzer Braunkohleretagebaugebiet. *In* R.F. Hüttl, E. Weber & D. Klem, eds. *Ökologisches Entwicklungspotential der Bergbaufolgelandschaften im Niederlausitzer Braunkohlerevier*, pp. 258–274. Stuttgart, Leipzig, Wiesbaden, B.G. Teubner.

Golldack, J., Münzenberger, B. & Hüttl, R.F. 2000. Mycorrhizierung der Kiefer (*Pinus sylvestris L.*) auf forstlich rekultivierten Kippenstandorten des Lausitzer Braunkohlenreviers. *In* G. Broll, W. Dunger, B. Keplin & W. Topp.eds. *Rekultivierung in Bergbaufolgelandschaften. Bodenorganismen, bodenökologische Prozesse und Standortentwicklung*, pp. 131–146. Berlin, Springer.

Graefe, U. 1997. *Bodenorganismen als Indikatoren des biologischen Bodenzustandes*. Mitt. DBG, 85: 687–690.

Grote, R. 1999. Simulation der forstlichen Ökosystemproduktion in Kiefernwäldern der Bergbaufolgelandschaften. *In* R.F. Hüttl, D. Klem & E. Weber, eds. *Rekultivierung von Bergbaufolgelandschaften. Das Beispiel des Lausitzer Braunkohlereviers*, pp. 131–145. Berlin, New York, Walter de Gruyter.

Heinkele, T., Mayer, S., Weber, E. & Heuer, V. 1995. *Auswahl von Versuchsflächen für die Chronosequenz unter Kiefer*. BTUC Innovationskolleg Bergbaufolgelandschaften. Bericht zum Teilprojekt Flächenauswahl. (unpublished).

Heinkele, T., Neumann, C., Rumpel, C., Strzyszcz, Z., Kögel-Knabner, I. & Hüttl, R.F. 1999. Zur Pedogenese pyrit- und kohlehaltiger Kippsubstrate im Lausitzer Braunkohlerevier. *In* R.F. Hüttl, D. Klem & E. Weber, eds. *Rekultivierung von Bergbaufolgelandschaften. Das Beispiel des Lausitzer Braunkohlereviers*, pp. 25–44. Berlin, New York, Walter de Gruyter.

Heinsdorf, D. 1992. *Untersuchungen zur Düngebedürftigkeit von Forstkulturen auf Kipprohböden in der Niederlausitz*. Habilitationsschrift, Dresden, TU.

Hüttl, R.F. 2000. Forstliche Rekultivierung im Lausitzer Braunkohlerevier. *Rundgespräche der Kommission für Ökologie*, pp. 53–66. Band 20, Bergbaufolgeschäden und Ökosystemanalyse. München, Verlag Dr. Friedrich Pfeil.

Hüttl, R.F. & Bradshaw, A.D. (eds.). 2000. Aspects of reclamation ecology. *Landscape and Urban Planning* 51: 73–193.

Hüttl, R.F. & Bradshaw, A.D. 2001a. Future minesite restoration involves a broader approach. *In* R.F. Hüttl & A.D. Bradshaw, eds. *Ecology of post-mining landscapes.* Ecological Engineering 17.

Hüttl, R.F. & Bradshaw, A.D. (eds.). 2001b. Ecological management of post-mining areas. *Waste Management*. 21: 117–205.

Hüttl, R.F., Klem, D. & Weber, E. (eds.). 1999. *Rekultivierung von Bergbaufolgelandschaften. Das Beispiel des Lausitzer Braunkohlereviers*. Berlin, New York, Walter de Gruyter.

Hüttl, R.F., Weber, E. & Klem, D. (eds.). 2000. *Ökologisches Entwicklungspotential der Bergbaufolgelandschaften im Niederlausitzer Braunkohlerevier*. Stuttgart, Leipzig, Wiesbaden, B.G. Teubner.

Illner, K. & Katzur, J. 1964. Betrachtungen zur Bemessung der Kalkgaben auf schwefelhaltigen Tertiärkippen. *Z. Landeskultur* 5: 287–295.

Jordan, W.R., Gilpin, M.E. & Aber, J.D. (eds.). 1987. *Restoration Ecology—a synthetic approach to ecological research*. Cambridge, Cambridge University Press.

Katzur, J. & Hanschke, L. 1990. Pflanzenerträge auf meliorierten schwefelhaltigen Kippböden und die bodenkundlichen Zielgrößen der landwirtschaftlichen Rekultivierung. *Arch. Acker-Pflanzenbau Bodenkd* 34: 35–43.

Keplin, B. 1997. *Forschungen zur Bodenökologie und Rekultivierung am Lehrstuhl Bodenschutz und Rekultivierung der BTU, Cottbus*. Mitt. DBG 83: 167–170.

Keplin, B., Düker, C., Kielhorn, K.H. & Hüttl, R.F. 2000. Bodenorganismen als Bioindikatoren für Veränderungen in der Habitatqualität von Kippenstandorten. *In* R.F. Hüttl, E. Weber & D. Klem, eds. *Ökologisches Entwicklungspotential der Bergbaufolgelandschaften im Niederlausitzer Braunkohlerevier*, pp. 319–327. Stuttgart, Leipzig, Wiesbaden, B.G. Teubner.

Kielhorn, K.H., Keplin, B. & Hüttl, R.F. 1999. Ground beetle communities on reclaimed mine spoil: effects of organic matter application on revegetation. *Plant and Soil* 213: 117–125.

Knoche, D., Schaaf, W., Embacher, A., Faß, H.J., Gast, M., Scherzer, J. & Wilden, R. 1999. Wasser- und Stoffdynamik von Waldökosystemen auf schwefelsauren Kippsubstraten des Braunkohletagebaus im Lausitzer Revier. *In* R.F. Hüttl, D. Klem & E. Weber, eds. *Rekultivierung von Bergbaufolgelandschaften. Das Beispiel des Lausitzer Braunkohlereviers*, pp. 45–71. Berlin, New York, Walter de Gruyter.

Kobel-Lamparski, A. & Lamparski, F. 2001. *Morphologie und Systemeigenschaften bei Humusprofilen im Laufe der Sukzession*. (in preparation)

Kolk, A. & Bungart, R. 2000. Bodenmikrobiologische Untersuchungen an forstlich rekultivierten Kippenflächen im Lausitzer Braunkohlenrevier. *In* G. Broll, W. Dunger, B. Keplin & W. Topp, eds. *Rekultivierung in Bergbaufolgelandschaften. Bodenorganismen, bodenökologische Prozesse und Standortentwicklung*, pp. 187–205. Berlin, Springer.

Laves, D., Franko, U. & Thum, J. 1993. Umsatzverhalten fossiler organischer Substanzen. *Arch. Acker-Pflanzenbau Bodenkd* 37: 211–219.

Neumann, C. 1999. *Zur Pedogenese pyrit- und kohlehaltiger Kippsubstrate im Lausitzer Braunkohlerevier*. Cottbuser Schriften zu Bodenschutz und Rekultivierung. Band 8. Cottbus, BTU.

Neumann, C., Heinkele, T. & Hüttl, R.F. 1997. Zur Pedogenese und Klassifikation von Kippenböden einer Chronosequenz auf primär schwefelhaltigen Kippkohlelehmsanden im Lausitzer Braunkohlerevier. *Mittlgn. Dtsch. Bodenkundl. Gesellsch.* 84: 37–40.

Pflug, W. 1998. *Braunkohlentagebau und Sanierung—Landschaftsökologie, Folgenutzung, Naturschutz*. Berlin, Springer.

Rumpel, C. 1999. *Differenzierung und Charakterisierung pedogener und geogener organischer Substanz in forstlich rekultivierten Kippböden*. Cottbuser Schriften zu Bodenschutz und Rekultivierung. Band 5. Cottbus, BTU.
Rumpel, C. & Kögel-Knabner, I. 2000. Mikrobielle Abbaubarkeit von geogenem Kohlenstoff in braunkohlehaltigen Kippböden. *In* R.F. Hüttl, E. Weber & D. Klem, eds. *Ökologisches Entwicklungspotential der Bergbaufolgelandschaften im Niederlausitzer Braunkohlerevier*, pp. 19–37. Stuttgart, Leipzig, Wiesbaden, B.G. Teubner.
Rumpel, C., Skjemstad, J.O., Knicker, H., Kögel-Knabner, I. & Hüttl, R.F. 2000. Techniques for the differentiation of carbon types present in lignite-rich mine soils. *Organic Geochemistry* 31: 543–551.
Schaaf, W., Knoche, D. & Dageförde, A. 2000a. Wasser- und Stoffhaushalt der Kiefern- und Eichenökosysteme—eine Zusammenschau. *In* R.F. Hüttl, E. Weber & D. Klem, eds. *Ökologisches Entwicklungspotential der Bergbaufolgelandschaften im Niederlausitzer Braunkohlerevier*, pp. 305–318. Stuttgart, Leipzig, Wiesbaden, B.G. Teubner.
Schaaf, W., Wilden, R., Scherzer, J. & Gast, M. 2000b. Dynamik von Stoffumsetzungsprozessen in zwei Kieferökolsystem-Chronosequenzen auf rekultivierten Kippenstandorten des Lausitzer Braunkohlenreviers. *In* G. Broll, W. Dunger, B. Keplin & W. Topp, eds. *Rekultivierung in Bergbaufolgelandschaften. Bodenorganismen, bodenökologische Prozesse und Standortentwicklung*, pp. 223–237. Berlin, Springer.
Schötz, A. & Pietsch, W.H.O. 2000. Standortzeiger Vegetation—Sukzession der Vegetation auf Kippenböden und deren Indikatorfunktion. *In* R.F. Hüttl, E. Weber & D. Klem eds. *Ökologisches Entwicklungspotential der Bergbaufolgelandschaften im Niederlausitzer Braunkohlerevier*, pp. 91–105. Stuttgart, Leipzig, Wiesbaden, B.G. Teubner.
Thum, J., Wünsche, M. & Fiedler, H.J. 1992. Rekultivierung im Braunkohlenbergbau der östlichen Bundesländer. *Bodenschutz* 10: 1–38.
Vetterlein, D. (ed.). 1999. Organic matter application and element turnover in disturbed terrestrial ecosystems. *Plant and Soil* 213: 1–250.
Vetterlein, D. & Hüttl, R.F. 1999. Can applied organic matter fulfil similar functions as soil organic matter? Risk–benefit analysis for organic matter application as a potential strategy for rehabilitation of disturbed ecosystems. *Plant and Soil* 213: 1–10.
Waschkies, C. & Hüttl, R.F. 1999. Microbial degradation of geogenic organic C and N in mine spoils. *Plant and Soil* 213: 221–230.
Weber, E. 2000. Querschnittsaufgabe "Punkt zu Fläche". *In* R.F. Hüttl, E. Weber & D. Klem, eds. *Ökologisches Entwicklungspotential der Bergbaufolgelandschaften im Niederlausitzer Braunkohlerevier*, pp. 357–362. Stuttgart, Leipzig, Wiesbaden, B.G. Teubner.
Wiegleb, G., Bröring, U., Mrzljak, J. & Schulz, F. (eds.). 2000. *Naturschutz in Bergbaufolgelandschaften—Landschaftsanalyse und Leitbildentwicklung*. Heidelberg, Physica.
Wilden, R. 2000. *Bodenlösungschemie und Elementbilanzen von vier forstlich genutzten Kippenstandorten im Lausitzer Braunkohlenrevier*. Cottbuser Schriften zu Bodenschutz und Rekultivierung. Band 12. Cottbus, BTU.
Wilden, R., Schaaf, W. & Hüttl, R.F. 1999. Soil solution chemistry of two reclamation sites in the Lusatian lignite mining district as influenced by organic matter application. *Plant and Soil* 213: 231–240.
Wulf, M., Schmincke, B. & Weber, E. 1999. Entwicklung der Bodenvegetation in Kippenforsten. *In* R.F. Hüttl, D. Klem & E. Weber, eds. *Rekultivierung von Bergbaufolgelandschaften. Das Beispiel des Lausitzer Braunkohlereviers*, pp. 89–100. Berlin, New York, Walter de Gruyter.

SESSION III

10 Rehabilitation of Malaysian forests: perspectives and delimitation of planting bamboo as a commercial species

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ABSTRACT

Bamboo has been a multipurpose plant associated with rural people since the old days. Its physiological characteristic as a very fast-growing species has given bamboo recognition as a suitable species for plantation purposes. Besides the shoot, its culm can be used anytime, especially in the rural areas, for small cottage industries. Based on the Forest Research Institute Malaysia's (FRIM) experiences, bamboo can be exploited as a potential plant for rehabilitation either on a small scale or as a plantation. This can be done in rehabilitating Malaysian forests as seen in ex-logging areas where bamboo has invaded more than 70% of these forest compartments. Bamboo established here is suitable for rehabilating purpose as the timber remnants are small in diameter and the amount is not economical for the next harvesting. Other unproductive forest and marginal lands can similarly be rehabilitated. Land areas where agricultural crops cannot be planted with maximum yield can be planted with bamboo species either as food from shoots or for the higher value-added culms. It is hoped that large tracts of land available in the forest can be rehabilitated as a money spinner, and create job opportunities for the rural poor. The delimitation and perspectives of planting bamboo, and government policy in tackling certain issues are also discussed in this paper.

INTRODUCTION

The total land area of Malaysia is 32.86 million ha, about 72% of which are under forest and tree plantations. Forests account for 19.4 million ha and tree plantations 4.2 million ha. Approximately 11.2 million ha of the Permanent Forest Reserves are earmarked as Production Forest. Areas within the Production Forest are commercially logged on a

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rotational cycle, under sustained yield management. Stateland forests of approximately 3.5 million ha are usually cleared before the land is put to other uses (Anonymous 1992).

Logging and clearing of forests denude the land drastically. The total forest area in the tropics has been reduced from 1 935 million ha in 1980 to 1 882 million ha in 1990. In contrast, the annual reforestation rate is only from 1.9 to 5.0 million ha, and natural forests under sustained management in 1988 were only 4.4 million ha (The World Resources Institute 1990).

SCENARIO OF MALAYSIAN FORESTS

Timber and timber products have emerged as important contributors to the Malaysian economy. The contribution of this sector to the GDP which accounted for 7.1% has been ranked the highest in terms of foreign exchange earnings. To ensure the continued survival of the timber industries, adequate and sustainable supply of timber is vital. Natural forests has been supplying timber for this country for decades. Due to continuous logging over the years without concerted and parallel efforts in reafforestation or a reduction of logging quota and gazetting of some forests as permanent forests, the timber supply has dwindled and become insufficient to meet the growing demands of the wood-based industry (Abd. Razak *et al.* 1997). There is now a tremendous pressure to conserve the existing forests due to environment consciousness and awareness of the important protective roles of the natural forests.

SECOND GROWTH STANDS

Many of the formerly logged areas are beginning to come under a second felling. Those that are felled on a highly selected basis but are not treated and consist of less commercial timber species can subsequently be rehabilitated with bamboo. In addition, if there are many natural stand bamboo clumps growing over more than 70% of the available areas, the bamboo can be managed. Due to the large demand for high value added products from timber for furniture, it is timely to introduce bamboo as a substitute for this purpose.

DEGRADED STANDS

These are forest areas where the existing stands are either very poor in timber or are stocked with poor quality trees (Appanah 2000). In such situations, these areas can be rehabilitated with bamboo. Gap areas not planted with any other commercial timber species can also be used for rehabilitation purposes.

WHY REHABILITATION WITH BAMBOO?

Rehabilitation means to restore the land to its original or improved situation. In this case, bamboo is recommended for rehabilitation in degraded stands and forest areas where clear felling or excessive felling has been done. The areas involved can be filled with 'green' vegetation such as bamboo due to many factors. They are:

Present in the ex-logging areas

There are abundant supplies of natural stand bamboo in the forest especially in the ex-logging areas. The vegetation can be of pure stands or mixed with other species in the forest compartments. The total estimated area of bamboo by forest compartment is 421722 ha accounting for 6.9% of the total forested land or 9.5% of the total forest reserves in Peninsular Malaysia. Pahang, Kelantan and Perak have the largest number of compartments containing bamboo, covering 120 000, 90 000 and 68 000 ha respectively (Lockman *et al.* 1994).

The areas with natural stand bamboo such as *Gigantochloa scortechinii* (buluh semantan) can be managed because this is one of the main commercial bamboos that is being exploited from the forest for the bamboo industries (Azmy *et al.* 1997). In addition, it was found that every 2 kg of compound fertiliser applied will help to increase the bamboo shoot yield by 30%. If the natural stand bamboo population exceeds 70% of the vegetation that includes timber trees in the ex-logging areas, then it is wise to manage the natural stand bamboo instead of concentrating on timber management in these areas (Azmy *et al.* 1997).

Fast-growing species giving a fast return

Bamboo is considered a fast-growing species and gives a fast return in terms of yield such as shoots. It takes 5–6 months to reach its maximum height (Liese 1985, Abd. Razak 1992). The shoot can be consumed as food and it can be commercialized for export earnings. Where there are big gaps in the ex-logging areas in forest compartments, commercial bamboos such as *Dendrocalamus asper* (buluh betung), *Gigantochloa levis* (buluh beting) and *Gigantochloa 'brang'* (buluh brang) can be planted on a large scale for shoot and culm production. These products can be exported and help to increase the GDP of the country if produced on a large scale. For example, the export of commercial bamboo shoots fetched US$2.9 million per year for Thailand (Songkram 1985).

The bamboo plant needs 2 to 3 years to establish and later produces a large biomass. The total above-ground biomass values of mature bamboo culms (3- to 4-year-old) gathered from 30 culms sampled from each bamboo species selected randomly in 6-year-old bamboo trial plots of *B. vulgaris*, *G. levis* and *G. scortechinii* are shown in Table 1. The total above-ground biomass values of these bamboos are about 6.4, 13.4 and 7.2 culm^{-1} while the culm dry weights are 3.8, 6.6 and 5.1 kg culm^{-1} respectively. A metric tonne of *B. vulgaris, G. levis* and *G. scortechinii* gives 261, 151 and 196 culms respectively. In a bamboo plantation aged about 5 years and above, the estimated annual culm biomass production is about 13.75, 16.32 and 29.04 tonnes ha^{-1} of *B. vulgaris*, *G. scortechinii.* and *G. levis* correspondingly. From the total annual culm biomass production, 60–70% is usually harvested for consumption.

Table 1. Biomass production of mature bamboo culms (3- to 4-year-old)

	6-year-old trial plots		
	Culm age (3- to 4- year-old)		
	B. vulgaris	***G. levis***	***G. scortechinii***
Average DBH (cm)	10.5	11	8.5
Average height (m)	12	15	13.5
Average dry weight (kg) culm^{-1}			
Culm	3.82	6.6	5.1
Branches	2.14	5.2	1.0
Leaves	0.44	1.6	1.1
Total dry weight	6.4	13.4	7.2
Estimated No. of culms ha^{-1}y^{-1}	3600	4400	3200
Culm dry weight (tonnes ha^{-1}y^{-1})	13.75	29.04	16.32
No. of culms tonne^{-1}	261	151	196

High production and short maturity cycle

Bamboo yield depends on the number of shoots sprouting per clump. A vigorous clump will produce more shoots from time to time and this can be maintained with proper maintainance. A bamboo plantation with a planting distance of 5 × 5 m will give 400 clumps per hectare and produce between 3 200 and 4 400 culms ha^{-1}y^{-1}. Bamboo has a short maturity cycle where 3-year-old bamboo culms are considered mature and ready to be harvested for utilization (Azmy & Abd. Razak 2001). This is fast compared to other timber species.

A multipurpose plant

Bamboo is a multipurpose plant whereby starting from its shoot it can be consumed as vegetable and as a culm, it can be converted into various forms, from traditional uses to commercial products. Most of the commercial products are baskets, chopsticks, toothpicks, skewers, blinds, joss sticks, papers and handycraft items (Azmy 1989, Wong 1989). Bamboo culm can also be made into high value-added products such as laminated panelling, based on its high productivity and physical and mechanical properties (Abd. Razak & Azmy 1990). Other high-value products are boards, parquet and laminates, usually produced by timber. Bamboo boards and laminates can be used to produce furniture and furniture components.

Continuous and increasing supply

Natural stand bamboos in the forest can be managed systematically with proper application of silvicultural practices. It was found that every 2 kg of compound fertiliser applied with a felling intensity of 40% will help to increase by 30% of the bamboo shoot yield. If the natural stand bamboo population exceeds 70% of the vegetation in an ex-logging area, then it is wise to manage the natural stand bamboo instead of concentrating on timber management in that particular area (Azmy *et al*. 1997). Silvicultural treatments such as fertilizer application and proper harvesting intensity will also help in prolonging the bamboo culms' supply continuously and at an increasing rate (Azmy & Abd. Razak 2001).

Soil conservation and erosion control

Extensive deforestration has resulted in soil erosion and unproductive land-use problems in Malaysia. Such degraded lands significantly reduce the potential productivity of trees planted on them. There are, however, a number of bamboo species that will grow satisfactorily on these poor sites. Bamboo with the ability to grow on poor soils is essential for land reclamation and restoration. Some bamboo species can be grown successfully in and rehabilitate tin tailings in Malaysia (Abd. Razak 1994). They can tolerate high acidity areas in the tropics.

Bamboo has a net-like root system that creates an effective mechanism for watershed protection, binding the soil together along fragile riverbanks and deforested areas. The wide-spreading root system, uniquely shaped leaves, and dense litter on the floor suggest that bamboo can greatly reduce rain runoff, preventing massive soil erosion.

Bamboo in the agroforestry system

Agroforestry is a collective name for all land-use systems and practices, where woody perennials are deliberately grown on the same land management unit as agricultural crops or animals in some form of spatial arrangement or temporal sequence (Shanmughavel & Peddappaiah 2000).

Intercropping of forest trees with agricultural crops or with any food crops that can maximise the total land usage would be beneficial to farmers or forestry community programmes. Forestry or agroforestry does not only meet the needs of the rural communities, but also generate income and employment opportunities in the rural areas (Chin 2000). This is in line with the government's New Policy. In the New Policy, with the existing limited land resources, depleting timber supply and the importance of food security, maximization of land is a priority (Mahmud 1997). A new crop with high potential value such as bamboo can be planted in between other crops. Bamboo can produce shoots as food and at the same time matured culms for higher value-added products such as parquet and furniture. Thus, bamboo can also be introduced as one of the priority species in agroforestry.

Bamboo can also be planted and mixed with medicinal plant species such as *Eurycoma longifolia* (tongkat Ali). The straight physiological features of tongkat ali stem facilitates its planting in between rows of bamboo such as *Dendrocalamus asper* (buluh betong). Tongkat Ali can be extracted for its medicinal value. Rehabilitation programmes, in this case involving the rural people, can benefit not only the farmers but also the country.

Aesthetic value

Besides culm and shoot production, bamboo, due to its graceful figure, is a popular plant for ornamental and landscape planting. Careful selection of bamboo species can provide aesthetic functions. The evergreen and delicate forms of the leaves and culms make the plants attractive. Bamboo also can be planted as hedges, wind-breaks and for shade. These functions can beautify the environment and benefit people.

Under the International Tropical Timber Organization (ITTO) guidelines and the pressure for Forest Certification in Sustainable Forest Management System, harvesting and utilization of timbers from the tropical forest are expected to be reduced in the coming years. With the consequences of timber shortages in the near future, integrated approaches in forest production for goods other than timber should be looked into. Based on research and development, bamboo could be a potential supplementary and alternative resource to support the increasing demand for timber-based products. This indirectly can save forests from heavy timber extraction.

In bamboo plantations, the production of bamboo shoot and culms starts at 3 to 4 years following planting. The production can continue for a period of 20 years or more if the plantation is properly maintained. For utilization purposes, 3-year-old bamboo culms are considered mature and ready to be harvested. This is fast compared to timber tree species which need more than 30 years to be harvested for downstream purposes.

RECOMMENDATIONS

Rehabilitation of Malaysian forests with bamboo is feasible under the following criteria:

1. The government has to look into the land policy whereby enterpreneurs can venture into large areas of unproductive forest lands for conversion into bamboo plantations. In addition, existing natural stand bamboos in the forest compartment can be leased to private organizations and entrepreneurs, for more than 30 years.
2. Promotion of bamboo as a commercial plant should be done throughout the whole country and this can be more effective with the help of the agro-based industries.
3. Various quality product designs using bamboo should be introduced.
4. Government incentives to implement this new concept of rehabilitation of Malaysian forests with bamboo should be introduced, especially to rural areas or people.
5. In parallel with this concept, bamboo industries should be set up near the resource base so that supply and demand cost could be reduced.
6. Agroforestry or community forestry could be practised in rehabilitating the forests involving especially the rural people and collectively supervised by the government or any agrobased agency.
7. In any rehabilitation programme, especially with bamboo, proper planning at the early stage should be done properly especially when dealing with large hectares of land.

Owing to the resilience of the plant and its tolerance to poor soil conditions, it is hoped that in future, bamboo can substitute or supplement timber in high value-added products such as furniture. The important role bamboo can play in rehabilitating degraded forests and lands must, however, be remembered.

REFERENCES

Abd. Razak, O. 1992. Shoot production and culm growth of two commercial bamboo species in Peninsular Malaysia. *Bamboo Information Centre India* 2(1): 5–7.

Abd. Razak, O. 1994. Growth of bamboos on degraded soil. *Proc. 4th International Bamboo Workshop—Bamboo in Asia and the Pacific*, pp. 92–94. Chiang Mai, Thailand, 27–30 November, 1991. Technical Document GCP/RAS/134/ASB, FORSPA Publication 6. IDRC, FAO & UNDP.

Abd. Razak, O., Abd. Latif, M. & Norini, H. 1997. Bamboo production and utilization: considerations as an alternative to timber. *In* S. Appanah, M.Y. Yusmah, A.W. Jasery & K.C. Khoo, eds. *Proceedings Fourth Conference on Forestry and Forest Products Research 1997*, pp. 124–134. Kepong, Malaysia, Forest Reseach Institute Malaysia.

Abd. Razak, O. & Azmy H. M. 1990. Bamboo plantation: sustainability in solving bamboo industrial problems. (Malay). *In* M. Abd. Latif, K.C. Khoo, & J. Mohd Dahlan, eds. *Proc. National Bamboo Seminar*, pp. 17–32. 22–25 August 1988, Forest Research Institute Malaysia, Kepong, Malaysia.

Anonymous. 1992. *Forever green. Malaysia and sustainable forest management*. Kuala Lumpur, Malaysia. Ministry of Primary Industries. 28 pp.

Appanah, S. 2000. Trends and issues in tropical forest management: setting the agenda for Malaysia. *In* I. Shamsudin, S. Nur Hajar Zamah & K.C. Khoo, eds. *Proc. Seminar on Tropical Forest Harvesting: New Technologies Examined*, pp. 1–21. 22–24 November 1999, Primula Parkroyal Hotel, Terengganu, Malaysia.

Azmy, H. M. 1989. *Perusahaan membuat bakul ikan atau sayur dan bakul arang*. FRIM Technical Information No. 8. Kepong, Malaysia, Forest Research Institute Malaysia. 8 pp.

Azmy, H.M. & Abd. Razak, O. 2001. Availability of non-wood resources. Part 1. Bamboo as an alternative to rubberwood. *In* M.S. Ahmad Shakri, K.S. Ho & J. Mohd Dahlan, eds. *Proc. National Seminar on Alternatives to Rubberwood*, pp. 55–61. 26 September 2000, Forest Research Institute Malaysia, Kepong, Malaysia.

Azmy, H.M., Norini, H. & Wan Razali, W.M. 1997. *Management guidelines and economics of natural bamboo stands*. FRIM Technical Information Handbook No. 15. Kepong, Malaysia, Forest Research Institute Malaysia. 40 pp.

Chia, T.Y. 2000. Community forestry in Peninsular Malaysia. *Malaysian Forester* 63(1): 17–31.

Liese, W. 1985. *Bamboo—biology, silvics, properties, utilization*. Schriftenreihe der GTZ, No. 180:132.

Lockman, M.S., Poh, L.Y., Mohd Shahwahid, H.O. & Saroni, J. 1994. Distribution of bamboo and the potential development of the bamboo industry. *In* W.M. Wan Razali & M. Aminuddin, eds. *Proc. National Bamboo Seminar*, pp. 6–19. 2–4 November 1992, Forest Research Institute Malaysia, Kepong, Malaysia.

Mahmud, A.W. 1997. Opportunities on the planting of forest species: agroforestry as an option. *In* S. Appanah, M.Y. Yusmah, A.W. Jasery & K.C. Khoo, eds. *Proceedings Fourth Conference on Forestry and Forest Products Research 1997*, pp. 223–228. Kepong, Malaysia, Forest Research Institute Malaysia.

Shanmughavel, P. & Peddappaiah, R.S. 2000. Bamboo for agro-forestry in India. *Malaysian Forester* 63(4): 147–158.

Songkram, T. 1985. Role of bamboos in rural development and socio-economics: a case study in Thailand. *In* A.N. Rao, G. Dhanarajan & C.B. Sastry, eds. *Proc. International Bamboo Workshop*, pp. 359–365. October 6–14, 1985, Hangzhou, People Republic of China.

Wong, K.M. 1989. Current and potential uses of bamboo in Peninsular Malaysia. *Journal of American Bamboo Society* 7 (172): 1–15.

World Resources Institute. 1990. *World resources 1990–1991*. New York, Oxford University Press. 106 pp.

11 Incentives for tree growing: setting the right instruments for sustained local participation

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ABSTRACT

Tree growing on public lands in the Philippines has been an object of continuous study in search of the most appropriate policy instruments for sustained local participation. Past experience using direct cash incentives failed because of superficial local participation. When payments got delayed participants' project engagement tended to retrogress and become counterproductive. Tree growing may not necessarily depend anymore on huge public investment. It can be spontaneous, spread out and sustainable if prospective tree growers are given the proper kind of incentives and support system. The paper challenges the sustainability of tree growing on public lands using direct payment as incentive for participation. It proposes a new kind of institutional arrangement among tree growers, the private sector and the government aimed at evolving the right kind of incentives for a specific context that will propel spontaneous tree growing at the farm level. Institutional incentives such as tenure, enabling policies (i.e. tax rebates, exemptions, subsidies), physical infrastructures (i.e. farm to market roads, transport, etc.), wood market, credit assistance and other support systems are among the essential instruments that can promote spontaneous and massive tree growing on both private and public lands. Some case studies in the field validated these claims. The paper concludes that selective application of specific incentives according to participants' needs and future project options is important in designing tree growing programme in order to ensure sustainable and massive local participation in tree growing on public lands.

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INTRODUCTION

Reforestation in the Philippines has been a major national concern of the government for years in response to the fast-degrading natural landscape in the country. Three main schemes are pursued: government-administered, private-industry initiated and spontaneous tree growing at the farm level. In the past, tree growing was a purely government-led activity, and usually collaborated by Timber Licensee Agreement (TLA) holders as part of the latter's moral responsibility.

Although reforestation started way back in 1916, the pace lagged far behind the rate of forest loss. From 1916 to 1987, or during a span of 71 years, only about 70 000 ha had been successfully reforested by the government and the wood industry, compared with the yearly average rate of deforestation of 100 000 ha during the same period (Forest Management Bureau 1996). This national reforestation effort is now being challenged by the increasing number of spontaneous tree growers at the farm level, despite no direct incentives from the government.

In Misamis and Bukidnon, northern Mindanao, rural farmers successfully transformed idle and abandoned lands into tree plantations. A number of upland farmers in Cagayan Valley intercropped *Gmelina* with corn and continuously expand their woodlots because of the advent of a local chipboard processing plant (Imperata Project Paper 1996/10). The Provincial Government of Quirino initiated the formation of province-wide tree growing cooperatives among small farmholders, in an attempt to transform the 38 000 ha under-utilized alienable and disposal (A & D) land into farm forestry (personal interview, September 2000). The Provincial Government of Nueva Viscaya also evolved a new version of countryside reforestation through its *Tree for Legacy* programme. Every citizen is encouraged to grow trees on public lands through a certificate of tree ownership (personal interview, 2002).

Such phenomenon is expected to gain momentum as forestry practice takes the following new emphases:

- change of the forestry sector's perception on rural population, i.e. from major wood biomass user to potential producer;
- shift of forest management system, from highly centralized state control towards community-based approach;
- increasing participation of Local Government Units (LGUs) in Natural Resource Management (NRM);
- conservation of natural forest for biodiversity, growing emphasis on genetic resource conservation and biomass production for carbon sequestration;
- institutionalization of *Sustainable Forest Management Certification* and *Carbon Trading* prospects between the developed and developing countries.

Against this backdrop, it implies that the future major source of timber and wood products will no longer come from natural forests but from farm forestry. Correspondingly, a new set of actors in the wood business may come into play. It will no longer be the traditional timber licensee but the small tree farmholders and agroforestry practitioners who will be at the forefront of the new forest resource regime.

This paper reviews the prospects and limitations of farm forestry as a complementary management strategy for reforestation of public lands in the Philippines. It espouses the idea that massive tree growing in the countryside may not necessarily depend on huge public investment or external funding. Rather, it can become spontaneous as an integral component of the farming household land-use practice, if farmers are given the proper kind of incentives and support system. Two main questions that this paper tries to address are:

1. Why do farmers grow trees voluntarily?
2. How can farm forestry be mainstreamed as a reforestation strategy in degraded open public lands in the country?

WHY DO FARMERS GROW TREES VOLUNTARILY?[2]

Growing trees at the farm level is a common practice in Third World Countries. Among rural farmers, growing trees may stem from one or more of the reasons/conditions discussed below.

Direct household needs

When tree products and other related uses meet a farmer's direct household needs, growing trees at the backyard or farmlot can become spontaneous, i.e. without government support. For most farmers, their immediate need for fuelwood, fodder and food can be the primary reason for growing trees. Senegal, Tanzania, Indonesia, Panama and Nepal provide examples where people plant trees primarily for wood, fruit or fodder (Campbell & Bhattarai 1983, Skutch 1983 as cited by Foley & Barnard 1985, Jones 1988). In other places, people grew trees spontaneously for windbreaks, fences, shade and for other benefits.

A number of case studies attest that tree growing projects on public lands which likewise meet immediate household uses are more successful than projects which do not simultaneously address the planters' tree needs. The Bangladesh Rural Advancement Committee Project, for instance, has sustained the farmers' interest in planting and protecting *Leuceana leucocephala* in single rows along roadsides because of the fodder that they receive for their livestock (Hasan 1990).

Direct cash from wood products sale

Earning an income is one of the strongest incentives in eliciting widespread participation in tree growing as it became clear from projects in Haiti, India, Kenya, the Philippines and the Republic of Korea (Gregersen *et al*. 1989). Arnold (1987) noted that nearly 40% of the rural households in the Kakamega District in Kenya maintain small nurseries and 80% have planted trees on their land to produce poles for sale. Likewise, in Kovilur, Trichurapalli, India, many resource-poor farmers planted cashew and eucalypt species on their small land holdings for the market. The high profit gained from tree crop production motivated farmers to invest in tree crops (Malmer 1987 as cited by Chambers *et al*. 1989).

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[2] Lifted from the author's Ph.D. dissertation, entitled, "*Tree growing on different grounds: an analysis of local participation in contract reforestation in the Philippines*", Leiden University, the Netherlands, 1996.

In Uttar Pradesh, India, many farmers were encouraged to convert part of their agricultural fields to eucalypt plantation because of the ready market with a promising price for wood, along with the soft loans and subsidies given by the government (Chowdhry 1984).

Land tenure security

Land tenure appears to be another crucial factor in motivating local people to plant trees. In Bong Country, Liberia, (Harbeson *et al*. 1984) and in the Babati District, Tanzania, (Johanson 1991), local people were induced to plan trees to demarcate property boundaries and as a legitimate symbol of their right over a disputed area. In areas where the governments are likely to expropriate land for public projects, land owners seldom plant perennial tree crops knowing that they would not benefit from them. It appears from these examples that aspiration for land rights can become a strong incentive for spontaneous tree growing on disputed or public land, but also that an unclear tenure situation may prevent people from planting trees.

Likewise, security of land tenure affects the spontaneity and sustainability of the farmers' tree growing efforts. Sellers (1988) noted that in Tucurrique, Costa Rica, the type of tenurial arrangements greatly determines the farmers' preference for forest plantations over short-term crops. Growing coffee, peach palms and other woody perennials was a spontaneous practice among farmers with secure titled land while those with less secure use rights or those under tenancy opted for short-term crops. Jones (1988) observed that the lack of security of land tenure in most farms in Honduras discouraged peasants from introducing fruit trees or plantation crops despite the prospect of high economic benefits from them.

Autonomous management arrangement

The degree of management responsibility given to local people is another factor that affects their motivation to participate in organized tree growing programmes. There are a number of successful forestry projects resulting from local initiatives. Leach and Mearns (1988) described the villagers in Um Inderaba, Sudan, who established a tree nursery, planted and protected a tree windbreak, fenced off a small area to allow for the regrowth of woody vegetation and planted trees for shade, fuel and fodder. These spontaneous activities were carried out by highly motivated farmers who were directly involved in project design, implementation and management despite it being a govern-initiated endeavour.

McGaughey and Gregersen (1988) observed that most forestry projects with the farmers' direct involvement, from tree management to tree harvesting, usually succeed. As such, it appears that one factor in the failure of government tree growing projects is the fragmented or discontinuous enlisting of the public from tree planting up to harvesting (Gregersen 1985). Where farmers merely execute government plans, quality and sustained participation cannot be guaranteed especially if the benefits will only be realized in the distant future.

Skutch (1993) discovered that about 44% of the village woodlots that she sampled in Tanzania had low farmers' project participation as a result of the Forest Service's 'prescriptive' and coercive management style. There was a risk that the real needs were not being addressed.

Access to future produce

Ownership right or usufruct practice over the land is not the only means to sustain farmers' motivation to grow trees on public lands. In the absence of land tenure, tree tenure may suffice farmer's striving for ownership rights over the future produce.

A number of field cases reveal that when there is no provision for farmers' rights over the trees they planted, they shy away from involvement (Jones 1988). When people are assured of direct benefits from the projects, they will more likely participate (Campbell & Bhattarai 1983). Sen *et al*. (1985) observed that farmers in West Bengal participated more actively in a farm forestry project when the benefits that they would receive were clearly defined.

In summary, farmers' motivation to grow trees voluntarily can be driven by their immediate needs or income generating potential. This can be enhanced by the effect of certain incentive system or can be suppressed by odd institutional arrangements. Table 1 summarizes the conditions in which farmers may or may not participate in tree growing.

Table 1. A guide showing the basic conditions in which a rural farmer may or may not participate in tree growing activities (modified version from Chambers *et al*. 1989)

Factor	Do not plant/protect	Do plant/protect
Land tenure	Insecure	Secure/aspire for security
Access to usufruct	Priority for government or subject to taxation	Vested primarily in the household, regularly exercised without restriction or rent
Security to future produce	Uncertain or not included	Provide and binding
Tree ownership	Owned by or shared with government or local authority or ambiguous	Owned by the household by law or in practice
Management system	Centralized and prescriptive	Participative or semi-autonomous
End-use	Social welfare	Specific household or communal needs
Production objective	Conservation and for wood industry needs	Equity and immediate household needs

CASE STUDIES OF TREE GROWING BY SMALL FARMERS[3]

The results of the four selected case studies of successful farm forestry in Luzon consistently support the findings of the literature review. A summary of these findings is presented in Table 2.

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[3] This section was taken from the author's technical paper in a book published by the Australian Centre for International Agricultural Research (ACIAR), entitled, "Improving smallholder farming systems in *Imperata* areas of Southeast Asia: alternatives to shifting cultivation", 1999, Canberra, Australia.

Table 2. Some successful farm forestry projects in Luzon

Site	Success conditions
1. Quibal, Peñablanca, Cagayan	• assured access/secured property rights • presence of wood market
2. Maguirig, Solana, Cagayan	• assured access/secured property rights • interest in other tree related uses • practice of intercropping • farmers' above-subsistence level situation • farmers' enterprising attitude
3. Nagtimog, Diadi, N. Viscaya	• assured access/secured property rights • interest in other tree related uses • practice of intercropping • farmers' above-subsistence level situation • farmers' enterprising attitude
4. Timmaguab, Sta. Ignacia, Tarlac	• assured access/secured property right • interest in other tree related uses • practice of intercropping • farmers' above-subsistence level situation • presence of wood market • farmers' enterprising attitude

The critical relevance of each success condition is discussed below:

1. ***Assured access/secured property rights***: Farmers in the four sites confidently grow trees because of the assurance that the future produce will accrue to them. In Nagtimog, DENR's provision of usufruct and tree tenure encouraged interested farmers to plant corn in between tree seedlings in the abandoned government reforestation site. Farmers in Maguirig succeeded in managing their own woodlots upon DENR's recognition of their legal claims over the disputed reforestation site. Both Timmaguab and Quibal farmers have long standing claim over the areas they planted with trees. In general, when farmers are assured of their ownership rights over future tree produce, more likely they will grow trees even on public lands despite no government direct cash payment
2. ***Interest in other tree related uses:*** Except for Quibal, farmers in the other three sites were not only interested in the wood products. They also grow trees for fodder, cash income, shade, aesthetics and other tree related uses. In other words, the more varied the benefits they can derive from trees to meet their household needs, the greater the likelihood farmers establish woodlots even without direct payment.
3. ***Practice of intercropping****:* Farmers in Nagtimog had successfully raised *Gmelina arborea* voluntarily in the abandoned reforestation site after government attempts failed (Pasicolan *et al*. 1996). The agricultural crops (e.g. corn, peanuts and mungbean) interplanted with the tree seedlings compelled the farmers to always keep the site free from grassland fires. Fire lines were constructed and banana or papaya is used as firebreaks. Farmers in Maguirig and Timmaguab adopted wide spacing for fruit trees to be planted in between forest seedlings. In short, the more diverse the crop planted in the area, the greater the farmers' stake over the site. Thus, there is regular care and maintenance of seedlings planted.
4. ***Farmers' above-subsistence level situation****:* The financial situation of the farmers is an important success factor of spontaneous tree growing at the farm level (Pasicolan *et al*. 1996). Farmers in Maguirig, Nagtimog and Timmaguab have other farmholdings

to obtain their main subsistence. Cash surplus farmers or at least those above subsistence have much time and resources to invest in other economic options. Because there is no pressure to hack out their daily subsistence, they can even venture into risky and long-term livelihood investment, like farm forestry.

5. ***Presence of wood market:*** Selling of firewood to neighboring towns and in Tuguegarao, the capital center of Cagayan Valley region makes a big business for firewood gatherers in Quibal. With the declining supply of timber in the nearby forest, however, a number of resource users began to plant *Gmelina arborea* and *Leuceana leucocephala* in their abandoned farmlots (Pasicolan & Tracy 1996). Self-sufficiency in household wood supply was the priority of farmers in Timmaguab. However, with the growing local demand for wood products like fencing materials, fuelwood, etc., this further encouraged the farmers to expand their woodlots. In both sites, the demand for the wood products became commercialized even without government or private sectors' initiative. In short, the presence of a wood market is a powerful incentive for small farmers to voluntarily grow trees.
6. ***Farmers' enterprising attitude:*** Opportunism and risk taking nature characterized the attitude of cash surplus farmers and those in search of more arable lands. In Nagtimog, farmers boldly took the risk to cultivate a portion of the DENR abandoned reforestation site. Likewise, the farmers in Timmaguab, despite their sufficient rice production, still invested in tree farming, a risky and laborious undertaking.

FARM FORESTRY AS A REFORESTATION STRATEGY

The following are the potential features of farm forestry as a reforestation strategy:

1. ***Sustainable***. Farmers' motivation to grow trees is in response to their direct household needs rather than superficial incentives like paying them to plant trees on public lands. It becomes an integral component of the household farming system because it is a local demand-driven tree growing scheme that recognizes the complementation of tree and short-term crops.
2. ***Spatially strategic***. It has the potential to rehabilitate adjacent marginal public lands because it starts from where the on-site actors are, and they can progressively expand their tree farms as they gain experience and profit from tree farming.
3. ***Cost-effective***. Government fund could be spared because tree growing was purely private individuals' initiative motivated by their felt needs. There is no need to rely heavily on huge foreign loans, as in the case of the past government administered Asian Development Bank (ADB) contract reforestation programme.
4. ***Can easily be replicated***. Farm forestry can easily spread out, if given the right kind of government and the private wood industry institutional support. Rural farmers tend to imitate their fellow peasants when they see tangible benefits gained by the latter from adopting certain land-use system. The start of most tree growing initiatives in Mindanao was a self-induced response to a local market demand. Farm forestry has spread out as a result of farmer-to-farmer technology promotion. Availability of local market and good price for wood are two powerful incentives that instantly attracted farmers to shift from their traditional crops to tree-based system.
5. ***Promotes grassroots' entrepreneurship***. As the small tree farmholders become experienced in tree husbandry, they also become entrepreneurs who are not only profit conscious but also begin to make risky investments in the wood business. Many farmers in Mindanao claimed to have become rich because of the income they gained from the trees they planted on their farmlots (Manila Bulletin, Oct. 3, 1999).

UPSCALING CONSTRAINTS

Although farm forestry can be a viable scheme to accelerate the government's snail pace reforestation strategy in the country, there are also some problems and difficulties in mainstreaming it, viz.:

1. ***Low capacity to expand***. Cash-deficient tree growers cannot easily expand their woodlots into large commercial scale plantation without full government support. Going big requires the private sector's financial assistance. Furthermore, the small size of land holdings, absence of security of tenure and assured wood market pose big limitations to the farm forestry expansion.
2. ***Farmers' limited options***. Resource-poor tree growers have limited capacity to respond to risks associated with tree growing, e.g. outbreak of forest pests, grassland fires, and other episodical hazards that tend to destroy their woodlots. Hence many of them are just contented with the little trees they planted because they avoid as much as possible gambling their limited resources to something that cannot provide them their instant need of the time.
3. ***Lack of support system***. Rural farmers have limited institutional linkages where they can source out technical and other logistic help for expansion, such as credit assistance, crop protection insurance, market information, training, and other necessary support systems.
4. ***Non-bankable.*** Besides the problem of cash flow, resource-poor tree growers could hardly borrow from private banks because they are not bankable in terms of their capacity to redeem their loans. The banks require stricter conditions or collateral from them than those who are cash sufficient.
5. ***Not profitable at certain kilometers radius from processing plant or market.*** The proximity of the market from the wood source is a crucial factor to consider in commercial scale farm forestry. A recent wood market study conducted in Mindanao claimed that forest plantations beyond 100 kilometers radius from the market or processing plant are no longer financially profitable because of the heavy transport cost (personal interview, 2000).
6. ***Relatively higher production cost per hectare.*** Small tree farms tend to have higher production cost per hectare than bigger or commercial size plantation because of the economy of scale factor. This applies in all aspects of the tree business operation, from site establishment, to plantation maintenance up to harvesting.
7. ***Lack of adequate planting area.*** Land availability remains a big constraint for small tree farm holders to venture into commercial size tree plantation. Despite government efforts to democratize the use of forest lands through leasehold or stewardship agreements, small farmers could hardly avail of these privileges because of the stringent legal requirements beyond their reach.

TREE GROWING UNDER NEW PARTNERSHIP ARRANGEMENT

This section explores the 'best fit' of complementation between the government's and the grassroots' roles in a tree-growing programme. It identifies the critical contributions of the private sector in sustaining the grassroots' tree-growing initiatives. The aim is to evolve an alternative co-management scheme between the government, local community and the private sector for the spontaneous regeneration of degraded forest lands in the Philippines.

FACILITATIVE ROLE OF THE GOVERNMENT

The government as represented by the DENR should cease from being always at the forefront of the tree-growing programme. Instead, it should take the role as facilitator providing enabling conditions for the different tree-growing actors to come together in mutual partnership. The following are the suggested key functions and activities that the government should do to enhance the greater participation of the grassroots:

1. Provide more enabling policies, such as attractive tenurial instruments and other forms of support services in favour of the small tree farmholders.
2. Simplify the process of complying with the legal requirements in availing of government institutional incentives and other support services for tree growing.
3. Release more public lands either for farm forestry or public tree growing.
4. Execute boundary delineation of released areas for communal tree growing.
5. Issue tax exemptions or rebates to private tree growers.
6. Encourage enterprising individuals or local groups to continue expand their clearings provided they will develop them into tree-based system.
7. Provide tree growers with communal fund for support livelihood projects.
8. Serve as a broker between capital owner (government or private bank) and the tree growers who are in need of production loans.
9. Provide incentives to private industries who are interested to invest in tree growing projects.
10. lnitiate and strengthen tripartite agreements or institutional arrangements with local tree growing communities and the private sector.
11. Provide infrastructure support to tree growers' physical and institutional needs.

GRASSROOTS' LOCAL COUNTERPART SUPPORT

The local people, oftentimes collectively represented by the community and other organized groups, are regarded as the main actors of the programme. In the past, they were treated as wage labourers of the project. This experience under the Contract Reforestation proved to be counterproductive. As the main stakeholders of the tree-growing projects, they too should bear certain costs especially in the maintenance and protection of the established plantation. By compelling them to invest their resources within their means, this would strengthen their long-term stake over the project. Among their possible contributions are:

1. family/communal labour;
2. local organization;
3. social capital: (local institutions, indigenous knowledge, best management practices, etc.);
5. financial or material contribution.

ENABLING ROLE OF SUPPORT ACTORS

The private sector, particularly the wood industry, plays a crucial role in stimulating and sustaining the tree growers' motivation to expand. Of equal importance is the financial support from lending institutions. Development NGOs can also assist tree growers cope with cash flow problems during the period between tree planting and harvesting. Among the important roles of each intermediary actor are:

a) *Wood industry*
   1. provide market security;
   2. provide collateral to the bank for the tree growers;
   3. provide or source out production capital for the tree growers;
   4. extend technical assistance.

b) *Lending Institution*
   1. provide production loans with low interest and long grace period;
   2. provide crop insurance;
   3. offer livelihood support fund.

c) *Development NGOs*
   1. create livelihood support for the community;
   2. provide community training programmes;
   3. extend other related community development services.

Table 3 summarizes the role and the corresponding counterpart contributions each partner institution can provide under the proposed co-management system of forest regeneration in the Philippines.

Table 3. Proposed institutional counterpart arrangements among different stakeholders of tree growing programme in the Philippines

Institution	Role	Nature of support
1. Government	Facilitator/enabler	• enabling policies (e.g. tax exemptions, rebates, etc.)
		• provide more lands
		• source out fund
		• broker between bank and tree growers
		• arbitration/mediator
		• legal support
		• work out infrastructures
		• technical assistance
2. Private sector:	Catalyst/reinforcer	• market security
a. Wood industry		• production capital
		• bank collateral for the tree growers
b. NGOs		• training programmes
		• livelihood support
		• community development services
c. Lending institution		• logistic support
		• production loans
		• crop insurance
		• livelihood fund
3. Tree growers/ community	Main project implementor	• organization
		• local management
		• communal cooperation
		• subsidized labour
		• social capital: local institution, ITK, etc.
		• financial and material

CONCLUSION/IMPLICATIONS

This paper concludes with the following points:

1. Reforestation in the Philippines can be much accelerated by increasing the active participation of the the citizenry through enabling government policies, incentive systems and other support services.
2. In order to mainstream farm forestry as a potential reforestation strategy in the country, there is a need to create a new kind of mutual partnership arrangement among small tree farmholders, the government and private sector.
3. Tree growing on public lands should be market demand-driven, whereby the wood industry enters into an agreement with the farmer producer for it to become spontaneous and sustainable.
4. By changing the role of the government's forestry agency, from programme implementor or regulatory body to facilitator, and tapping the private sector's financial investment to support small farmholders' tree growing initiatives, national reforestation programme may not necessarily depend on huge external capital outlay.
5. There will be spontaneous grassroots' participation in tree growing, if the necessary support systems aimed to circumvent the farmers' financial, physical, legal and institutional constraints are in place.
6. Failure to create the right blend between the government's institutional incentives, private sector's investment options and potential tree growers' resource capacities and stakes will continue to drain off national reforestation funds.

REFERENCES

Arnold, M.J.E. 1987. *Community forestry*. Ambio 16 (2/3).

Campbell, J.G. & Bhattarai, T.N. 1993. *People and forests in hilly Nepal: preliminary presentation of community forestry household and ward leader survey*. HMG/UNDP/ FAO Community Forestry Development Project, Nepal.

Chambers, R., Saxena, N.C. & Shah, T. 1989. *To the hands of the poor*. London, UK, Intermediate Technology Publication.

Chowdhy, K. 1984. Social forestry: Who benefits? *In* Y.S. Rao *et al.*, ed. *Community forestry socio-economic aspects*. Bangkok, Thailand, East-West Environment and Policy Institute and FAO, RAPA.

DENR, 1990. *DENR master plan for forestry development*. Funded through TA 933 PHI of the Asian Development Bank. Quezon City, Philippines, Bangkok, Thailand.

Foley, G. & Barnard, G. 1985. *Farm and community forestry.* Earthscan Technical Report 3 (3). London, UK, Earthscan Publications Ltd.

Gregersen, H.M. 1985. Incentives for forestation: a comparative assessment. *In* K.F. Wiersum, ed. *Strategies and design for afforestation, reforestation and tree planting.* Proceedings of an international symposium, Wageningen, September 19–23, 1983. The Netherlands, PUDOC.

Gregersen, H., Draper, S. & Elz, D. 1989. *People and trees: the role of social forestry in sustainable development*. EDI Seminar Series. Economic Development Institute of the World Bank.

Hasan, M.S. 1990. BRAC: protecting ecology and alleviating poverty. In *Grassroots actions in natural resources management*. Asian NGO Study Tour Report. Makati, Metro Manila Philippines, ANGOC for Agrarian Reform and Rural Development.

Johansson, L. 1991. *Successful tree growers*: *why people grow trees in Babati District*, *Tanzania*. Working Paper 155. Uppsala, Sweden, Swedish University of Agricultural Sciences, International Rural Development Centre.

Jones, J. 1988. Socio-cultural constraints in working with small farmers in forestry: case of land in Honduras. *In* L. Fortman & J.W. Bruce, eds. *Whose trees*? *Proprietary dimensions of forestry*. Boulder and London, Westview Press.

Leach, G. & Mearns, R. 1988. *Beyond the woodfuel crisis: people, land and trees in Africa*. London, UK, Earthscan Publication Ltd.

Manila Bulletin. October 3, 1999.

McGaughey, S.E. & Gregersen, H.M. 1988. *Increasing private investment. Investment policies and financing mechanisms for sustainable forestry development*. Washington DC, USA, Inter-American Development Bank.

Pasicolan, P.N., Calub, A. & Sajise, P.E. 1996. Dynamics of grassland transformation in Salingdingan, Ilagan, Isabela. Philippines Imperata Project Paper 1996/10, ACIAR Project. *In* K. Menz, D.M. Macandog & I.W. Rusastra, eds. *Improving smallholder farming systems in Imperata areas of SEA.* Canberra, Australia.

Pasicolan, P.N. & Paguirigan, D. 1991. *Promotion of fuelwood-based agroforestry system in Dy Abra: breaking the ground towards community self-help project*. Paper presented in the FAO 'Regional Expert Consultation on Local Organizations in Community Forestry Extension', Chiang Mai, Thailand, October 7–12, 1991.

Pasicolan, P.N. & Tracey, J. 1996. Spontaneous tree growing initiatives by farmers: an exploratory study of five cases in Luzon, Philippines. *In* K. Menz, D.M. Macandog & I.W. Rusastra, eds. *Improving smallholder farming systems in Imperata areas of SEA*. Canberra, Australia.

Sellers, S. 1988. The relationship between land tenure and agricultural production in Tucurrique, Costa Rica. *In* L. Fortman & J.W. Bruce, eds. *Whose trees*? *Proprietary dimensions of forestry.* Boulder and London, Westview Press.

Sen, D., Das, P.K. & Pundare, A.P. 1985. Peoples' participation in farm forestry: a case in West Bengal. *Journal of Rural Development in India* 4 (4): 441–481.

SIDA Report. 1988. *Employment and income generation through SF in India: review of issues and evidences*.

Skutch, M.M. 1993. *Why people don't plant trees: the socio-economic impacts of existing woodfuel programs. Village case studies, Tanzania*. Energy in Developing Countries Series, D-73P. Washington, DC, Resources for the Future.

12 Forest degradation and rehabilitation in China

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ABSTRACT

This paper consists of four parts. The first part describes a historical profile of the forest degradation process in China from pre-agricultural period up to the middle of last century. The second part introduces briefly the reforestation efforts made in China to reverse the deforestation and degradation processes and to achieve some increase of forest resources in the second half of last century. Both parts are illustrated by figures in two tables either by assumptions based on geobotanical analysis and historical reports or by the results of successive national surveys of forest resources in the last 30 years. In the third part the launching of two newly initiated forest rehabilitation projects, namely the Natural Forest Protection Project (NFPP) and Cropland Conversion to Forest/ Grassland Project (LCP), are expounded and some policies and implemental practices of these two projects are specified. These two projects constitute the mainstay of the great effort by the Chinese Government and people to rehabilitate in the new century the eroded and degraded lands on a large scale. Following some statements on the positive results of successful implementation of the NFPP and LCP, some defects of their implementation exposed by recent project evaluation are indicated in the fourth part and some corresponding suggestions to improve the policies and their implementation are delivered. They are mainly related to taking more care of the local people's interest and getting more involvement of the people in policy formation and implementation. It is also suggested that the policies and their implementation should be more flexible and region specific and more room should be left to use natural force for rehabilitation. The financial input for implementing these two projects should be enlarged to fully compensate the loss induced by the logging ban and to cover more expenditure for obtaining better results of tree planting and grass sowing in arid and semiarid regions.

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A HISTORICAL PROFILE OF FOREST DEGRADATION IN CHINA

China in the range of recent national territory was rich in forest resources in the pre-historical period. It is assumed, based on the different sources of scientific knowledge ranging from climatology to archaeology, that the southeast half of China having totally humid and semihumid areas was covered with a high percentage by forests and the northwest half of China having mostly arid and semiarid areas still had some forests on the high mountains towering over the grasslands and deserts. The overall forest coverage of China's territory in the pre-historical or pre-agricultural period (about 4000–5000 years ago) is estimated by different authors at 50 to 60 percent. Then the forest vegetation was destroyed or degraded in the long historical period up to the last century by agricultural and pastoral encroachment, overcutting for building material and fuel as well as by repeated wars and imperialist invasions. The historical profile of deforestation and forest degradation in China can be traced back by assumptions based on climatic and landscape analogy and by using historical records with descriptions of the localities in different historical periods. The long history of China's civilization provides us with rich literature material for nearly every county settled initially in ancient times.

By summarizing all these historical records with supplemental geobotanical analysis, a historical profile of the deforestation process in China can be revealed in a sketchy manner as illustrated in the following table (Table 1).

Table 1. Deforestation profile in the history of China

Historical period	Main damage in the past period	Forest coverage
4 000 years ago Pre-agricultural period (Shang dynasty)	Balanced with other vegetation types, small changes by hunting and collecting activities	≈60%
2 000 years ago (Han dynasty)	Most of plain forests vanished, damage along the Great Wall	<50%
1 000 years ago (Between Tang and Song dynasties)	Heavy damage of forest in Shanxi, Sha'anxi, Gansu Provinces and east of Sichuan	<40%
350 years ago (Beginning of Qing dynasty)	Most of the forests in north China destroyed, some damage of forests in south China	21%
50 years ago (Before the establishment of the P.R. of China)	Serious damage of forest in northeast and southwest China	12.5%

Source: Shen *et al.* (2000)

From Table 1 it can be inferred that the deforestation and degradation process has taken place in China for a long period of time in an accelerated manner up to the mid-20th century and it has always accompanied population growth and cropland expansion, with drastic acceleration during wars or at the shifting stage of two successive dynasties usually with social unrest and turmoil. Therefore, social stability and substantial economical growth combined with population control and restrained use of natural resources are essential to stop the deforestation process.

THE STRUGGLE FOR REVERSING THE DEGRADATION PROCESS IN THE SECOND HALF OF LAST CENTURY

Since the founding of the P.R.C., the Government has been aware of the lack of forest resources in China as a result of long-term deforestation in the past and has intended to reverse the degradation process by encouraging mass involvement in the afforestation campaign. Closing mountains for forest rehabilitation and establishment of shelterbelt systems in some eroded regions were practised widely in 1950s and 1960s and have received some positive results. But at the same time because of the need to support the national economy in the early years of industrialization, and because of the lack of scientific knowledge on rational forest management overcutting of forests, especially those in the northeast, was practised and continued for quite a long time. The depletion of forest resources in general and the excessive exploitation of the forests in the upper reaches of the Yantze River in the southwest in particular have led to negative ecological consequences and worsened the economical situation in local forestry enterprises. The national project of establishing Three-North Projective Forest System was initiated in 1978 as a first response to the environmental degradation in north China. It was followed by several national forestry projects in the 1980s and 1990s on the upper reaches of the Yantze River, in the coastal region, in the Taihang Mountain region, etc. Besides, targeting to meet the increasing demand for timber and paper products in line with economic development, a national project on establishing fast-growing and high-yielding forest plantations was also initiated and implemented with the help of the World Bank. All these efforts have made some compensations for past losses and the trend of decreasing forest resources in terms of land area and total growing stock was reversed in the period starting from the mid-1980s up to the end of last century. The results of all these efforts can be summarized and illustrated from the changes in forest resources at different periods during the second half of last century (see Table 2). The periodical national forest inventories, beginning from the 1970s provided helpful information (Table 2).

Table 2. Changes of forest resources in modern China (1949–1998)

Period	Forest area ($x10^6$ hm^2)	Forest coverage (%)	Total growing stock ($x10^8$ m^3)	Mature and overmature forest area ($x10^6$ hm^2)
Before 1949	≈120	12.5	116	≈48
1950–1962	113.36	11.8	110	41.71
1973–1979 1st nat. inv.	121.86	12.7	105	28.12
1977–1981 2nd nat. inv.	115.28	12.0	102.6	22.05
1984–1988 3rd nat. inv.	124.65	12.98	105.7	14.20
1989–1993 4th nat. inv.	133.70 (145.23*)	13.92 (15.12*)	117.8	13.49
1994–1998 5th nat. inv.	158.94*	16.55*	124.9*	13.30*

*According to the new standard of forested area (above 0.2 crown density).
nat. inv. is the abbreviation for national inventory.

From Table 2, it can be seen that the forest coverage in the first 30 years remained at almost the same level because of the compensatory effect of afforestation on overcutting in some forest regions, but the total growing stock was decreasing. However, from the 1980s, the forest resources have increased significantly in terms of land area and total growing stock. But the available mature forest resource for timber production was still decreasing and the quality of forest resource was low with respect to age structure, productivity, valuable timber in species composition, etc. It should also be mentioned that environmental degradation in China has not been stopped despite the rehabilitation efforts. Additional concerns about global climate change and biodiversity conservation, which have been raised in the last decades, have made the Chinese Government more consistently consider environmental issues as a main task of modern forestry.

THE LAUNCHING OF NEW FOREST REHABILITATION PROJECTS

The big flooding by the Yantze and other rivers in 1998 stimulated the environmental awareness of the government leaders and the public. In response, some immediate measures were taken including a logging ban in the forests located at the upper and middle reaches of the Yanzte and other big rivers. In fact, the policy on conservation of natural forests had been discussed at the central governmental level for several years especially in 1996–1997, and the big flooding in 1998 stirred the policy-makers to make up their minds and accelerated the process of implementing the policy and adopting the project on natural forest protection (NFPP). It is also evident that a single project of protecting the existing forests is not enough to reverse the environmental defects; soil erosion control should be enforced especially on those croplands on steep slopes, which contribute more than 70% of the total eroded silts in river basins. Thus following the NFPP a new project on Cropland Conversion to Forest Grassland or Grain for Green Project (LCP) was initiated in 1999 to tackle another aspect of environmental degradation. These two projects, the NFPP and LCP combined, represent the mainstay of China’s rehabilitation efforts in the new century.

The policy and implementation of the National Forest Protection Project (NFPP)

This project was inaugurated in 1998 and had gone through a pilot stage of implementation up to the year 2000. Now it is in the process of full implementation and has been included in the 10th national 5-year plan of economical and social development (2001–2005). The main tasks of the NFPP consist of two parts. The first part is the logging ban of natural forests in the upper reaches of the Yantze River and upper and middle reaches of the Yellow River. These regions spread over 764 counties and forest enterprises within 13 west provinces (or autonomous regions), in which 30.38 million hm^2 of natural forest are under strict protection, while another 30.38 million hm^2 of forest land (including shrubs and newly planted areas) are under supervised management. The second part is the natural forest protection for national forests located in northeast China and the eastern part of Inner Mongolia (Great Xing’an Mountain forests) on a differentiated management basis. Within the total area of 34.18 million hm^2 forested land, 14.09 million hm^2 are allocated for strict ecological protection, another share of 12.06 million hm^2 is allocated for balanced protection and management in the common protective zone, and only 8.03 million hm^2 of forested areas, that constitute 23.5 percent of the total are considered to be commercial forests. A diminished logging quota has been set up, that is 7.5 million m^3 less than 5 years ago in the region alone.

A large amount of financial resources has been put in the NFPP to support a substantially large staff for forest protection, reforestation and management and to compensate for the loss caused by reducing timber logging.

The policy and implementation of Cropland Conversion to Forest/ Grassland Project (LCP)

This project was inaugurated in late1999 and had gone through 2 years (2000–2001) of the pilot stage of implementation in several provinces, and beginning from this year (2002) is getting into full implementation covering almost all provinces. It also has been included in the 10th national 5-year plan. The policy of the LCP is to convert those croplands exposed to erosion (on steep slopes or on other degraded lands) to forests or grasslands. As compensation for the loss of crop harvest the government provides subsidies to the farmers at 100–150 kg grain (depending on the regions) and 20 yuan cash for every mu (1/15 of hm^2) of land conversion. Besides, the government also provides 50 yuan for each mu of land conversion for the purchase of tree seeds or nursery stocks for afforestation. The LCP policy aimed at environmental rehabilitation, rural poverty alleviation and transformation of rural economical structure has been much welcomed by the farmers and grass root units. Up to the middle of 2002 year, more than 2.3 million hm^2 of eroded croplands have been converted. A 10-year plan of LCP has been worked out, which has set a target of more than 14.7 millions hm^2 of degraded lands to be converted to forests and grasslands with total financial input of about 350 billions yuan. By the end of the 10-year plan of the LCP the forest and grassland coverage in the projected regions should be increased by 5 percent and the land area of about 1.9 million km^2 will be thus protected to some degree.

These two newly launched rehabilitation projects, the NFPP and LCP, are functioning as the mainstay of a large-scale system of ecological construction in China, where some old projects like the Three-North Projection Forest System are still being implemented in a combined way. A new project on desertification control around the capital is in operation right now in response to the serious sand storm damage occurring in recent years.

SOME DEFECTS IN IMPLEMENTING THE REHABILITATION PROJECTS AND SUGGESTIONS FOR THEIR IMPROVEMENT

In general, these two new rehabilitation projects are being implemented quite successfully. The natural forests, especially those in the west regions, are carefully protected and the logging ban has been realized under strict control. The land conversion has been carried out in large areas and most farmers are happy getting grain and money as compensation. Ecological conditions in some regions have been improving with reduced water and wind erosions. The planting of fruit and nut trees, and bamboo, etc. is promising to increase the income of the farmers, whereas the sowing of grass, alfalfa in many cases, has activated cattle and sheep breeding in villages. Nevertheless, there are defects or shortcomings in implementing these projects which should be regarded seriously.

Some defects in implementing the rehabilitation projects

(a) The coverage of the NFPP is too wide; not only are the national natural forests under the logging ban, but collectively owned forests (usually village community forests) and private forests are also affected. Some of the community and private forests are of artificial origin, and were planted for commercial purposes using World Bank Loans and alike. The logging ban by the government undercuts the promising income and threatens the security of forest tenure and ownership.

(b) Logging ban in its conventional sense means only the banning of commercial logging but in reality the government officials, being afraid of illegal cuttings, have been imposing a ban of any kind of cutting, including intermediate and sanitary cuttings. Such kind of overall cutting ban has made forest management very difficult that will have negative impact on forest conditions.
(c) The government input for implementing the NFPP is not big enough to cover all the costs including the cost of reduced employment in the logging industry and the cost to support sufficient staffs for rational forest management. There are evident signs of poverty in the forestry related communities due to losses of income related to logging.
(d) The policy of the LCP is too rigid for all regions which are quite varied in their natural and socio-economic conditions. Some people from certain regions are not satisfied with the amount of compensation they receive, while others would not accept the afforestation recommendations made by local governments. The imposed ratio between forests and grasslands being converted and the imposed limitation of economical (NTFP) forest ratio (no more than 20 percent of afforestated area) do not always correspond with the regional specifics.
(e) The artificial afforestation orientation after land conversion is exaggerated in some regions, especially in the arid and semiarid regions, where the afforestation effort should be conditioned by the water resource availability. The potential of natural rehabilitation has not been used fully, because the converted land under natural rehabilitation would not get the government subsidy.
(f) The NFPP and LCP are only parts of the regional ecological construction programme. Their implementation can be more effective through comprehensive coordination with other measures such as terracing and amelioration of the remaining croplands, improvement of irrigation, construction of check-dams for erosion control, use of agricultural techniques to increase crop yield, grassland fencing and amelioration, control of grazing, etc. But in reality, every project is run by a separate sector and there is lack of coordination among different sectors running different projects.

All these defects mentioned above may occur here or there and to some extent they have originated from the top-down nature of the policies and from the rigidity of the policies that does not allow the local implementing units some room for flexibility. Besides, there are some scientific uncertainties and technical difficulties regarding the interrelation between vegetation cover and water resource availability. There is also a lack of available techniques for successful afforestation in arid and semiarid regions.

Some suggestions for improvement in policies and their implementation

(a) The top-down rehabilitation policies should be further improved by collecting different opinions and responses from the local people and farmers and making adjustments according to local specifics.
(b) The National Forest Protection Project (NFPP) should place more emphasis on sustainable management of natural forests. The logging ban should be clarified and incorporate transitional characteristic; a strict ban on harvest cuttings should be imposed only in restricted areas of ecologically sensitive natural forests, mostly national forests. Most of the natural forests should be oriented to rational management in a sustainable manner which allows sustainable use of forest resources, with rationalized intermediate cuttings and other improvement management prescriptions to be encouraged.

(c) More financial input for natural forest conservation should be allocated to support a sufficient and efficient force of forest management staff and to compensate for the loss of forest related activities caused by the logging ban.
(d) The policy of the Land Conversion Project should have some flexibility for different regions. The ratio between forest and grassland to be converted and the ratio between economical forest (for NFPP) and so-called ecological forests should be determined scientifically and locally. The natural rehabilitation of lands after farming is stopped should be encouraged, especially in arid and semiarid regions.
(e) All those government projects oriented at forest rehabilitation and environment protection should be coordinated and run by people from different sections in a combined manner. The leading bodies of local governments, especially at the county level, may play a very important role in the coordination of comprehensive efforts. Some policies should be clarified giving the county government leaders some power in regulating and coordinating the different projects being implemented concurrently in the same regions.

BIBLIOGRAPHY

Chinese Forestry Association. 1992. *Historical changes of Chinese forests*. Chinese Forestry Publishing House.

Chinese Forestry Society. 2001. *Proc. Forum on Ecological Environment of the Great Northwest in China*. Chinese Forestry Publishing House.

Ministry of Forestry P.R.C. 2000. *Statistics of forest resources in China*. P.R.C., Ministry of Forestry.

Shen Guofang *et al*. 2000. *Forest resources and sustainable development in China*. Guangxi Scientific and Technological Publishing House.

Zhang Peichang, Zhou Xiaofeng & Wang Fengyou. 1999. *Outline of natural forest protection project*. Chinese Forestry Publishing House.

13 Integrating rural livelihoods with forest rehabilitation: need for community forest management

P.K. Biswas*

ABSTRACT

In India it has been observed that wherever there is large concentration of forest, there is also high concentration of tribal and rural population. Rural livelihood is dependent on forest resources. For many of these people, not only does the forest provide economic sustenance but it is also a way of life for them socially and culturally. Degradation and depletion of the forest resources are increasing poverty and misery among the rural population. Therefore, it is imperative to rehabilitate degraded forest resources for sustaining rural livelihood. It is possible only through devolution of power to the communities for the management of forest. The National Forest Policy, 1988, of the Government of India envisaged the communities' involvement in conservation, protection and management of forest. With the active support of local organizations, people's participation in forest management was initiated which is generally known as Joint Forest Management (JFM) in India. This paper tries to examine the experiences of JFM for integrating rural livelihoods with forest rehabilitation. This paper also pleads for strategies for community forest management (CFM) to ensure rural livelihood along with rehabilitation of forest.

INTRODUCTION

There has been considerable activity since independence in the field of economic development. A vast amount of money has been spent by the government and various international agencies for the upliftment of the poor. And yet the level of development remains alarmingly low. There is still much poverty, malnutrition, unemployment and underemployment. In general, the conditions of the poor, both in urban and rural areas, have worsened. Whatever economic growth has taken place, has occurred in an inequitable manner. The gap between the poor and rich has increased considerably.

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Thanks to current policies and programmes the lot of the rural poor as compared to that of the urban dwellers is perhaps more severe, more pernicious and more hopeless. The roots of the problem of rural poverty are, in general, population growth and rising expectations. It is almost impossible to maintain the desired level of production from the available land area. Therefore, to augment agricultural production and to create industries, forest land has been cleared. This is more so in the thickly populated regions where the rural poor live. The tribal communities in India largely occupy the forested regions. They live away from the mainstream of life but in harmony with nature. With the large scale indiscriminate felling of trees and the resultant deforestation and degradation, the tribals in particular, and the rural poor in general, have been badly hit. This has often led to soil erosion and environmental degradation. Further loss of forest cover would create ecological insecurity and increase poverty and misery amongst the rural poor.

CONTRIBUTION OF FOREST TO DEVELOPMENT

In the above context, it is imperative to examine the contribution of forest to the development of the rural poor. India still is a developing nation. The majority of its population lives in rural areas. Forests play a vital role in the rural economy. For nearly three-quarters of the population of developing countries wood is the staple energy source. In many areas, particularly where a majority of the population is landless, forests and trees are among the few resources that are available to rural dwellers. They provide three different kinds of benefits: *jobs and incomes* often needed to supplement inadequate returns from agriculture; *produce* such as fuelwood, food, fodder and building poles for the home; and—less directly but just as importantly—a range of *environmental benefits*, without which other activities, such as agriculture might be impossible.

The forest sector is important as it is the second largest land use after agriculture, it is a source of goods and services used by the society. In remote forest fringe villages about 300 million tribal and other local people depend on forest for their subsistence and livelihood and about 70 percent of India's rural population depend on fuelwood to meet their domestic energy needs. For about 100 million of them, forests are a main source for livelihood and cash income from fuelwood, non-timber forest products (NTFP) or construction materials. More than half of India's 70 million tribal people, the most disadvantaged section of society, subsist from forests. Forests protect important catchments for water, conserve soil, ameliorate climate and combat against global warming and desertification. They provide services such as wildlife refuge, watershed protection, prevention of soil and water runoff, and ground water recharge. Both wood and non-wood products are important, so are environmental services of flora and fauna.

India's biodiversity is rich and unique. India is one of the 12 mega diversity countries in the world having a vast variety of flora and fauna, which collectively account for 60–70 percent of world's biodiversity. Its ten biogeographic regions represent a broad range of ecosystems. India has the world's 6 percent of flowering plant species and 14 percent of the world's avian fauna (World Bank 1996). There are nearly 45 000 species of plants in the country and similarly, in fauna there are 81 250 recorded species (NFAP 1999). It has 80 national parks and 441 sanctuaries, known as protected areas, which are about 14.8 million ha and 4.5 percent of the country's land area and 14 percent of its forest area.

Forests contribute 1.7 percent of the GDP of the country. However, this figure does not take into account their numerous non-market and external benefits and the vast amount of fuelwood and fodder and other forest products collected legally or illegally. One estimate shows that the total annual removal from the forest is worth about US$7.1

billion or INR30000 crores which include about 270 million tonnes of fuelwood, 280 million tonnes of fodder and over 12 million cubic meter of timber and countless non-timber forest products (NTFP). This does not include the value of environmental services provided by the forest, which according to one estimate are equivalent to US$19 billion per year.

PRESENT STATUS OF FOREST IN INDIA

The land area of India totals 328.7 million ha of which 142.5 million ha (43.3 percent) are under agriculture; forests cover 76.5 million ha (23.27 percent) of the total land area. According to the State of Forest Report, published by the Forest Survey of India (FSI) in 1997, the actual forest cover is 63.34 million ha (19.27 percent of the country's area) of which 26.13 million ha are degraded (NFAP: 1999). State figures of recorded forest area and actual forest cover are shown in Table 1.

Table 1. Recorded forest area and actual forest cover in states/UTs assessed in 1997 (area in sq. km)

State/UT	Geographical area of state/UT	Recorded forest area	Actual forest cover in 1997	% of actual forest to geographical area
Andhra Pradesh	275 068	63 814	43 290	15.7
Arunachal pradesh	83 743	51 540	68 602	81.9
Assam	78 438	30 708	23 824	30.4
Bihar	173 877	29 226	26 524	15.3
Delhi	1 483	42	26	1.7
Goa	3 702	1 424	1 252	33.8
Gujarat	196 024	19 393	12 578	6.4
Haryana	44 212	1 673	604	1.4
Himachal Pradesh	55 673	35 407	12 521	22.5
Jammu & Kashmir	222 235	20 182	20 440	9.2
Karnataka	191 791	38 724	32 403	16.9
Kerala	38 863	11 221	10 334	26.6
Madhya Pradesh	443 446	154 497	131 195	29.6
Maharashtra	307 690	63 842	46 143	15.0
Manipur	22 327	15 154	17 418	78.0
Meghalaya	22 429	9 496	15 657	69.8
Mizoram	21 081	15 935	18 775	89.1
Nagaland	16 579	8 629	14 221	85.8
Orissa	155 707	57 184	46 941	30.1
Punjab	50 362	2 901	1 387	2.8
Rajasthan	342 239	31 700	13 353	3.9
Sikkim	7 096	2 650	3 128	44.1
Tamil Nadu	130 058	22 628	17 064	13.1
Tripura	10 486	6 292	5 546	52.9
Uttar Pradesh	294 411	51 663	33 994	11.5
West Bengal	88 752	11 879	8 349	9.4
Andaman & Nicobar Islands	8 249	7 171	7 613	92.3
Chandigarh	114	31	7	6.1
Dadar & Nagar Haveli	491	203	204	41.5
Daman & Diu	112	–	3	2.7
Lakshadwwep	32	–	–	–
Pondicherry	493	–	–	–
Total (in ha)	3 287 263	765 210	633 397	19.27

Source: FSI (1997).

In terms of per capita forest area, India ranks amongst the lowest in the world. The per capita forest area of 0.16 ha in 1960–61 has been reduced to 0.08 ha. The following table (Table 2) depicts the real scenario.

Table 2. Per capita forest land in the Asia Pacific region, 1990

Country/ geographical area	Per capita availability of forest (ha)	Per capita GNP (US$)
India	0.08	360
Sri Lanka	0.11	470
Indonesia	0.64	560
Malaysia	1.02	2 330
Fiji	1.17	1 780
Tropical Asia	0.21	475
Total Asia-Pacific	0.17	602
Total Developing Country	0.50	763
Total World	0.64	4 063

Source: FAO (1995).

However, forest area is being rapidly depleted due to the heavy pressure of population on land. Having about 2.5 percent of world's geographic area, India at present is supporting 16 percent of the planet's human population and 18 percent of the cattle population. The forest cover has been declining both in quality and extent. The degradation is not only indicated by crown density decline but also soil erosion and lack of natural regeneration. Between 1950 and 1980 India lost about 4.3 million ha of forest land for non-forest uses like development of agriculture, heavy industries and other developmental processes. Complete with this there are serious problems of encroachment, grazing, forest fire, shifting cultivation and illegal felling. Most of the flora and fauna species are endangered with a serious economic implication. A recent World Bank report estimated that due to degradation and deforestation the loss has been up to one million ha per year during the 1970s and 1980s. The rate has somewhat slowed after promulgation of the Forest Conservation Act, 1980, but it still remains a cause of concern and alarm.

The depletion of the forest resources has aroused the passion of the rural poor in particular and the general public. As such, there have been spontaneous popular movements like the "Chipko Andolan" in U.P. Hills, the "Jharkhand Mukti Morcha" in the tribal areas of Bihar and adjoining states, "Jungle Bachao" in Maharashtra, "Aapiko Movement" in Karnataka, and "Save the Western Ghats" in southwestern India. Conservation, protection and rehabilitation of forests have become top priorities in the country's development.

In this context, we need specialised management skills to manage the forest. On the occasion of the Forestry Education Centenary Celebrations at the Forest Research Institute and colleges, DehraDun (19 December 1981), the late Prime Minister Smt. Indira Gandhi said:

"Specialization is an inescapable in our age of advanced technology but how can it yield the desired results unless it fits into the overall social situation in our country? Our forests can survive only if forestry is attuned to the goals of national development, and long-term ecological welfare as well as that of the communities which live nearby".

As remedial measures, various innovations were introduced to rehabilitate the degraded forest lands.

EFFORTS IN FOREST REHABILITATION

Traditionally, forest management practices were aimed at developing and understanding the protective and productive aspects of natural forests. Biological, technical and macro-economic considerations received overriding priority. In the process, people's livelihood issues were relegated to secondary position and people's role in safeguarding the resources and their active participation were relegated to secondary place. Only recently the social role of forests and forestry together with their protection and production roles has received attention.

After all, forestry is about people. It is about trees only in so far as trees can serve the needs of the people (Westoby 1989). Forestry and Forest Policy should concern in every conceivable way, forests, wood lots and trees that can contribute to the livelihood of people in particular and human welfare in general. This fact has been recognized by professional foresters the world over. Therefore, the theme of the 8th World Forestry Congress, 1978, Jakarta, was "Forestry for the People". The 9th World Forestry Congress held at Mexico in 1985 reinforced this by adopting the main theme of the Congress as "Forest Resource for the Integral Development of Society". In fact, the future of human society is intrinsically linked to the future of the forest.

Social forestry

To arrest further degradation and to rehabilitate the degraded forest lands, social forestry, in the mid-1970s, provided the most challenging area for social analysis in rural livelihood scenario and development. The National Commission on Agriculture (NCA), 1976, stressed the socio-economic importance of social forestry and primarily aimed at providing goods and services to the rural poor.

In the context of India, social forestry was conceived as the science and art of growing trees and/or other vegetation on all land available for the purpose, in and outside traditional forest areas. The existing forests are managed with intimate involvement of the people which is more or less integrated with their operations, resulting in a balanced and complementary land use that provides a wide range of goods and services (Tiwari 1983).

The social forestry programme was designed to cover all segments of society – rural and urban—for an overall development of the nation. The main objectives *vis-à-vis* development of rural poor were: to provide fodder, firewood and small timber; to provide timber for sustaining and creating village level cottage industries based on wood; to provide livelihood options at village level through increased avenues for gainful employment; to optimize the use of agricultural land through agroforestry practices and to increase the farmers' income level; and to improve the income from marginal agricultural land through tree plantation. It aimed at growing trees in groups, strips, in lines or singly over vacant lands near habitation which were otherwise not utilized.

State level social forestry projects were supported by the World Bank, the Canadian International Development Authority (CIDA), the Swedish International Development Authority (SIDA), the Overseas Development Administration (ODA) and other agencies. It helped, to some extent, increase biomass production, and in the promotion of agroforestry on private agricultural lands, afforestation of public and common non-forest lands, in awareness raising and the beginning of community participation in forest rehabilitation.

However, the major drawbacks of the implementation of the social forestry programme were lack of transparency and accountability, exaggeration of physical target achievements and unsustainable investments. It did not help in institutional reforms, and on the contrary led to large recruitment of staff and diversion of attention from natural forest management to poorly productive plantation forestry. It has not been proved, as originally conceived, that the social forestry would result in reversing the trend of degradation of forests by meeting demand for fuelwood, fodder and small timbers from the plantations raised outside forest lands. The economic benefit to the landless poor people came through wage employment. Beyond this, the community participation was not very significant.

JOINT FOREST MANAGEMENT

Simultaneously with social forestry, other forestry projects for rehabilitation, plantations and protection made attempts to check further degradation of the forests to alleviate the miseries of the rural poor and to provide livelihood options. These activities focused on the vital issue of people's involvement in forest protection and management. The policy-makers realized that along with the Government, the people and the people's institutions are the real stakeholders in forest management. Some of such experiments have borne results—like the experiences of Arabari in West Bengal, Sukhomajri in Haryana, Dasoli Gram Samaj Mandal in U.P., the Forest Protection Committee in Orissa and elsewhere. In many places the villagers have zealously protected the forests on their own. Such attempts by the villagers need encouragement and patronage.

It was increasingly realized that unless the opportunities for rural livelihood are created, rehabilitation of forest would be an extremely difficult task. The peoples' motivation centers on livelihood options as they depend on forest resources for economic sustenance.

The initial experiment started in 1972 at Arabari in Midnapore district in West Bengal. For protection of the forest, village forest committees were formed and, in turn, were provided with usufructs of all non-timber forest products (NTFP), first preference for employment, plus 25 percent of net cash benefit from the sale of sal (*Shorea robusta*) poles. The material benefits which are potentially sustainable were the clear motivation. This kind of joint effort/collaboration between government and people led to the evolution of the Joint Forest Management (JFM) programme in India.

Coupled with such experiences, the genesis of JFM is rooted in the National Forest Policy (NFP), 1988. This policy made a significant departure from the earlier policies of 1952 and 1894. Though the NFP 1988 has its main thrust on the conservation of flora and fauna diversity it clearly recognizes that "the life of tribals and other communities living within and near forests, revolves around forests. The rights and concessions enjoyed by them should be fully protected. Their domestic requirements of fuelwood, fodder, minor forest produce and construction timber should be the first charge on forest products" (NFP 1988). Conservation and the people's livelihoods are integral part of the forest development and development of the rural poor.

The NFP 1988 has been further strengthened by the 1 June 1990 circular of the Ministry of Environment and Forests, Government of India. It has highlighted both the need and process of involving village communities and voluntary agencies/non-governmental organizations (NGOs) in the protection, development and rehabilitation of degraded forests. It encouraged the forming of village level institutions for forest management. Formally, the NGO has been identified to provide interface between the forest department and rural communities. The benefit-sharing mechanisms have also been outlined to enable rural communities to develop an equity-based stake in the protection, development and rehabilitation of the degraded forests.

The JFM strategy sought departure from the earlier conventional mode in the following manner as given in Table 3. It also differed from social forestry, which laid the main emphasis on plantation.

Table 3. JFM strategy

From	To
Centralized management	Decentralized management
Revenue orientation	People orientation
Large working plan	Microplan
Target orientation	Process orientation
Unilateral decision-making	Participatory decision-making
Controlling people	Facilitating people
Department	People's institutions
Plantation as first option	Low input management and regeneration
Fixed procedures	Experimentation and flexibility

Though the social forestry programme also emphasized on people's participation, there was no definite mechanism to ensure it. In JFM, however, the main emphasis is on natural regeneration, protection and rehabilitation of forest. It operates through village forest committees, which are recognized by the forest department. The management functions are to be carried out by such committees. Once natural forests are regenerated and degraded forests are rehabilitated, people will get forestry products in a sustainable manner. Continuous availability of forest produce can bring significant development for the rural poor.

JFM *VIS-À-VIS* LIVELIHOOD OPTIONS

Forest resources embody all the quantitative and qualitative dimensions in natural forests, plantations, agroforestry and farm forest plots, urban plantations, small woodlots and wildlife refuge. Over the years, forestry has evolved from tree management to the management of complex ecosystems and their utilization. As it makes several contributions in supporting sustained livelihood options, the involvement of people in forest management is of critical importance. People's dependence on forest is very significant not only in India but in the entire developing countries of South and Southeast Asia as it is evident in Table 4.

Table 4. People dependent on forests

Country	No. of people (millions)	
	Living on forest lands	Dependent on forests
INDIA	100	275
Indonesia	40–71	n.a.
Philippines	20	25–30
Thailand	14–16	20–30
Myanmar	8	n.a.
Papua New Guinea	3.5	3.5
Bangladesh	5	10
Nepal	8.5	n.a.

Source: Lynch (1992).

Forest rehabilitation and improvement of the village community are interdependent. JFM provides an opportunity for managing forest resources for better productivity and availability of forest produce. The forest provides direct benefits (physical products such as wood, food, medicine, fuel, fodder, fiber, organic fertilizers and a host of other products) and indirect and attributable benefits for environmental enrichment. As an inseparable component of the total land-use system, forestry has significant inter-relationships with agricultural, pastoral and food-producing systems. Through soil and water conservation, and maintenance of soil fertility, the forest provides critical support for agricultural development. In addition, forest-based small and cost-effective enterprises can help increase rural employment and raise the income and living standards of rural people including forest dwellers and indigenous groups. The quality of life in rural areas depends on the rehabilitation of forests, which in fact, is the principal aim of Joint Forest Management.

Let us critically examine what kind of significant contributions JFM is bringing to the millions of rural people of India. It is a fact that the rural population depends mainly on fuelwood for cooking and heating. In the rural areas, more than 75 percent of the total energy is derived from biological produce, including cow-dung. Due to shortage of fuelwood, cow-dung is being used increasingly. A time may come when there may be food to eat but no fuelwood to cook it!

About 250 million people in India live below the poverty line. Most of them live in mountains, uplands and ecologically fragile areas. In their case, forestry is often the only source of employment and income. For example, head-loading of fuelwood for sale is an important source of income for many fringe communities. Some 2 million people are said to be making a living as head-loaders (NFAP 1999).

The JFM strategy requires that forestry be integrated to other sectors of development. It tries to conserve the forest resources by creating alternative arrangements for livelihoods. In addition, due to protection and other activities undertaken, there is productivity and income generation and integration of agriculture and allied activities with forestry development. The case study of Karidongri Village Forest Committee, Bilaspur (M.P.) is a pointer to this (Box No. 1).

Box No. 1. Case study of Karidongri VFC, Bilaspur
In Karidongri village of Bilaspur District there were 57 families out of which 15 families were landless. In 1995, the Village Forest Committee (VFC) was formed and under the ageis of the Forest Department various activities were undertaken to win the confidence of the people and motivate them to share the responsibilities of forest management. Some of the activities were diversion channel, new stop dam (for water conservation), bunding of 20 acres of agricultural land, wells with eight electric pumps, leveling of lands, a general store, pisciculture for income generation. Owing to this livelihood, opportunities were available from sources other than forests. The self-help group (SHG) of workers was assisted by DWACRA in manufacturing bricks and grain banks. The motivated villagers protected the forest against illicit felling, grazing, fire and encroachment. They helped in registering 51 forest offences. Besides protection, a plantation of 54 780 seedlings was undertaken in 60 ha of land. They have sown 192 kg of seed in 1996–97 in blank forest out of which 13 300 seedlings have been established. They have resolved to plant 1 000 seedlings in a non-forest area and name it 'Shakti Van' for fuelwood.

Source: M.P. Human Development Report (1998).

The agricultural sector depends almost entirely on livestock for the energy needed for various farm operations. The economics of maintaining cattle, sheep and goats is largely dependent on forests as a source of fodder—be it grass, leaf or fruit fodder.

Wood (timber) is also required to make various types of ploughs and agricultural implements, each with a different life-span. The bullock-cart is the main means of transport in the rural sector. According to one estimate, there are about 13 million bullock-carts in the country, which account for about INR3000 crores. About 2 crore people find direct or indirect employment in the bullock-cart transportation system.

The village community also requires timber for the construction of houses. Apart from this, bamboo (generally known as the poor man's timber) is used for various other purposes. Agricultural implements and tools are made from wooden poles and bamboo. Animal husbandry and dairy development programmes are also related to the availability of grass, fodder, leaves and so on. House construction in tribal area is undertaken with materials collected from forests. Timber, bamboo, grass, creepers and bark are useful for this purpose. The community depends on forest for various edible products as well. Forestry, in this way, is a part of the livelihood strategies of the rural people and tribal communities in particular. Not only does it meet the basic needs by supporting food securities and poverty alleviation, and providing health needs and shelter all in a sustained manner, it also provides means of employment, income, food, fuelwood, fodder, agricultural productivity. By JFM, ecological balance is ensured along with productivity of the forests so essential to improve the quality of life.

The life of the indigenous people (tribals) is connected, in one way or the other, with the forest, right from birth to death. Their folklores, rites and rituals revolve around the forest. In times of distress the forest is the last resort for them. Even in areas where forests do not exist, tribals continue to periodically visit distant forests to procure traditional requirements. Apart from this, some financial benefits accrue to them from the collection and sale of non-timber forest products (NTFP). Forests are their economic resource base and occupy a central position in the tribal economy. Tribal life is profoundly affected by whatever happens to the forests.

For several tribal groups living in or near forests, about 30 percent of their diet is derived from forest sources (i.e. wild vegetables, tubers, fruits, nuts, bamboo shoots, small animals). Medicinal plants are important in the primary health care system. The indigenous people have developed an interesting, and often sophisticated knowledge system of ethno-medicine and use of a vast variety of plants for medicinal purposes (NFAP 1999).

The forest also offers scope for the development of village industries. Many trees provide the source of raw materials for cottage industries, such as *tassar* and silk production, rearing milch cattle, *pattal* (leaf plate) making, basket weaving, oil, paper-making and others.

The potential of NTFPs for poverty alleviation is very important. The rural poor and tribal communities collect various kinds of products throughout the year to sustain their livelihood. Activities related to NTFPs provide employment during slack periods in the agricultural cycle and provide a buffer against risks and household emergencies. These constitute a part of the household activity and in several cases can be the main source of income. The importance of NTFP in rural livelihood is indicated in Box No. 2.

Box No. 2. Case study of women Forest Protection Committees (FPCs) in Jaypur Range of Bankura (North) Division, West Bengal
In a study of three FPCs, in Tribanka, Gopal Nagar, and Brindaban Pur in Jaypur Range of Bankura (North) Division, West Bengal, it was found that NTFPs contribute significantly to the economy of the rural poor. In these villages, FPCs were formed between 1990 and 1991. With proper protection by the villager, the sal forest was regenerated to a great extent and other products like mushrooms and medicinal plants contributed to the income of the VFCs. During 1992–93, each of the VFC earned about INR1.0 lakh only by selling sal leaf products. According to the Range Officer of Jaypur, his beat had the potential to produce 30 quintals of mushroom in a single week, with proper dehydration technology. Apart from these, the villagers were collecting mahua, satmuli and 29 varieties of medicinal plants both for self consumption and sale. This has tremendous potential for the rural poor.

Source: Biswas (1994).

The plantation programmes to rehabilitate forests under JFM have tremendous potential for livelihood options as most of the forestry programmes are labour intensive. Employment in forestry benefits mostly the rural households, women, tribal community and the backward areas. Various donor agencies as well as the government are providing funds for the implementation of JFM. This can generate employment in the following sectors: preparatory work for plantation, maintenance of plantation, protection of forest areas, NTFP collection, village cottage industries, village dairy industry and others.

Thus, the rural folk can be gainfully employed in the village itself. This can check the 'push and pull' factors of migration. As the population pressure is too high on the land many people remain unemployed in the villages and 'push' out of the village. On the other hand, economic avenues in the urban sector 'pull' the rural folk. JFM, which creates livelihood opportunities, has the potential to arrest this process.

CURRENT STATUS OF JFM

From the foregoing discussion, it is evident that the answer to India's immediate problem of poverty lies in increasing the biomass available in nature. If we fail to recreate nature on a massive scale in a manner that provides livelihood options and equity, both the villages and urban centers will be difficult places to live in.

Joint Forest Management is an attempt to alleviate such situation. According to the Ministry of Environment and Forests, Government of India, by March 2002, 27 Indian states have adopted JFM as the main strategy to augment the forest resources. There are about 63000 village forest protection committees (FPC) which are implementing JFM in 14 million hectares of forest area (See Table 5).

Table 5. Status of JFM (as of 1 March 2002)

Sl. No	State	Area under JFM (sq. km)	No. of FPCs
1.	Andhra Pradesh	17 675.70	6 816
2.	Arunachal Pradesh	58.10	13
3.	Assam	69.70	245
4.	Bihar	741.40	296
5.	Chattisgarh	28 382.55	6 412
6.	Goa	130.00	26
7.	Gujarat	1 380.15	1 237
8.	Haryana	658.52	471
9.	Himachal Pradesh	1 112.47	914
10.	Jammu and Kashmir	795.46	1 895
11.	Jharkhand	4 304.63	1 379
12.	Karnataka	1 850.00	2 620
13.	Kerala	49.95	32
14.	Madhya Pradesh	43 000.00	10 443
15.	Maharashatra	6 866.88	2 153
16.	Manipur	5 072.92	82
17.	Mizoram	127.40	129
18.	Nagaland	1 500.00	55
19.	Orissa	7 834.67	12 317
20.	Punjab	735.60	184
21.	Rajasthan	3 093.36	3 042
22.	Sikkim	6.00	158
23.	Tamil Nadu	3 733.89	999
24.	Tripura	319.89	180
25.	Uttar Pradesh	507.03	540
26.	Uttaranchal	6 066.08	7 435
27.	West Bengal	4 880.95	3 545
	Total	**140 953.60**	**63 618**

Source: Government of India (2002)

IMPACT OF JFM

JFM programmes have led to several positive impacts. Some of them are discussed briefly here.

Rehabilitation and improvement in the conditions of forests

There is evidence that JFM has rehabilitated the country's degraded forests. In the past few years, the overall forest cover of the country has increased by 3 896 sq km. One main reason for this rehabilitation and improvement is the successful implementation of the JFM programme. In areas under JFM incidents of illicit felling have sharply declined. It has been reported that in Rajasthan, unlike in the past, people did not resort to tree felling in JFM areas even during droughts. A study carried out by the Andhra Pradesh Forest Department indicated that between 1996 and 1999, dense and open forest covers have increased by 18 percent and 22 percent respectively, mainly due to the introduction of JFM. Another study in Sabarkantha District and Vyara Division of Gujarat has indicated significant improvements in forest cover after the initiation of JFM. One of the more immediately visible ecological effects of JFM has been the recovery of fodder resources in JFM areas. The prolific growth of understorey vegetation, in many instances, has led to increased biodiversity and relatively rapid increases in wild herbivore population.

Increase in livelihood options

JFM programmes have created livelihood opportunities at several places. The communities have benefited from livelihood options under JFM projects, through microplanning, sale of NTFP, share in the final harvest, etc. Further, JFM has helped many FPCs to build up a substantial level of community funds, which are used for local development activities.

Reduction in encroachments

At several places, JFM has helped reduce the area under illegal encroachment and the rate of fresh encroachments. In Andhra Pradesh nearly 12 percent of the encroached forest land has reportedly been vacated since the JFM programme was initiated.

Involvement of NGOs

The JFM programme has let to a considerable involvement of NGOs in the forestry sector, although there is significant variation from state to state. This has facilitated interaction among communities and the government.

Change in attitude and relationship

One of the most significant impacts of JFM has been the change in attitude of the local communities and forest officials towards each other and towards the forest. For instance, members of the Botha FPC in Buldhana, Maharastra, even postponed a wedding in their village in order to fight a forest fire. This was unthinkable in pre-JFM days. In several FPCs, traditional forest protection practices have been revived, for example, *kesar chhannta* (sacred groves) in Rajasthan. The large number of training and orientation exercises carried out in the different states has also contributed to a positive change in attitude (Government of India 2002).

CONCLUSION

Of course, there is no single best strategy available as a universal key to all development approaches in JFM. The strategies span a broad spectrum and alternatives are available or can be devised depending on the prevailing situation. In keeping with the philosophy of Decentralized Governance, people's involvement in the decision-making process and consequent empowerment are crucial in such efforts. Village dynamics and social processes have to be understood properly. Sociological insight, perception and knowledge are, therefore, instrumental and essential for formulation, designing and implementing any effective approach to JFM which will lead to an integrated development of the rural poor.

Sustainable forest management is key to sustainable rural livelihood. There has to be a harmonious balance between conservation of forests and development of communities through livelihood security. Forestry is no more a technical subject dealing with trees only. It is socio-technical and now a synthesis of wide-ranging and diverse subjects. Silvicultural practices and forest management have to be integrated with subjects like sociology, anthropology, economics, law, environmental science, remote sensing, system science, computer science, cartography, business administration, communication, tribal art, culture, museum, parks of wildlife management, hydrology and plant and animal genetics as we are dealing with a whole complex ecosystem, which is trying to address the poverty of this country. The holistic view is but essential. A sustainable alliance has to be forged among government organisations, non-government organisations and local level organisations. There has to be an effective partnership among all the stakeholders for capacity building, monitoring and evaluation of JFM to achieve the ultimate goal of planning and development, i.e. self reliance. And Gandhiji's *'Gram Swaraj'* may become a reality.

Even in the age of liberalization and globalization it has to be understood that there can be no financial assets if there are no ecological assets. Sustainable livelihood is increasingly linked to environmental conservation. Here, it is apt to quote a tribal chief who said:

> *Only after the last tree has been cut down*
> *Only after the last river has been poisoned*
> *Only after the last fish has been caught*
> *Only then will you find that money cannot be eaten.*

What a commentary on our contemporary society indeed! JFM as a strategy has its ups and downs. It is still evolving. There is no single best strategy; neither is JFM the panacea for all the evils of environmental degradation.

However, it is clear that forest productivity will ensure equity and livelihood for the rural poor. The rural livelihoods must be integrated with the rehabilitation of forests, with the involvement of communities in the form of village forest committees/forest protection committees. Once these are involved, the forest resource cycle will be completed. The following schematic diagram depicts the real scenario (Diagram 1)

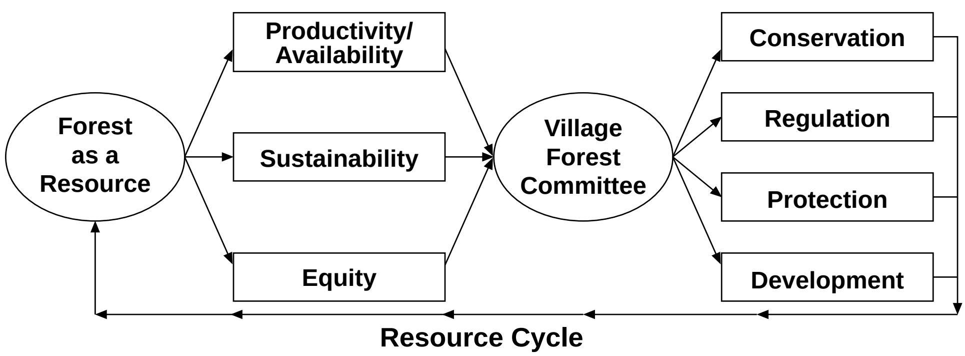

Diagram 1. Forest resource cycle
Source: Biswas (1993).

It is important to empower communities to take decisions on the management of forests. There has to be a legal sanctity to village forest/forest protection committees. It is imperative to have a memorandum of understanding signed between communities and the Government. In forestry, unlike agriculture, the gestation period is long. Only NTFP based activities would provide livelihood options. The JFM experience is only a decade old. On the basis of this it is strongly recommended that JFM should move towards community forest management (CFM), implying more legitimacy and power to the communities. The National Forest Policy, which essentially pleads for community empowerment, needs to be backed up by appropriate acts and legislations. There is an urgent need to amend various forest laws and acts to facilitate the process of CFM. This needs to be harnessed properly for environmental stability and ensuring rural livelihoods. There is need for CFM to ensure rural livelihoods and forest rehabilitations, which go hand in hand. We need to strengthen it and sustain it for the bright future of both.

REFERENCES

Biswas, P.K. 1988. Sociological issues in forestry. *Indian Journal of Social Sciences* 1(2).

Biswas, P.K. 1993. Forestry-based sustainable development: the social dimensions. *Indian Journal of Public Administration*. Vol. XXXIX No. 3.

Biswas, P.K. 1994. *Women FPCs in Jaypur Range of Bankura (North) Division, West Bengal*. Indian Institute of Forest Management, Bhopal. (mimeo)

FAO. 1995. *State of the world's forests*. Rome.

Forest Survey of India. 1997. *State of forest report*. New Delhi, Govt. of India.

Government of India. 2002. *Joint forest management: a decade of partnership*. New Delhi, Joint Forest Management Monitoring Cell, Ministry of Environment and Forests.

Lynch, O.J. 1992. Securing community based tenurial rights in the tropical forests of Asia. *Issues in development report*. Washington, DC, World Resources Institute.

M.P. Human Development Report. 1998. Bhopal, Govt. of Madhya Pradesh.

National Forest Policy. 1988. Govt. of India, New Delhi.

National Forestry Action Programme (NFAP) India. 1999. New Delhi, Ministry of Environment and Forests, Govt. of India.

Tiwari, K.M. 1983. *Social forestry for rural development*. Dehradun, International Book Distributors.

Westoby, J. 1989. *The purpose of forestry: follies of development*. Oxford, Basil Blackwell.

World Bank. 1996. *India, country economic memorandum*. Washington, DC.

14 Forest recovery with villagers—based on a case study in Khong Chiam, northeast Thailand

Anders P. Pedersen* and Chana Piewluang**

ABSTRACT

Khong Chiam is chosen as a case study because of its remoteness, unique forest type, and its vulnerability as a public forest. Its relatively poor legal status of Reserved Forest makes it particularly vulnerable. In 1983, 700 ha were selected and established as an in situ gene conservation area. The objectives were to protect the forest and its genetic resources, particularly targeting Pinus merkusii, which is a valuable population with faster growth compared to highland pines of the same species and is recognised as a high-priority provenance for planting programmes. Pinus merkusii in this area is one of the last and largest lowland populations remaining in Thailand. Other important tree species are found, for example, Dipterocarpus alatus, Irvingia malayana, Peltophorum dasyrachis, Pterocarpus macrocarpus and Anisoptera costata. Immigrants have, over the years, caused an increasing pressure on land resources and the whole ecosystem is threatened. Conservation based on protective and prohibitive regulations has proved unsuccessful. Recovery of the forest resources may not be possible without the awareness and active support and participation of local communities. Sustainable conservation relies on good relations between forestry staff and local people. A new participatory approach based on generating alternative income other than forest exploitation is being established. It consists of four main activity groups. There are social aspects, aspects of income and livelihood, area and tree populations, and research and development aspects. All these efforts have projected development in the right direction and are alleviating the problems. However, continuation of external inputs, presence in the area, conducting meetings, facilitation of alternative products and markets, are detrimental for continued success—

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at least at this early stage. The presence of forest authorities is deemed essential in order to guide the community legally and in order to set limits for any trespassers or aggressors, who may not be easy to control locally.

BACKGROUND

In Thailand, *Pinus merkusii* is found mainly in lower montane forest in the north at altitudes between 600 and 1 200 m and smaller stands are found in the lowland (70–170 m) in the southwest and eastern/northeast (DFSC 2000). The average precipitation at Khong Chiam district in northeast Thailand is 1 835 mm annually (Meteorological Department 1998). The pine yields important forest products such as timber, resin, tender wood, and produces a very good pulp (FAO/UNDP 1968). The lowland sources from northeast Thailand have a shorter and less pronounced grass-stage[1] with faster early growth than highland provenances. The large variation among Thai provenances was confirmed by tests since 1971 under the Pine Improvement Programme in Chiang Mai. Soon, attention was drawn to sources from the northeast with a fast and early growth as a source for improvement work. Moreover, it was revealed that one of the most seriously threatened forest types was the mixed broad-leaved/pine type occurring in the south and southeast of northeast Thailand (Granhof 1998). Therefore, a *P. merkusii* stand in Khong Chiam forest area in northeast Thailand was chosen to establish an *in situ* gene conservation area. The objectives of the programme were divided into two parts. There were broad and narrow objectives. The broad objective was protection, maintenance and management of genetic resources of living tree species in their natural environment for present and future generations. The narrow objective was conservation of the pine stand for seed production, selection and possibly future breeding.

In 1983, 700 ha were selected as “a core area” to protect the forest. Danida (Denmark) and the Royal Forest Department (Thailand) joined forces to explore the area and establish a permanent *in situ* Gene Conservation Station (Sa-ardavut *et al*. 1989, Granhof 1998). The station was established as a part of the Royal Forest Department (RFD) with local forest staff to supervise the activities and monitor forest coverage and quality and to prevent encroachments. Early conservation measures entailed mapping, demarcation, relocation of illegal settlers, prohibiting agricultural activities and charcoal burning, and establishing firebreaks. At present, the station furthermore focuses on conservation and research implementation as follows (Piewluang *et al*. 2001):

- establishment of a seed production area;
- establishment of some research trials;
- study on characteristics of structure and floristics of forest community;
- culture and collection of seed from seed production area;
- establishing access/inspection roads and firebreaks;
- ploughing the area for natural regeneration implementation;
- enrichment planting in degraded areas.

[1] The grass stage is considered as a temporary adaptation to seasonal drought and fire. During the grass stage, the young seedling remains suppressed for 2–4 years forming a dense cover of long needles that protect the shoot. Meanwhile, the root system strengthens (Sirikul 1980).

Recently, the area of the Conservation Station, including settlements, is estimated to be about 1 040 ha (Figure 1) (DFSC 2000, Piewluang *et al*. 2001).

The pine stands are found in a poor site area with low yielding agriculture due to shallow soils and a very hot dry season. In addition, the forest area has legal status of being a forest reserve. However, forest reserves in Thailand are not protected by strong legislation and enforcement such as National Parks. Therefore, they are often heavily degraded or in reality converted to swidden agriculture, or settlement areas.

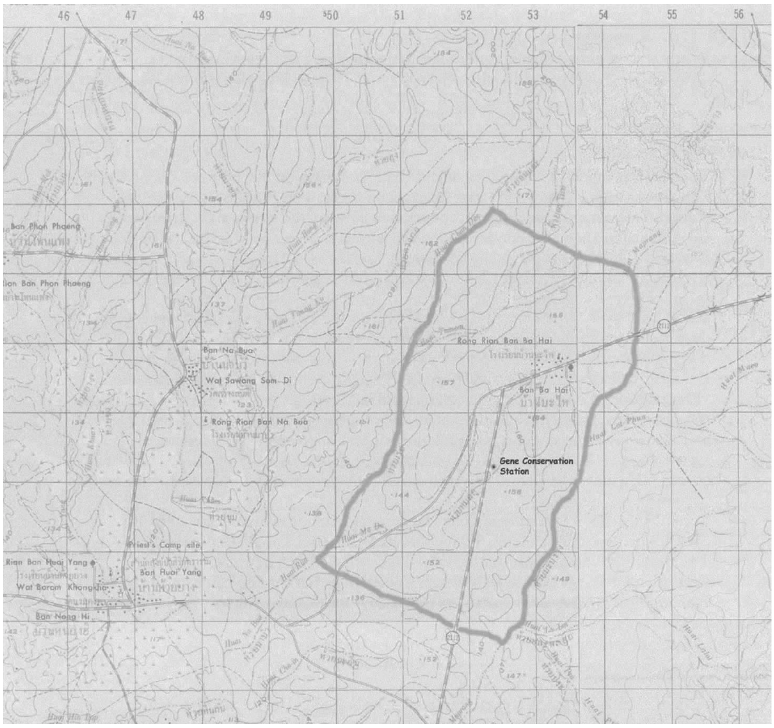

Figure 1. Location of Ubon Ratchathani Gene Conservation Station and surrounding villages in Khong Chiam district, northeast Thailand

Over the years, surrounding villages expanded in number and size due to immigrants from both neighbouring provinces and their own increasing population that has caused an increasing pressure on land resources. The forest became further exploited, degraded and settlers continued to take over forest land. In response to the unsuccessful protection, the conservation area was selected as a pilot project site in 1999 when the RFD and the Forest Genetic Resources Conservation and Management Project (FORGENMAP) initiated a new participatory approach (pilot project: *Partnership in Conservation of Forest Genetic Resources*) based on generating alternative income other than forest exploitation.

THE RESOURCE AND THE PROBLEM

The entire ecosystem of the area is threatened and fragmented due to illegal agricultural activities, settlers, clearing, cultivation, forest fires, firewood chopping, illegal logging, and charcoal production. The concern is how to protect the genetic resources of the forest, particularly targeting *Pinus merkusii*.

The population of *P. merkusii* is valuable due to a number of reasons. It is one of the last and largest lowland populations remaining in Thailand. It yields more and grows faster as compared to highland pine of the same species and is recognized as high priority provenance for planting programmes. The species prevails at higher altitudes but the advantages of the lowland type are faster growth and absence of "grass-stage", a serious disqualifying drawback in the years after planting.

Other important tree species found are *Anisoptera costata, Dalbergia cochinchinensis, Dipterocarpus costatus, D. alatus, Irvingia malayana, Peltophorum dasyrachis, Pterocarpus macrocarpus, Anisoptera costata, Shorea roxburghii* and *Schima wallichii.*

Figure 2. A group of *Pinus merkusii* trees scattered in the area of Ubon Ratchathani Gene Conservation Station

Some endemic species occur in the area. New orchid and ginger species have been found recently and more species are likely to be found from further studies. The ecosystem is of a rare and highly threatened type. The forest has become insular fragmented or an island in an agricultural landscape.

The pine has been reduced in number and an estimate predicts that less than 3 000 trees are left of which the majority are dying due to severe damage (Figure 2). The seed setting of the remaining trees is poor due to damage from chipping, cutting, resin tapping and forest fires (Figure 3) (DFSC 2000). Regeneration does not effectively take place due to more frequent annual fires (Figure 4).

Figure 3. *Pinus merkusii* wood chipping

Figure 4. The poor natural regeneration of *Pinus merkusii* in the conservation area

The forest thus decreases in area and coverage. Many forest products are becoming either scarce or are no longer available. Large animals have disappeared. This is likely due to habitat destruction but also increased hunting pressure. Lack of large animals reduces the seed dispersers and thus further impacts biodiversity. Tree species are declining and sensitive animal species are disturbed, and disappearing.

At Ba Hai village (the village located closest to the conservation area) alone, for example, the settlements increased from 10 houses in 1986 to 100 houses in 1997 (Granhof 1998). Forest fires affect the few, very big trees still present, typically *Dipterocarpus* spp. and *P. merkusii*. This, and storms have resulted in many fallen trees and small seedlings are destroyed by an increasing number of forest fires. People from outside cut wood to sell elsewhere (personal communication, villagers). At present logging operations have ceased due to the poor value of the remaining wood. However, forest fires are still destructive (FORGENMAP 2000).

Table 1. Problem matrix on the forest and communities around the conservation area

Threat to the forest	Community problem
• Forest fire	• Poverty
• Logging, clearing and resin tapping	• No land for agriculture
• Encroachment from outsiders who come to collect, catch, cut, and exploit the diminishing natural resources	• Too dry / too poor soil for farming • Population increase • Gambling and drugs
• No clear boundaries of the area—not clearly defined	• No land rights • Lack of knowledge, understanding, and co-operation with other organisations • No alternative job/income

Sources: FORGENMAP 2000.

There are increasing problems sustaining people's livelihood in the area due to an increasing population, higher demands for access to modern life and commodities, and less favourable growth/production conditions (Table 1). At present the responsibility for the area is in the hands of government officials. Provided there are officials and adequate budgets, the conservation can carry on over a long period. In the case of unchanged attitudes or government negligence, the deterioration will continue at a faster rate. Conservation and management for sustainable forest use should be undertaken by cooperation of the local people, government officials and NGOs.

In the year 2000, a survey for situation analysis was made through a rural research appraisal among the villagers in Huai Yang Sub-district. Table 2 lists the products and the yield trends for edibles/consumables of the area.

Table 2 indicates degradation of the ecosystem. This complies with a diminishing biodiversity and more prevailing occurrences of pioneer species at the expense of climax forest and species.

Table 2. Forest edibles – before[2] and now[3] status based on interviews with Huai Yang villagers

Forest edible	Season	Area of catching	Amount status 2000
Bamboo shoots	June–September	Bamboo forest towards the west	Same level as before
Mushroom “koon”	June–October (depends)	Area around station	Less now
Mushroom “pooh” Mushroom “kai”	June–February	Dry dipterocarp forest, evergreen forest	Less now
Red ants eggs	February–April	Here and there in forest	Less now
Forest vegetable 1	March–April	Anywhere	More than before
Forest vegetable 2	March–April	Everywhere	More than before
Forest ginger	Throughout	Evergreen forest	Less now
Thorny vegetable	April–December	Along streams	More than before
Edible fruits	March–August	Frequent in forest	Less now
Snakes	Occasionally	Frequent in forest	More than before
Squirrels	Occasionally	Anywhere Less	
Forest bees	March–May	Frequent Less	
Birds	Anytime	Everywhere	Less
Beetle, *Buprestis* sp.	August–October	Hill tops	Same level
Forest chicken	Occasionally	Frequent	Same level
Flying squirrel, civet, rabbit	Occasionally	Depend on species, luck and skills	Less
Frog, toad, bull frog (*Rana catesbejana)*	May–June	Along streams	Less
Fish, shrimp and shells	Rainy season. From August and onwards diminishing	Along streams	Less
Other edible animals	Occasionally	Evergreen and dry	Less

Sources: FORGENMAP (2000).

THE PILOT PROJECT

Following the unsuccessful forest protection approach focusing on protective and prohibitive regulations, FORGENMAP eventually decided to set criteria for selection of pilot project sites in 1999. The major criteria were areas located outside the protected area system, representing different ecosystem, forest remaining with some degree of disturbance, and availability of major agencies involved in rural development. The conservation area at Khong Chiam has matched those criteria. Therefore, the area was selected as one of four pilot sites and the pilot project was started in 2000 (FORGENMAP 2000).

The objectives of the pilot project are to investigate possibilities and conditions for a conservation model (partnership in conservation) under different conditions (forest types, ethnic groups and social conditions) and to bring together the RFD conservation objectives and legitimate rural needs. The initial activity of FORGENMAP was to make

[2] “Before” is not clearly defined, but refers to the situation 10–20 years ago.

[3] “Now”: The interviews were carried out in 2000 as part of a Rural Rapid Appraisal.

villagers understand the project objectives and the importance/benefits of the forest. To achieve that target, a number of training courses, meetings and workshops were set up and were joined by the selected active/interested people from involved agencies as well as villagers, GOs and NGOs. FORGENMAP and the responsible local agencies organized these activities.

It was concluded that a work plan for the conservation area should be to compile the needs of all partners. The work plan consists of a description of the area and vegetation, social aspects, aspects of income and livelihood, and research and development. To decrease forest exploitation and to increase income generating activities, the partners of the conservation area decided to introduce the activities with a social aspect and aspects of income and livelihood before undertaking other activities. The first work plan was initiated in 2000.

THE HUMAN RESOURCE AND PARTNERSHIP

The conservation area is surrounded by eight villages: Naa Bua, Ba Hai, Huay Yang, Lao Jereun, Nong Hee, Naa Don Yai, Yang Soo Paa and Nong Phoue (Figure 1). The villagers agreed on the project objectives and implemented the initial activities of the project. However, Ubon Ratchathani Gene Conservation Station, the local agency responsible, selected Ba Hai village as the only village partner due to the project's limited resources. Moreover, since most Ba Hai villagers do not have land rights for creating income, they exploit the benefits from the forest area more heavily than other villages, which lie further outside the forest area.

The Ba Hai village headman works closely with his villagers to initiate and undertake most activities contained in the work plan with advice from the staff of the conservation station. Whenever the activities are implemented, the villagers supply the manpower while the conservation station staff provide materials and equipment as well as recommendations/suggestions for carrying out the activities. These partnerships are functioning well and are seen as evidence of a unique cooperation.

RESULTS

Research and development aspects

FORGENMAP requested the Forest Restoration Research Unit (FORRU) in Chiang Mai Province to organize a training course on forest rehabilitation in 2001. Staff members of this conservation station including three foresters from the other pilot sites attended the training course. The activity aims to teach the participants handling of new species and steps in forest rehabilitation using the framework work concept such as seed collection, nursery cultivation, site preparation, planting, etc.

Area and tree populations

FORGENMAP and the Ubon Ratchathani Regional Forest Office surveyed the status of *P. merkusii* in the conservation area. It was revealed, that out of 2 000 trees surveyed, 1 049 trees were found undamaged and 951 trees were damaged. For the GBH class, it was found that there were only 83 seedlings smaller than 10 cm, 191 trees in the 10–30 cm class and 1 726 trees larger than 30 cm respectively. The stem damage was caused by wood chipping and resin tapping. Forest fires, pests and diseases (Community Forestry Group 2000) cause other damage.

It is concluded that this stand is in continuous degradation and unable to regenerate sufficiently. Therefore, pine seedlings from 40 selected mother trees are now grown to establish a *circa situ*[4] conservation stand at its site next year. Seedlings from each mother tree will be planted in square plot with spacing 4 x 4 m. The stand will consist of eight replications and will cover about 2.24 ha. This plantation will be used as a seed source for seed, scions and for other genetic observations/collections of this provenance for the future.

FORGENMAP staff cooperated with the conservation station staff and villagers on forest inventories. The objectives were to 1) assess the genetic resource, 2) monitor the status over time, 3) test methods prescribed in the forest inventory manual, and 4) train the partners for forest inventory in the future (Figure 5).

A B C

Figure 5. Steps of data collection, (A) Locating and measuring the distance to a tree, (B) Measuring girth of a selected tree, (C) Identification of a tree species

Many villagers/partners have learned the process of forest inventory well and are now capable to conduct further surveys of the forest area in the future. The results from the inventories reveal four forest types in the conservation area and each forest type maintains a variety of tree species (Table 3).

[4] *Circa situ* conservation is a conservation method "between" *in* and *ex situ*: It aims by active conservation and planting to enrich or reestablish the local genetic resource by using its own offspring.

Table 3. IVI top 5 for all forest types and their species characteristics in Khong Chiam (Greijmans & Piewluang 2002)

REDE	REDO	REFR	IVI	Species scientific name
Seasonal evergreen forest				
3.3	25.6	3.6	32.5	*Anisoptera costata*
3.8	6.1	4.2	14.1	*Irvingia malayana*
3.8	2.9	4.2	10.9	*Lithocarpus lindleyanus*
1.6	8.4	0.6	10.6	*Pinus merkusii*
8.7	1.3	0.6	10.6	*Shorea roxburghii*
Total 275 trees per ha & basal area of 8.3 m^2 ha^{-1}				
Dry dipterocarp forest				
6.9	22.9	7.9	37.7	*Parinari anamense*
8.3	22.2	3.2	33.7	*Dipterocarpus intricatus*
4.2	10.7	3.2	18.1	*Vitex pinnata*
6.9	2.5	7.9	17.3	*Pterocarpus macrocarpus*
4.2	4.3	4.8	13.3	*Madhuca kerrii*
Total 151 trees per ha & basal area of 7.6 m^2 ha^{-1}				
Mixed deciduous forest				
17.3	26.5	14.6	58.4	*Canarium subulatum*
21.2	15.8	17.1	54.1	*Pterocarpus macrocarpus*
9.6	7.1	7.3	24.0	*Terminalia corticosa*
9.6	1.5	9.8	20.9	*Xylia xylocarpa* var. *kerrii*
3.8	10.4	2.4	16.6	*Shorea roxburghii*
Total 410 trees per ha & basal area of 11.9 m^2ha^{-1}				
Mix of seasonal evergreen & dry dipterocarp forests				
16.7	28.9	18.2	63.8	*Dipterocarpus intricatus*
10.4	25.8	11.4	47.6	*Irvingia malayana*
8.3	3.4	6.8	18.5	*Pterocarpus macrocarpus*
4.2	10.3	2.3	16.8	*Pinus merkusii*
4.2	6.6	2.3	13.1	*Terminalia corticosa*
Total 232 trees per ha & basal area of 10.5 m^2 ha^{-1}				

Abbreviations:

REDE is the number of species' individuals per ha divided by the total number of individuals x 100%.

REDO is the dominance or basal area of a species per ha divided by the dominance or basal area of all species x 100%.

REFR is the frequency of a species divided by the sum of the frequency of all species x 100% and IVI (importance value index) is the sum of REDE, REDO and REFR of a species.

Based on the data it was suggested that the forest area should be divided into three parts for different forest management according to different purposes, viz. 1) a biodiversity conservation, 2) a forest rehabilitation, and 3) a plantation or multipurpose area (Figure 6).

A B C

Figure 6. Management options, (A) Biodiversity conservation area, (B) Forest rehabilitation area, and (C) Plantation or multipurpose area

The staff from the Ubon Ratchathani Gene Conservation Station together with Ba Hai villagers built a public hall in the conservation area (Figure 7). The objectives of this activity are to create a place for demonstration and distribution of technical forest information about the station and for local activities as well as a meeting place.

Figure 7. The public hall under construction

Social aspects (training courses/meetings/workshops)

In the early stage of the pilot project, FORGENMAP in cooperation with the Regional Community Forestry Training Centre (RECOFTC), Ubon Ratchathani Regional Forest Office and Ubon Ratchathani Gene Conservation Station, the local responsible agency, organized about five training courses/workshops /meetings during 2000–2001 (Figure 8). The local partners were given a far higher understanding of the situation than otherwise because of these activities. Fortunately, the local responsible agency often organized a number of meetings, for instance, progress evaluation and discussion on the activities contained in the work plan.

A B

Figure 8. (A) Discussion on project objectives status and the villagers' needs, (B) Discussion on the forest among the partners

Aspects of income and livelihood

The pilot project supports establishment of non-destructive production. For example, brooms, silk, sales of mushrooms, honey and ant eggs are making up for the unwanted wood sale, which exploits the forest negatively (Figure 9). Further, village forest committees, VFC, are going to formulate guidelines in coherence with the overall public forest laws to define the limitations of forest use.

A B C

Figure 9. Alternative occupations for the community income development, (A) Broom-making, (B) Silkworm culture, (C) Local cloth-weaving

CONCLUSION

At this early stage, most of the activities on the pilot project at the conservation station were mainly concentrated on the social aspects, aspects of income and livelihood, forest area and tree populations. The purposes by focussing on social aspects were to create a better understanding of the project objectives, the importance/benefits of the forest, and to create a better relationship between the villagers and the foresters through deeper mutual understanding of others' needs/problems. At the same time, the involved agencies have started to implement activities on the aspect of income and livelihood in a potential village (Ba Hai village) in order to improve the people's lives and serve as an example to others. Moreover, the inventory of the pine population, as well as training on forest inventory and forest rehabilitation, provided information and improved the management and rehabilitation skills of the staff. In future, involved agencies will undertake more activities on aspects of area and tree populations, and research and development aspects in order to focus more on the improvement of the forest status. Agencies will continue to undertake activities on social aspects and aspects of income and livelihood.

Some bottlenecks that occurred are, e.g. lack of market outlets where villagers can sell their products, low quality of products, and forest conservation/management information not continuously distributed to the community. Moreover, the communication between foresters and villagers or among villagers themselves is insufficient to fulfill some activities such as prevention of forest fire and illegal cutting.

LESSONS LEARNT

A conventional forest conservation approach based solely on protective and prohibitive regulations proved unsuccessful. Conservation of the forest resources may not be possible without the awareness and active support/participation of the local communities. Sustainable conservation relies on good relations between the forestry staff and local people.

Villager's ability to control the forest resource must neither be underestimated nor overestimated. Presence of foresters is useful to set ultimate limits. External attention and interest spur awareness among villagers.

The complexity of villages including their problems is rarely the same—a specific approach must be tailored in each case. Extra attention costs resources and skills—but eventually pays off in terms of better understanding, consensus, and significant results in terms of development and more effective forest conservation.

RECOMMENDATIONS

- Villagers and foresters shall learn how to deal with each other to improve communication and understanding.
- Limits for forest use must be set clearly.
- Consequences for trespassers must be established.
- Information level must be sufficient and clear.
- Alternative NWTP activities and products are to be stimulated by inputs, demonstrations, support and trials.

BIBLIOGRAPHY

Community Forestry Group. 2000. *Report on the inventory of the status of Pinus merkusii in the area of Ubon Ratchathani Gene Conservation Station, Khong Chiam District, Ubon Ratchathani Province.* Ubon Ratchathani, Thailand, Community Forestry Group, Ubon Ratchathani Regional Forest Office, Royal Forest Department. (in Thai)

DFSC. 2000. *Conservation of genetic resources of Pinus merkusii in Thailand*. DFSC Series of Technical Notes. TN 58. Humlebaek, Denmark, Danida Forest Seed Centre.

FAO/UNDP. 1968. *Paper and pulp raw material survey*. Rome.

FORGENMAP. 2000. *Forgenmap coverage of aspects of forest genetic resources conservation and biodiversity rehabilitation*. Bangkok, Thailand, Royal Forest Department. (revised)

FORGENMAP. 2000. *FORGENMAP/RECOFTC*: *Study on partnership in forest genetic resources conservation and management (Vol.2).* Bangkok, Thailand, Royal Forest Department.

Granhof, J. 1998. *Conservation of forest genetic resources without people's participation —an experience from northeast Thailand*. Thailand, FORGENMAP, Royal Forest Department.

Greijmans, M. & Piewluang, C. 2002. *Manual for biodiversity inventory and rehabilitation for partnership in conservation Part 2: forest data interpretation & implementation in management plan*. FORGENMAP Manual 13. Bangkok, Thailand, Royal Forest Department. 21 pp.

Meteorological Department. 1998. *Meteorological data for Thailand*. Bangkok, Thailand, Meteorological Department, Ministry of Transport and Communications.

Piewluang, C., Srijamorn, P. & Thongai, S. 2001. *Ubon Ratchathani Gene Conservation Station*. Handout for SE-Asia Moving Workshop in Thailand on Conservation, Management and Utilization of Forest Genetic Resources, 25 February–10 March 2001. Bangkok, Thailand, FORGENMAP, Royal Forest Department. 9 pp.

Sa-ardavut, P., Chairuangsirikul, T., Chanpaisaeng, S. & Granhof, J. 1989. *In situ* gene conservation in northeast Thailand. *In* G.L.Gibson, A.R. Griffin & A.G. Mathesson, eds. *Breeding tropical trees: population structure and genetic improvement strategies in clonal and seedling forestry*. Oxford UK, Oxford Forestry Institute and Winrock International.

Sirikul, W. 1980. *The grass-tree stage of Pinus merkusii Jungh. and de Vriese*. Australian National University. (M.Sc. thesis).

SESSION IV

15 Measuring forest capital of India—its usefulness for forest regeneration

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ABSTRACT

There is an immediate need to develop uniform measurement tools, to appraise the current status of landscapes relative to their potential in the normally naturally forested zones. Spatial coverage as well as the quality of the forest interms of functionality and biodiversity of the fauna and flora has to be assessed not only to keep track of the forest wealth, but also to enhance it in a conscious manner. Such information is woefully inadequate in India. The forest area index shows that States (province) of Madhya Pradesh, Andaman Nicobar Island, and northeastern States of Arunachal Pradesh, Nagaland and Manipur are better off than the rest of India. Indian forest cover has declined since the mid-seventies by about ten million hectares. There seem to be an overlapping of dense forest area with tree crops and plantation crops. The areas of managed forest and prime forest are not available separately. Both commercial greed as well as poverty needs seem to cause degradation. Illegal felling, mining leases in dense forest areas and submerging forests in irrigation reservoirs are some of the causes. Clearing forest to extend the crop cultivation, shifting cultivation, excessive grazing on forest lands, and collection of fuel wood by millions of villagers also seem to cause degradation. Given the positive levels of carbon sequestration of Indian forests, the Kyoto Protocol, if negotiated well by the Government of India, could generate funds not only for regeneration, but also for joint forest management and poverty alleviation. The forest regeneration programme should not only ban commercial activities but also provide for livelihood generation for the poor.

WHAT IS FOREST CAPITAL?

In its 1999 final report, the World Commission on Forests and Sustainable Development (WCFSD) stated that: "We are drawing on the world's natural capital far more rapidly that it is regenerating. Rather than living off the 'interest' of the 'natural capital', we

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are borrowing from poorer communities and from future generations.” Global forest area has declined from 44 percent about eight thousand years ago to 28 percent at present. About 14 million hectares of tropical forests have been lost annually since 1980. As a result changes have occurred in the watersheds, soil moisture, timber and non-timber forest products. Not only the special coverage, but also the quality of the forests in terms of crown density, functionality, fauna, flora and biodiversity has changed. There is an immediate need to develop uniform measurement tools such as “forest capital index” to record these changes.

“The health of the global ecosystems has been judged on the basis of their ability to produce the goods and services that the world currently relies on. These include production of food, provision of pure and sufficient water, storage of atmospheric carbon, maintenance of biodiversity and provision of recreation and tourism opportunities.” (Pilot Analysis of Global Eco Systems [PAGE]). Similarly, “the value of the …forests as the largest reservoir for plants and animals on land, and their role in maintaining supplies of clean water, in creating and retaining soil, in stabilizing slopes and preventing erosion and landslides, in contributing to the productivity of fisheries and agriculture, in helping to regulate climate, as home for indigenous peoples, as a provider of recreational, aesthetic and other amenities” have to be taken into consideration and measured (Salim & Ullsten 1999).

FOREST COVER OF INDIA

The forest cover of India has declined over the last few decades. The depletion appears to be large, since the mid-seventies for which we have comparable remote sensing data. Between 1972–75 and 1993–95 the dense forest area in India declined from 46.42 million hectares to 36.73 million hectares, a decline of about 10 million hectares over two decades. The area under plantation crops, of tea, coffee and rubber has increased from 0.672 million hectares in 1970–71 to 1.269 million hectares in 1995–96. In 1996–98 the dense forest cover seems to have gone up slightly to 37.74 million hectares, an increase of about a million hectares in about five years (Table 3). This again could be due to the increase in the agricultural crop trees. The area under fruit trees has gone up. The area under coconut, areca nut and cashew nut has also gone up. The area under coffee and rubber plantations has also increased. In 1995–96 the area under fruit tree crops of banana, citrus, apple, grapes, guava, litchi, mango, sapota and papaya alone came to about 2.7 million hectares. The area under coconut, areca nut and cashew nut plantations in the major growing states alone is about 25.83 million hectares. The area under coffee and rubber constitutes 0.73 million hectares. All these add up to 29.26 million hectares, not considering the states that produce these tree crops in small quantities. At least parts of this area might have been overlapping the dense forest area in some states such as Kerala. The dense forest area for the country was 36.73 million hectares. However, the states in which plantation crops are widespread are not the states reporting a dense forest cover. Hence there is reason to believe that most of the plantation crops might have been excluded from the forest statistics, but, how much of it is overlapping is difficult to say. We therefore need to know more details about the forest area spread, before we can conclude about the prime forest cover, which is still intact in the country. As per the statistics, about 37 million hectares of dense forest area and more than 30 million hectares of tree cover exist. It is important to know the overlapping areas. Soon the plantation crops and other tree covers may exceed the dense forest area. It is also important to assess the functionality of such landscape. In recent years, the forest statistics have combined the remote sensing data with ground verification. Hence we hope that the overlapping of dense forest with plantation crops is minimal.

If we deduct the area under the managed forests, which contain timber trees planted and harvested, the prime forest would be even less. The actual planted forest area is also not available accurately. It is because some areas of the forests are planted with 7–10-year-old fast-growing species and clear felled and re-grown. They are counted twice. In some areas the planted areas may not have any survival rate. All areas are considered as planted forest areas. From 1951 to 1999 a total of about 31 million hectares were planted. However, nothing much can be said about the actual managed forest area of the country. Thus the area under prime forests and managed forests is not known. The only consolation is that tree cover of any sort is better than open forest area or scrubland.

The functionality and the biodiversity of the original dense forest cover have been lost forever. The plantation crops and fruit crops do not protect the soil moisture and soil organic matter in the same way as the original forest. The loss of prime forest is not exactly known in hectares. There is every reason to believe it has drastically decreased. From 1997 to 1999, an increase in the dense forest area by 10 098 square kilometres and a decrease in the open forest cover by 6 246 square kilometres have been reported. It is important to find out how much of the real forest has been restored and how much of the increase was due to non-forest tree cover.

Susceptibility to fire also increases as the soil moisture retention declines. Higher incidence of forest fires is another indication of the reduced forest wealth. More than 175 thousand hectares of forest land were reported as having been affected by fire in 1994–95. The unreported area would be more, since some states with large forest areas such as the State of Orissa did not collect the information on fires (Table 3).

About 25.50 million hectares of the forest land were under the category of open forest and 5.20 million hectares were under scrublands. The distributions of open and dense forests are almost equal in some states such as Andhra Pradesh, Bihar, Jammu and Kashmir and Tamil Nadu. In some states such as Manipur, Meghalaya, Mizoram and Nagaland, more than half the forest area is under the category of open forest. The dense forest area is less than the open forest area.

Madhya Pradesh is the only state with the largest area under dense forests in the country. Madhya Pradesh and the northeastern states account for about 47 percent of the forest area. More investment is required for regeneration work. About 81 million hectares in Madhya Pradesh and about 58 million hectares in Arunachal Pradesh have dense forest cover. The open forest areas ideally should be the first target for conversion into dense forests.

Thus about 11.48 percent of the total geographical area is under dense forest cover of more than 40 percent crown density. About 7.76 percent of the geographical area is an open forest, with a crown density varying between 10 and 40 percent. About 1.58 per cent of the geographical area is under scrubs. Mangrove forests that constitute the special coastal ecological system constitute less than one percent of the total geographical area.

DEGRADATION OF FOREST LANDS—COMMERCIAL INTERESTS VS POVERTY NEEDS

There are several reasons for the decline of forest area. Commercial greed on one hand and the need of the poor on the other are the present challenges. Commercial felling of the forest continues both illegally and legally, despite the laws and regulations on felling of trees. The supreme court of India diluted the laws in 1996, by removing the ban on felling of the trees. Illegal felling and transport of timber are a common phenomenon. Even the protected forests and reserved forests are not free from felling. About 15.6 million hectares of forest area have been declared as protected area.

Though the value of the forests to the country is much more than the value of timber, commercial interests are the major reason for such activities. The volume of timber, as estimated in the states reporting the data, comes to about 2.37 million cubic metres in 1997–98 as per the Indian forest statistics. It also includes firewood and pulpwood in a few states. However, the estimation may not have a large error since it includes most of the states. In contrast, the FAO estimates of round wood were far higher. India is a net importer of wood and wood products.

Wood products including the value added through manufacturing in the national income accounting were estimated to fetch about 15 billion rupees or about US$300 million in India in the year 1995–96. This amount included the income of all the workers in the wood products industry including those in retailing and transportation. The value of Indian timber probably constitutes a small share of the total value. To keep the industry and the jobs going, it may not be necessary to log domestic timber. The country may use imported wood and non-wood substitutes.

There are certain collective needs that lead to the destruction of the forests. Mining activities destroy forests. It has been found with the help of the Geographical Information System, that about 53 thousand hectares, with 71 percent dense forest cover and 29 percent open forest cover, presently fall under the mining leases in the States of Orissa, Bihar and Madhya Pradesh. Bauxite, copper, iron, chromites and manganese are the important metals mined in the forest areas of these states (GoI 1999). Mining will lead to environmental degradation and the prime forests destroyed will be lost forever. Hence a special policy decision is necessary to avoid mining in the forest areas. The Indian Bureau of Mines and Metals should look for alternative sites for mining activities and protect the forests and cancel the leases.

Diversion of forest land to non-agricultural uses also contributes to forest loss. The land put to non-agricultural uses has increased to 7 percent of the geographical area in recent years from about 4 percent in early fifties. Another important destroyer of the forests is the reservoirs of the big irrigation dams and hydroelectric projects. Thousands of hectares of forests are submerged and permanently lost in the huge reservoirs of the irrigation projects, while the benefits of irrigation are short-lived and often less than expected. Out of the forest land uses permitted by the government, a large percentage is for major and medium irrigation projects in all the states. Such large-scale forest depletion and environmental disasters can be avoided by a change in the government policy.

The reason for such ambitious short-lived irrigation projects is two fold. The main reason is the increasing moisture scarcity for crops as the population crossed the one billion mark, leading to the search for water. Secondly, many technical persons, who are overawed by the technical achievements and the novelty of these big projects, do not pay attention to and try to understand the importance of forests to the health of agriculture and long-term water availability.

A number of the poor depend directly on the various physical and functional services provided free by the forest. With the degradation of the forests, moisture retention being low, the crop yields in the uplands have declined. Even water for drinking becomes difficult in the summer months. Tribal people walk long distances down hills to the valleys in search of water. The amount of fuelwood collected has been dwindling. Several other tradable forest products are non-existent today. A number of foods once available in the forests for the tribal people to eat in the lean months are not available any more. The hardship of those who live in the forests has increased many folds. Their natural habitat has been eroded over time through the felling of trees, for timber production, and through the conversion of forest land to non-forest uses. As a result of the disappearing forests, the tribal community has become the most vulnerable community from the point of view of food security. Very often whenever droughts and floods occur, the isolated tribes face starvation. This is an issue to be solved through immediate measures to provide sustainable alternate livelihoods for them through food for work programmes and establishment of grain banks.

A number of the rural people living in the villages close to the forest land also depend upon the forest. Due to the lack of alternative energy sources, and affordability of such fuels, many rural poor still depend on forests for fuelwood in India. Due to the exhaustion of common green areas, and vegetative cover in the outskirts of the villages, the villagers are forced to enter the forests for the collection of fuelwood, and non-timber forest products and the grazing of their cattle. The volume of fuelwood is estimated for the country as a whole at about 1.87 million cubic meters. This constitutes the fuel removed from the forest areas. The total fuelwood production for all the areas would be very much higher.

Social forestry of fuelwood planting may be encouraged closer to villages, where people cannot shift to alternate affordable sources of fuel. In some states (provinces) such as Andhra Pradesh, the Government has promoted schemes and successfully replaced firewood with gas in many villages, through microcredit organized by self-help groups. Such schemes not only reduce carbon dioxide emissions, but also reduce eye diseases in women due to continuous exposure to smoke during cooking. This livelihood promotion of the poor should be the key issue.

In some areas, tribal people continue to practise shifting cultivation. In the country more than 3.8 million hectares of forest land were adversely affected by shifting cultivation. The tribal people clear the forests for the cultivation of the crops for a few seasons and shift to other forest areas and cut the forest to make way for cropland. Activities such as fuelwood collection and shifting cultivation did not matter much when the forest cover was larger and the population lower in the forties and fifties. With a depleting forest cover, when lakhs of people enter the forests for their daily needs, the degradation increases. Shifting cultivation has to be stopped. Hence, while working towards the regeneration of forests, the needs of the poor dependent upon the forests should be built into the programmes. The tribal population should be settled on some plots of land and encouraged to grow high yielding varieties of crops to improve their livelihood and food security. Alternately, they can take up joint forest management of plots and be paid in wages for the work done.

The context of forest wealth helps us to reward the poor communities who do not degrade the forests, including those who participate in joint forest management and help us bring back forests. Without a system of rewards the forest cover cannot increase. It is also important to reward those who refrain from using fuelwood and are willing to shift to alternative fuels available, to using cattle feed instead of grazing, and to alternative livelihoods in place of shifting cultivation. Sustainable livelihoods of these people affect the health and wealth of the forests. The forest capital index becomes a guide to progress.

It is simply not possible to engage all the people in joint forest management in a sustainable fashion. Priority should be given to the tribal persons presently living inside the forest areas. Normally, crop cultivation is more labour intensive than tree growing. Hence fewer people are required for joint forest management. Others should be provided with alternative livelihoods so that they will be able to afford more expensive fuels and more expensive cattle feed. The scenario has to be changed with the help of training and credit for ecologically friendly enterprises, such as poultry production, cattle rearing with improved breeds of cattle, and mushroom production, and education in the use of biopesticides, biofertilizers and so on. Provision of ecofriendly sustainable livelihoods with market links for the products is a pre-requisite to forest conservation and forest protection in the long run.

Hence the cost of forest regeneration is not only the actual cost of planting and caring but also the efforts of providing alternative and viable livelihoods for the people living in the vicinity of the forest, who have been suffering due to depletion of forests.

In the present system the states with large areas under dense forests are the states with fewer livelihood opportunities. The fact that these are more sparsely populated makes it even more costlier to bring the forest dependent people together and provide the infrastructure needed for the enterprises, including the market link-ups.

As the scheduled tribe populations dependent on forests are the poorest, it is important to devise special reward systems and additional funds to enable the people to preserve the forests and water. The aim should be a management based on integrated landscape rather than just the forests. Forests, soils, water bodies, vegetative cover, and agriculture that includes crop, animal and fish production are parts of joint management. Further development in non-agricultural enterprises is also vital to shift people to more viable livelihoods.

The pressure of more than a billion population has left its footprint on the forest land of India. At present, as against the recommended 30 percent of the geographical area to be under dense forest cover, only about 11.48 per cent of the total area is under forest cover of more than 40 percent crown density. About 7.76 percent of the forest area is open forest, with a crown density varying between 10 and 40 percent. And about 1.58 per cent of the geographical area is under scrubs. Mangrove forests that form the special coastal ecosystem constitute less than one per cent of the total forest area.

The state with the largest area under dense forest cover is Madhya Pradesh. Madhya Pradesh and the northeastern states contribute about 47 percent of the forest area. Madhya Pradesh has more than 81.6 thousand square kilometres of forest area, followed by Arunachal Pradesh with 57.8 thousand square kilometres of forest. The other important states with dense forest cover are Maharashtra, Orissa, Karnataka, Andhra Pradesh and Uttar Pradesh, having forest cover ranging from 22 thousand to 26 thousand square kilometres. Madhya Pradesh is also an important state for forests as it also has a large area under open forest. These states which have large areas of open forest possess the potential for forest regeneration, through converting the open forest areas into dense forest areas. Additional areas are denoted as cultivable waste lands.

From 1997 to 1999, an increase in dense forest area by 10 098 square kilometres and a decrease in open forest cover by 6 246 square kilometres have been reported. More investment is required for restoration work (GoI 2000).

INDEX OF FOREST AREA

The physical characteristics of the forest such as dense forest area, open forest area, level of degradation over a period, as well as the functional aspects of the forest need to be considered as a tool in the development of measurement. Biomass index, habitat value, mean annual increment in the above-ground biomass, leaf area index, and susceptibility to fires are the more easily measurable indices, if data exist. Efforts will have to be made to collect the information in India at the state and district levels. Data on many aspects are not available in India.

Due to the paucity of detailed state information in recent years on the exact area under well preserved prime forests, planted forest areas, areas under plantation crops and tree crops, data on flora and fauna and richness of species and so on, it is difficult to get a clear picture of the forest wealth. The potential to bring back the forests in the normally forested zones is another important information required. Unless we know the levels of degradation, it is difficult to know whether the degradation has reached a point of no return. All the same, on the basis of information available we have computed an index of forest area.

Only three indicators are considered at present for the calculation of the composite index of forest capital for various states in India, viz. area under dense forest cover, area under open forest and the degraded dense forest area in the past couple of decades. Each of these indicators is converted into individual indices and averaged together to get the composite forest area index. The indexing is similar to the human development index.

The method of calculating the index is simple. Each indicator is first converted into an individual index. The state (province of India) with the worst possible situation is equated to one and the state with the best possible situation is equated to zero. The others are between zero and one. Thus the index varies between one and zero. The individual index for an indicator measures the shortfall of the natural forest endowment of the state from the existing best level of forest endowment among the states, as a proportion of the difference between the best-endowed state, and the worst endowed state.[1] An index value of 0.85 for a state means that it has a shortfall of 85 percent of present and potential resources of the best endowed state in terms of forest wealth. A value of 0.15 means that the state has a shortfall of 15 percent of the natural endowment of the best naturally endowed state. The best state gets a value of zero, the worst endowed states gets a value of 1, indicating the worst state has 100 percent less endowment compared to the best state. The best state has zero shortfall. The composite forest area index is nothing but the average of all individual indices calculated from the chosen indicators. Equal weight is given to all the indicators in the group index.

The composite index has been calculated from the general formula,

$$I_1 = \frac{1}{n}\left[\sum_{i=1}^{n} \{(X_{ij} - X_{min}) / (X_{max} - X_{min})\}\right]$$

where,

I_1 = composite index one

X_{ij} = i^{th} indicator in the group for the j^{th} state

X_{min} = i^{th} indicator of the state with minimum value

X_{max} = i^{th} indicator in the state with maximum value

'i' = 1 to n indicators

'j' = 1 to k state considered in the group index.

[1] All the final data on indicators chosen are made unidirectional in the index form, so that larger values represent the worst situation. Hence the indexing formula adopted for dense forest area and open forest area subtracts the present value of the state from the maximum value among the states. The numerator of the formula is ($X_{max} - X_{ij}$). In the case of the magnitude of degraded dense forest area from 1972–75 to 1993–95, the numerator is ($X_{ij} - X_{min}$).

The numerator of the formula differs, depending upon the values of the indicators. The composite index also ranks the states. The rank one is given to the state with minimum forest wealth and the rank 28 goes to the state with maximum forest wealth (see Tables 1–4).

The islands of Andaman and Nicobar come out as the region with best forest cover followed by Arunachal Pradesh and Nagaland (Table 4). Manipur and Mizoram come next. The States of Assam, Mizoram, Meghalaya and Sikkim also fare well. Dadra and Nagar Haveli, Goa, Daman and Diu and Kerala get a rank of higher than 19. Assam gets a rank of 18. Among the bigger states, Madhya Pradesh fares better with a rank of 17. Madhya Pradesh is more important than the other states from the point of view of largest area under dense forests at 81.6 thousand square kilometres, as it has a larger area under forest than the other states followed by Arunachal Pradesh. Himachal Pradesh and Orissa appear to get the middle ranks of 16 and 15. Karnataka, Uttar Pradesh and Maharashtra are just below the half way mark with the ranks of 14, 13 and 12. The worst states in terms of forest wealth are Rajasthan, Punjab, Haryana and Andhra Pradesh. Andhra Pradesh fares badly due to high levels of degradation in recent years and the likely loss of even the existing forests.

The above index is only an indication of the distribution of forest wealth in comparison to the requirement. More detailed information is necessary to assess the forest capital.

POLICY OPTIONS FOR FOREST REGENERATION AND IMPROVING THE FOREST WEALTH

The foremost concern is to stop further depletion of prime forest stock. The next priority is to reverse the process of degradation and bring back some of the lost forests. The forest wealth of a country can be increased with conscious effort by the government and people. All the open forest areas can be converted into dense forested areas, through special efforts of regeneration. India can improve the dense forest cover of the country by converting at least part of the 25.5 million hectares of open forest area into dense forest area, since it was a naturally forested area that had degraded in recent times.

A number of measures are necessary. Some of the important ones are listed here:

1. enlisting the support of NGOs and the general public through awareness campaign for joint forest management;
2. preventing illegal logging and protecting the prime forest areas;
3. preventing mining in the dense forest areas;
4. preventing submergence of forest lands in the irrigation projects;
5. preventing the diversion of forest land to crop production and other non-agricultural activities;
6. undertaking afforestation and reforestation of all naturally forested areas;
7. using food for work programmes to pay the local population for the forest regeneration work and joint forest management works;
8. setting aside funds for the poor for alternative livelihoods or alternative sources of animal feed and fuelwood.

Long-term planning and sustained efforts are necessary to bring back the forests.

These activities require large funds to sustain the activity over long periods of time:

a. borrowing from international agencies such as World Bank;
b. spending funds from the tax revenues of the state governments;
c. trading credit received for carbon sequestration in the forest regeneration programme.

Of these we shall consider the possibilities of financing forest regeneration through emission trading.

CARBON SEQUESTRATION AND CARBON TRADING TO RAISE FUNDS

The role of the forest ecosystem in storing carbon and stabilizing the atmospheric temperature is well known. The removal of the atmospheric carbon is known as carbon sequestration. It has been estimated that in 1996, carbon sequestration in Indian forests, net of carbon emission was 6.9 million tonnes (Ravindranath 1996). Estimation of net annual carbon sequestration from 1972–73 to 1999–2000 appears to be positive, mostly due to the plantation of secondary forests in the past two decades (Kanchan Chopra *et al*. 2002). Thus Indian forests can raise funds under the Kyoto Protocol by trading in the sequestrated carbon with the developed nations.

Things will now change under the new provisions of the Kyoto protocol. Once all the provisions are put in place, the third world countries may be left with very little opportunities to raise funds. It is time for India to wake up and take active interest and see if there is still some scope to raise funds for the forests and the poor that depend upon the forests through emission trading. Things are not rosy as they stand now! Yet India has a large scope for carbon trading, by converting the open forest areas into dense forest areas.

The Kyoto Protocol and its implications to funding forest regeneration

Many nations in the World have become more concerned about the increasing concentration of greenhouse gases such as carbon dioxide, causing global warming. They joined together in 1992 to sign the United Nations Framework Convention on Climate Change (UNFCCC). It included a legally non-binding, voluntary pledge that the major developed nations would reduce their greenhouse gas emissions to 1990 levels by the year 2000. It did not happen. The first commitment period now is extended to 2007–2012. Parties to the treaty decided in 1995 to enter into negotiations on a protocol to establish legally binding limitations or reductions in greenhouse gas emissions. The negotiations took place in 1997 at a meeting from 1–11 December in 1997 at Kyoto, Japan. Following completion of the Protocol in December of 1997, details of a number of the more difficult issues remain to be negotiated and resolved. The protocol allows the Annex One countries (developed and industrialized countries) to trade emissions to a limited extent with the Annex Two countries (developing countries). Eight Conferences of the Parties (COP) have been held since 1992. The Kyoto meeting was the fourth one. COP 8 was held at Delhi in October 2002.

The Kyoto protocol only recognizes the land use and land-use change in forestry activities (LULUCF) and the associated net carbon sequestration flows estimated for the purpose of emission trading in terms of net removal units.

At the COP 7 in the Marrakesh Accord, naturally occurring carbon removals, and removals as a result of anthopogenic effects were excluded from being traded. Any re-release of the greenhouse gases, through forest fires will have to be accounted for.

1. The forest is defined. A minimum tree height between 2 and 5 meters is necessary for a forest. These values will have to be chosen only once by the country and they remain fixed as a definition of forests. The activities such as afforestation and reforestation are defined.
2. The parties should choose other land-use activity for emission targets in addition to afforestation, reforestation and deforestation. The carbon sink activities in addition to forest regeneration are forest management, crop land management, grazing land management and re-vegetation.
3. Removal of greenhouse gases is measured in removal units called (RMUs). For the first commitment period there is a 4-tier capping system. Only afforestation and reforestation projects are eligible for the clean development mechanism. Removal units cannot be carried forward to the next year. Any emissions occurring from LULUCF including afforestation, deforestation and reforestation must be set off elsewhere.
4. Emissions and removals from crop land management, grazing land management and re-vegetation management can be accounted for on a net-to-net basis, meaning thereby the levels of removal that are over and above the 1990 level are taken into account. If the carbon removals are the same as the 1990 level there will not be any credits.
5. Issues such as emissions from forest harvesting and wood products have been resolved.

There are still many issues to be settled before the methodologies of computations of removal units and emission units are standardized and other issues such as verification and compliance are resolved. However, India has to closely follow the developments, collect more accurate statistics and compute an emission trading relevant to the net forest wealth index for various states. Long-term planning of reforestation is necessary to choose the tree size, non-forest activity and so on. More thorough and in-depth studies of implications are necessary for India to improve its forest cover and benefit from emission trading. One should not be under the impression that all the sequestrated carbon in the fast-growing plantations is tradable, without any reference to the level of activity in 1990, level of deforestation, timber removal and forest fire. There is an opportunity for the governments to improve the forest cover and the livelihoods of the poor, if only they are willing to act now!

REFERENCES

Chopra, K., Bhattachrya, B. B. & Kumar, P. 2002. *Contribution of forestry sector to gross domestic product in India*. New Delhi, Institute of Economic Growth.

GoI (Government of India). 1999. *State of forest report 1999*. Dehra Dun, Forest Survey of India.

GoI (Government of India). 2000. *Forestry statistics of India—2000*. Indian Council of Forestry Research and Education.

Ravindranath, N. H., Somasekar, B. S. & Gadgil, M. 1996. Carbon flows in Indian forests. *Climate Change* 35(3).

Salim, E. & Ullsten, O. 1999. *Our forests and our future—report of the World Commission on Forests and Sustainable Development*. Cambridge University Press.

Table 1. Extents of dense forest, open forest and mangrove in States (sq.km)

S .No.	State/Union territory	Dense forest	Open forest	Mangrove	Total forest cover	Scrub
1	Andaman & Nicobar	6 515.00	125.00	966.00	7 606.00	0.00
2	Andhra Pradesh	24 190.00	19 642.00	397.00	44 229.00	9 559.00
3	Arunachal Pradesh	57 756.00	11 091.00	0.00	68 847.00	104.00
4	Assam	14 517.00	9 171.00	0.00	23 688.00	324.00
5	Bihar	13 274.00	13 200.00	0.00	26 474.00	1 914.00
6	Chandigarh	6.00	1.00	0.00	7.00	0.00
7	Dadra & Nagar Haveli	159.00	43.00	0.00	202.00	10.00
8	Delhi	35.00	53.00	0.00	88.00	3.00
9	Goa, Daman, Diu	995.00	251.00	5.00	1 251.00	16.00
10	Gujarat	6 430.00	5 504.00	1 031.00	12 965.00	2 948.00
11	Haryana	449.00	515.00	0.00	964.00	191.00
12	Himachal Pradesh	9 120.00	3 962.00	0.00	13 082.00	566.00
13	Jammu & Kashmir	11 019.00	9 422.00	0.00	20 441.00	3 089.00
14	Karnataka	24 832.00	7 632.00	3.00	32 467.00	4 489.00
15	Kerala	8 429.00	1 894.00	0.00	10 323.00	91.00
16	Madhya Pradesh	81 619.00	50 211.00	0.00	131 830.00	3 853.00
17	Maharashtra	26 613.00	19 951.00	108.00	46 672.00	7 160.00
18	Manipur	5 936.00	11 448.00	0.00	17 384.00	177.00
19	Meghalaya	5 925.00	9 708.00	0.00	15 633.00	261.00
20	Mizoram	3 786.00	14 552.00	0.00	18 338.00	125.00
21	Nagaland	5 137.00	9 027.00	0.00	14 164.00	14.00
22	Orissa	26 073.00	20 745.00	215.00	47 033.00	5 439.00
23	Punjab	517.00	895.00	0.00	1 412.00	107.00
24	Rajasthan	4 309.00	9 562.00	0.00	13 871.00	6 921.00
25	Sikkim	2 363.00	755.00	0.00	3 118.00	386.00
26	Tamil Nadu	8 659.00	8 398.00	21.00	17 078.00	2 836.00
27	Uttar Pradesh	22 902.00	11 114.00	0.00	34 016.00	1 177.00
28	West Bengal	3 565.00	2 672.00	2 125.00	8 362.00	98.00
	All India	377 358.00	255 064.00	4 871.00	637 293.00	51 896.00

Table 2. Percentages of forest area to the total geographical area

S. No.	State/Union Territory	Total geographic area (TGA)	Percentage of dense forest to TGA	Percentage of open forest to TGA	Percentage of mangrove to TGA	Percentage of forest cover to TGA	Percentage of scrub to TGA
1	Andaman & Nicobar	824.90	78.98	1.52	11.71	92.21	0.00
2	Andhra Pradesh	27 504.50	8.79	7.14	0.14	16.08	3.48
3	Arunachal Pradesh	8 374.30	68.97	13.24	0.00	82.21	0.12
4	Assam	7 843.80	18.51	11.69	0.00	30.20	0.41
5	Bihar	17 387.70	7.63	7.59	0.00	15.23	1.10
6	Chandigarh	11.40	5.26	0.88	0.00	6.14	0.00
7	Dadra & Nagar Haveli	49.10	32.38	8.76	0.00	41.14	2.04
8	Delhi	148.30	2.36	3.57	0.00	5.93	0.20
9	Goa, Daman, Diu	381.40	26.09	6.58	0.13	32.80	0.42
10	Gujarat	19 602.40	3.28	2.81	0.53	6.61	1.50
11	Haryana	4 421.20	1.02	1.16	0.00	2.18	0.43
12	Himachal Pradesh	5 567.30	16.38	7.12	0.00	23.50	1.02
13	Jammu & Kashmir	22 223.50	4.96	4.24	0.00	9.20	1.39
14	Karnataka	19 179.10	12.95	3.98	0.00	16.93	2.34
15	Kerala	3 886.30	21.69	4.87	0.00	26.56	0.23
16	Madhya Pradesh	44 344.60	18.41	11.32	0.00	29.73	0.87
17	Maharashtra	30 771.30	8.65	6.48	0.04	15.17	2.33
18	Manipur	2 232.70	26.59	51.27	0.00	77.86	0.79
19	Meghalaya	2 242.90	26.42	43.28	0.00	69.70	1.16
20	Mizoram	2 108.10	17.96	69.03	0.00	86.99	0.59
21	Nagaland	1 657.90	30.98	54.45	0.00	85.43	0.08
22	Orissa	15 570.70	16.74	13.32	0.14	30.21	3.49
23	Punjab	5 036.20	1.03	1.78	0.00	2.80	0.21
24	Rajasthan	34 223.90	1.26	2.79	0.00	4.05	2.02
25	Sikkim	709.60	33.30	10.64	0.00	43.94	5.44
26	Tamil Nadu	13 005.80	6.66	6.46	0.02	13.13	2.18
27	Uttar Pradesh	29 441.10	7.78	3.77	0.00	11.55	0.40
28	West Bengal	8 875.20	4.02	3.01	2.39	9.42	0.11
	All India	328 730.00	11.48	7.76	0.15	19.39	1.58

Table 3. Deforestations and areas in affected by fires

S. No.	State/Union Territoty	Deforestation (1972–1995) (Lakhs hectares)	Area Involved in forest fire ha (1995–96)
1	Andaman & Nicobar	–3.200	6.000
2	Andhra Pradesh	17.300	n.a.
3	Arunachal Pradesh	–3.700	219.120
4	Assam	3.200	0.000
5	Bihar	4.900	n.a.
6	Chandigarh	0.000	n.a.
7	Dadra & Nagar Haveli	–0.100	526.590
8	Delhi	–0.010	2.000
9	Goa, Daman, Diu	0.100	19.000
10	Gujarat	0.700	0.000
11	Haryana	–0.100	1 254.000
12	Himachal Pradesh	2.900	57 143.000
13	Jammu & Kashmir	8.300	680.000
14	Karnataka	1.300	n.a.
15	Kerala	–0.800	1 821.570
16	Madhya Pradesh	6.000	1 578.204
17	Maharashtra	5.400	21 613.000
18	Manipur	8.700	n.a.
19	Meghalaya	6.100	n.a.
20	Mizoram	8.900	876.330
21	Nagaland	3.600	n.a.
22	Orissa	11.200	n.a.
23	Punjab	0.400	9 637.330
24	Rajasthan	4.700	n.a.
25	Sikkim	–1.100	0.000
26	Tamil Nadu	4.800	2 192.000
27	Uttar Pradesh	1.200	77 610.000
28	West Bengal	2.200	n.a.
	All India	96.900	175 178.144

Table 4. Forest area indices of India

S. No.	State/Union Territory	Percentage of dense forest to TGA	Dense forest area index	Rank	Percentage of open forest to TGA	Open forest area index	Rank	Deforestation (1972–1995) (million hectares)	Deforestation index	Rank 0.1	Weighted composite index *	Rank
1	Andaman & Nicobar	78.98	1.0000	28	1.52	0.0094	3	–0.320	0.98	27	0.75	28
2	Andhra Pradesh	8.79	0.0998	13	7.14	0.0919	17	1.730	0.00	1	0.09	4
3	Arunachal Pradesh	68.97	0.8716	27	13.24	0.1815	23	–0.370	1.00	28	0.71	27
4	Assam	18.51	0.2244	19	11.69	0.1587	22	0.320	0.67	13	0.25	18
5	Bihar	7.63	0.0849	10	7.59	0.0985	18	0.490	0.59	9	0.14	11
6	Chandigarh	5.26	0.0545	8	0.88	0.0000	1	0.000	0.82	21	0.12	9
7	Dadra & Nagar Haveli	32.38	0.4023	25	8.76	0.1156	19	–0.010	0.83	23	0.37	21
8	Delhi	2.36	0.0172	4	3.57	0.0396	8	–0.001	0.82	22	0.10	6
9	Goa, Daman, Diu	26.09	0.3216	21	6.58	0.0837	15	0.010	0.82	20	0.31	20
10	Gujarat	3.28	0.0290	5	2.81	0.0283	6	0.070	0.79	18	0.11	8
11	Haryana	1.02	0.0000	1	1.16	0.0042	2	–0.010	0.83	23	0.08	3
12	Himachal Pradesh	16.38	0.1971	15	7.12	0.0916	16	0.290	0.69	14	0.22	16
13	Jammu & Kashmir	4.96	0.0506	7	4.24	0.0493	11	0.830	0.43	5	0.09	5
14	Karnataka	12.95	0.1530	14	3.98	0.0455	10	0.130	0.76	16	0.19	14
15	Kerala	21.69	0.2652	20	4.87	0.0586	12	–0.080	0.86	25	0.27	19
16	Madhya Pradesh	18.41	0.2231	18	11.32	0.1533	21	0.600	0.54	7	0.24	17
17	Maharashtra	8.65	0.0979	12	6.48	0.0823	14	0.540	0.57	8	0.14	12
18	Manipur	26.59	0.3280	23	51.27	0.7395	26	0.870	0.41	4	0.44	25
19	Meghalaya	26.42	0.3258	22	43.28	0.6222	25	0.610	0.53	6	0.42	23
20	Mizoram	17.96	0.2173	17	69.03	1.0000	28	0.890	0.40	3	0.43	24
21	Nagaland	30.98	0.3844	24	54.45	0.7861	27	0.360	0.65	12	0.51	26
22	Orissa	16.74	0.2018	16	13.32	0.1826	24	1.120	0.29	2	0.21	15
23	Punjab	1.03	0.0001	2	1.78	0.0132	4	0.040	0.80	19	0.08	2
24	Rajasthan	1.26	0.0031	3	2.79	0.0281	5	0.470	0.60	11	0.07	1
25	Sikkim	33.30	0.4141	26	10.64	0.1432	20	–0.110	0.88	26	0.39	22
26	Tamil Nadu	6.66	0.0724	9	6.46	0.0819	13	0.480	0.60	10	0.13	10
27	Uttar Pradesh	7.78	0.0868	11	3.77	0.0425	9	0.120	0.77	17	0.14	13
28	West Bengal	4.02	0.0385	6	3.01	0.0313	7	0.220	0.72	15	0.10	7
	All India	11.48	0.1342		7.76	0.1010		9.69				

* The composite index gives 0.65 weight to dense forest, 0.25 weight to open forest, and 0.15 weight to deforestation

16 How can silviculturists support the natural process of recovery in tropical rain forests degraded by logging and wild fire?

Charles Garcia* and Jan Falck**

ABSTRACT

In all regions with tropical rain forests there are secondary forests degraded by insensitive logging and by wild fires. The demand for rehabilitation of these most degraded forests is set by conservationists and sometimes by forest owners wishing to certify their forest. Most rain forests have the capacity to gradually recover from selective harvesting, but after repeated harvests at too short intervals or if the forest is damaged by wildfires "rehabilitation plantation" is probably necessary. This paper shares the experience of a collaborative project (INIKEA) between the Swedish foundation, "Sow a Seed", sponsored by IKEA of Sweden, and the latter's customers and local counterpart in Sabah, Innoprise Corporation Sdn Bhd. The project is funded by the foundation and supervised by the Swedish University of Agriculture Sciences. The aim of our programme is primarily to improve the biodiversity of a heavily degraded tropical rain forest. Natural fauna and flora are expected to migrate into the area after the rehabilitation plantation. In the current study, located in Sabah, we investigate the feasibility of rehabilitation plantation in a secondary tropical rain forest degraded by harvesting and by wildfire in 1983. Under the canopy of a Macaranga-dominated forest, more than 25 species mainly belonging to the Dipterocarpaceae family, and some fruit trees are planted using two different plantation concepts, i.e. line plantation and gap plantation. In the first phase of the project from 1998 to 2003, an area of 4 000–5 000 ha will be enrichment planted with seedlings and wildings. The study also includes tests of different techniques for seedling and wilding production and in the forest different shade adjustment procedures that involve girdling and felling in the upper and lower canopies of the pioneer vegetation. The main results so far are that gap plantation is cheaper than line plantation, mainly because the required number of compass lines in line planting is double that for gap planting. Gap plantation

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seems to create a more natural structure of the new Dipterocarpaceae forest because the 100 small groups of 3 seedlings per hectare are more irregularly distributed in the forest than in line plantation. The survival of the seedlings in this environment is high during the first year but natural damage and some mortality to the seedlings take place later even after intensive maintenance.

INTRODUCTION

In the late 1982 and early 1983, a severe prolonged drought triggered forest fires all over Sabah causing extensive and severe damage to the forest. The rain forest which does not readily burn is not adapted to fire. The impact was devastating. Although the fire crept on the forest floor, seldom up to the canopy, most of the forest species were destroyed. Some bigger trees suffered partial damage in the trunk and survived. But the smaller ones succumbed. The areas badly burnt were immediately infested by pioneer trees and vines. The once complex structure of the rain forest changed to a simpler forest structure with fewer plant species. The surviving larger trees interspersed the continuous canopy of mostly *Macaranga*. Regeneration of the primary species depends very much on the surviving mother trees and in some areas, this is very limited to a few primary species.

In June 1998, Innoprise Corporation of Sabah and Sow-A-Seed Foundation of Sweden signed a Memorandum of Agreement to collaborate in a forest rehabilitation project (INIKEA project) in the Kalabakan Forest Reserve within the Yayasan Sabah Concession area. The project area was severely damaged during the drought in 1982/83, followed by log extraction a few years later. The aim of the project is to improve the biodiversity in this forest. Sow-A-Seed Foundation provides financial assistance for five years and Innoprise Corporation sees to the implementation of the project.

THE PROJECT AREA

The project area is 14 300 ha located west of Tawau. A major part of the forest within this area suffered wildfire in 1983 followed by logging a few years later. This severely degraded forest is now characterized by a continuous canopy of mostly *Macaranga* sparsely interspersed with dipterocarps. The task of the project for the first five years is to rehabilitate 4 000 to 5 000 ha of severely degraded forest by enrichment planting with timber and fruit tree species.

The project makes two important distinctions—one is the engagement of directly-employed locals for all its operations, except for the road-making and maintenance by a contractor, and two is the restricted use of chemicals in all its operations, especially herbicides. In the nursery it may be necessary to resort to fungicides and insecticides to control pests and diseases.

ENRICHMENT PLANTING

There has been numerous mentions of rehabilitation projects in many countries for various reasons. However, the project drew a lot of direct experience from projects in Sabah, especially the Luasong project (Awang Mohdar 1995), Innoprise Corporation–FACE

Foundation project (INFAPRO) (Moura-Costa *et al*. 1993), and the Deramakot project by the Forestry Department of Sabah (Martin *et al*. 2001). The project adopted the line-planting method as practised in INFAPRO at 3 m (within the lines) by 10 m (between the planting lines). The gap-cluster planting was formulated to simulate natural openings in the forests. In this case rather small gaps are created by selectively removing overhead shade.

Sub-blocking

In the INIKEA project, the area is divided into blocks of about 200–300 ha. These blocks are then further sub-divided into sub-blocks or work areas of 10–50 ha which are the basic work units for operational practicality during planting and tending. The boundaries are surveyed and the roads built before site preparation begins. Generally, there is already a ready network of ex-logging roads that need only to be upgraded.

Species

For biodiversity a minimum of 25 species is dispatched to the sub-blocks. The nursery ensures that no single species makes up more than 20 percent of the total to be dispatched. In the field these species are planted in a mix. In the lot 5 percent are fruit tree species. Generally, a majority of the dispatch plants are the dipterocarps.

Line planting

The planting lines are created at intervals of 10 m apart. These lines are cleared to 2 m wide and the planting points staked with a belian marker every 3 m (Figure 1). *Macaranga* trees in and between the lines are selectively ring-girdled to open up the upper canopy. Non-commercial small trees, shrubs and undergrowth along the lines are also cleared. This is followed by a 100 percent climber cutting.

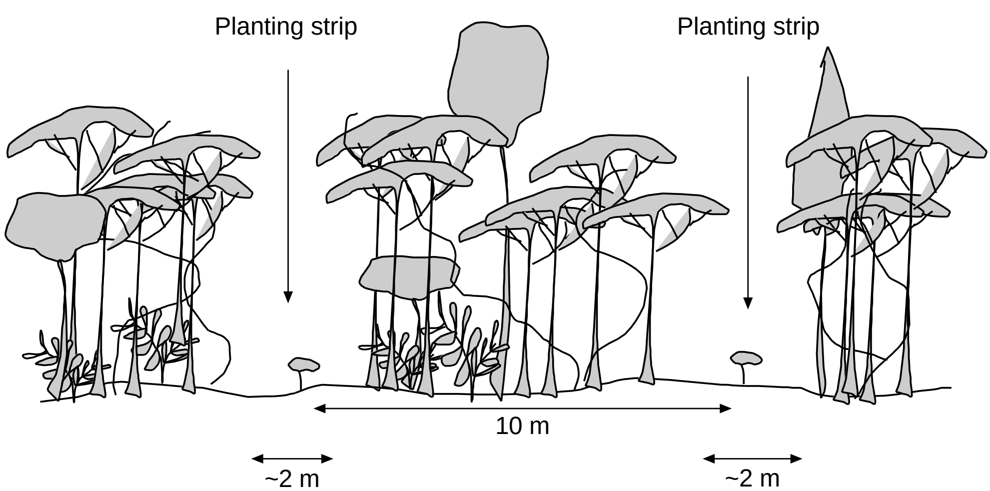

Figure 1. The layout of the planting strips in line planting

Normally, the opening of the canopy is rather gradual. First removal of small trees, shrubs and undergrowth along the lines creates an immediate opening at the lower canopy. Next the drying up of the leaves of the lianas in a week or two again adds up to the opening. Finally, the girdled trees will slowly dry up. This could start as early as three months up to a year.

Open areas of shrubs and grasslands pose a special problem. They occur in small patches scattered all over, marking ex-landings, ex-camps and along the roadsides. Planting in these highly degraded sites has always resulted in high mortality rates, mainly because of the very poor soils and the intense weed competition. In the Deramakot project it is recommended using tall plants raised in larger polythene bags (Martin *et al*. 2001). The plants may have a better chance to survive against the weeds.

In the INIKEA project, the open areas are planted with *Pterocarpus indicus*. Potted plants and stick cuttings are used. Using stick cuttings, however, is tricky. They have to be planted during continuous rainy days. Once established they are able to grow normally putting on numerous heavy branches providing shade.

Gap-cluster planting

Forest gaps are the results of the fall of canopy trees. Normally such gaps are small if they involve few trees. In gap-cluster planting, gaps are deliberately created by girdling unwanted trees, bringing about a gradual change in the opening of the forest.

In the INIKEA project, the gap-planting method allows great flexibility of locating the planting points compared to the systematic lines approach. The gap location is selected inside a 10 x 10 m sub-quadrate.

A 20 x 20 m grid is created by cutting systematic lines 20 m apart (see Figure 2 below). These lines serve as access and reference to the quadrate centers. Every 20 m along the line is marked with a stake indicating the quadrate center. The quadrate is halfway to the previous stake (10 m) and halfway to the next stake (10 m) and another halfway to the lines left and right. So each quadrate is 20 by 20 m on each side. The quadrate is further sub-divided into 4 sub-quadrates of 10 by 10 m each. Within each sub-quadrate, the gap is located at the most suitable place for planting.

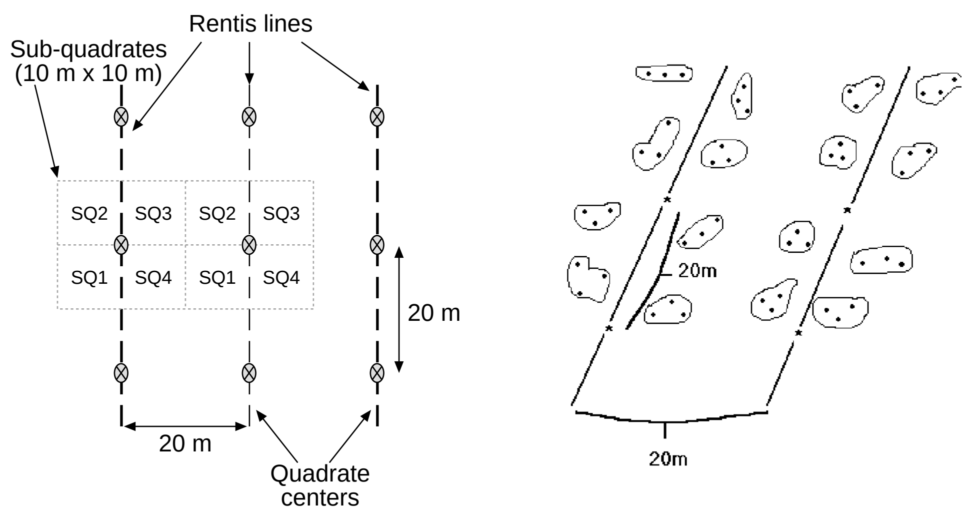

Figure 2. The gap-planting arrangement

The field crew has first of all to decide whether planting is necessary in the sub-quadrate based on the presence or absence of natural regeneration. If there are fewer than five species within the sub-quadrate, the sub-quadrate should be planted. Once that is decided, the choice of placing the gap inside the sub-quadrate rests on the crew according to certain criteria:

- the spot has already a natural gap to minimize further openings;
- the spot is suitable for planting, i.e. away from obstacles, e.g. rocks, streams, steep slopes, buttresses of big trees, etc.;
- if there is no natural gap, there should be a possibility of creating one by girdling some undesirable trees.

The chosen spot is then staked to mark the gap centre. In these gaps of about 3 to 4 m diameter, a cluster of three seedlings is planted, each 1–1½ m away from the gap centre.

As in line planting, climber cutting is done for the whole area.

POST-PLANTING OPERATION

Maintenance and shade adjustment

The project recognizes the need for frequent maintenance when the plants are still small. In the first two years, weeding was three times annually. After that the weeding was less frequent. If necessary, the maintenance will follow up to 10 years.

After 1½ to 2 years planting, a shade manipulation operation was carried out to open up the overhead shade. Initially, the shade adjustment took out more upper-canopy trees, the *Macaranga*. The result was a thickening of the foliage of the lower-storey vegetation giving a lot of shade on the planted seedlings. So in the subsequent operations the focus was equally on the removal of the lower-canopy shade as well as the upper canopy. In the lower canopy shrubs and small trees of no commercial value were removed.

Two rounds of shade adjustment may be necessary. The second round should be about four years after planting.

Survival

A 10% census was carried out three months after planting. The survival after the first census averaged over 90%. The survival was especially poor on open sites infested by *Imperata* grass and shrubs. Now these sites are planted with *Pterocarpus indicus* which is adapted for very open sites. Damage to the surviving plants occurs in many forms. Physical damage leading even to mortality from falling twigs, branches and even stems is common. This is especially after the girdled trees begin to fall. So far the damage has not been quantified.

Damage by deer and wild boars has also been detected. Deer rubbing their antlers on the trees can most of the times completely debark the trees and kill them. Wild boars are especially destructive during their breeding season. They would snap thumb-sized plants and even bigger trees for their nests.

Insect damage although quite common on some species, particularly *Parashorea*, is at least not fatal. In the forest most of the species are free of major pest and disease problems.

PLANT PRODUCTION

The nursery is located in Luasong. When required, the nursery can be made to hold 1 million plants at any one time. The source material for planting stock production is from seeds or wildings. Although propagation by means of rooted cuttings is possible, this method is not considered for the project for reasons of biodiversity. Procuring regular supply of seeds and the difficulty of storing fruits have always been a problem to rehabilitation projects. Since the project started in 1998, there has been no major fruiting in Sabah. Several rather localized flowering and fruiting amounted to modest quantities of fruits. Poor fruit harvest has much to do with infestation by insects when the fruits are on the trees and mammals, especially wild boars, when the fruits fall to the ground. It was only in early and mid-2002 that there was substantial flowering and fruiting of dipterocarps and non-dipterocarps near Luasong.

The nursery now has a stock of about 500 000 plants comprising more than 60 species, mostly dipterocarps.

For the first years of the project, there was a heavy dependence on wildings. The collection of wildings compelled the nursery staff to explore further into the surrounding forests since there had been no major fruiting the previous years. Luckily, surplus stock was available for purchase from the INFAPRO nursery, another of ICSB's collaborative forest rehabilitation project with FACE Foundation in Lahad Datu. These supplemented the requirement to make up the required quantity and the minimum number of 25 species per sub-block planting.

The plants are raised in 3" x 8" black polybags, except for species with larger fruits, for example, belian (*Eusideroxylon zwageri*), tengkawang (*Shorea mecistopteryx*, *S. macrophylla*) and merbau (*Intsia palembanica*), requiring larger bags of 6" x 9". The potting mixture is wholly forest topsoil, of heavy clay loam with poor drainage. Sand and peat to improve the soil mix are presently not easily available. Aerial growth is apparently not seriously impaired using this soil, but inspection of the roots revealed inadequate development of tertiary roots.

With the prohibition of using herbicides, thick black plastic sheets are placed at the base of the beds to suppress weed development. Weeds in the pot are manually removed. The use of fungicides and insecticides is allowed only when absolutely necessary. So far there has not been any major pest and disease outbreaks in the nursery. Those species known to be susceptible to fungus, for example, mengaris (*Koompassia excelsa)*, keranji (*Dialium indum*) and kayu malam (*Diospyros* spp.), especially at germination and very young stages, are kept in small isolated batches to minimize spread of disease.

Each pot is given a one-time application of Agroblen®, a controlled release fertilizer at 4 g per pot just after transplanting.

WILDINGS

The use of wildings adds an extra step to the nursery process which is the acclimatization stage in humidity chambers. The wildings collected in the field are kept in moist cool boxes and transferred promptly to the nursery. The roots are trimmed to fit into the polybags and the leaves clipped to minimize dehydration. The plants potted into bags are placed in the chambers. These chambers are bamboo or wooden frames covered with transparent plastic sheets. In the chambers the wildings are watered and sealed in to maintain high humidity. The plants remain inside the cover for 2 to 3 months, depending on the species, after which the plastic covering is gradually removed over a few days until the plants are ready for the open.

Ideally, smaller wildings are preferred. They recover and reestablish much quicker than taller ones. Plants more than 40 cm height are less able to survive and slower to recover. The hardier species are *Dryobalanops lanceolata, Aquilaria malaccensis* and *Pentace laxiflora.* Overall, most species have good survival rates, for example, most *Dipterocarpus* spp., *Shorea oleosa* and *S. parvifolia.* The leguminous species, *Koompassia excelsa*, *Sindora* sp., *Intsia palembanica* and *Canarium* sp., are also easy to transfer to the nursery.

RESEARCH

Canopy opening before and after planting is crucial in canopy under-planting. The question is whether the opening should be drastic or gradual and by how much. A study was recently started as part of a Ph.D. programme of the Swedish University of Agriculture Science to test different pre-planting shade adjustment procedures involving girdling and felling in the upper and lower canopies of the secondary forest (Romell 2002). The eventual outcome of the study will assist in refining the present site preparation procedures.

The factorial design's main treatment is the removal of shade at the upper canopy (more than 15 m high) by felling and girdling. The additional treatment is the removal and the retention of the lower-storey vegetation of saplings and shrubs. The study uses two species of *Dipterocapus* and two species of *Shorea*.

CONCLUSION

In line planting, different line directions have been recommended (Appanah & Weinland 1993, Adjers *et al*. 1996). The question is whether a particular direction is suited to the many species used for this project, coupled with the highly heterogeneous forest conditions. For operational efficiency, it is best to lay the lines perpendicular to the main access for easier distribution of the plants during planting and also it would be easier to relocate during maintenance.

Deciding on the widths of the planting lines and gaps to optimize plant growth has always pestered the manager's mind. In general wider openings are better (Adjers *et al*. 1996) but more costly. Also there is a risk of promoting weed growth, for example, small trees, shrubs and herbaceous plants, causing more shading to the planted seedlings. There is a need to strike a balance between operational considerations and plant growth. In the case where so many species are planted, a conservative opening initially is probably better overall. The subsequent maintenance and shade adjustment rounds will gradually open up the canopy after the plants are safely established.

The procedures, whether in line or gap planting are made simple enough to be implemented in the field. In general there is a preference for gap planting mainly because it requires half less lines to cut. Furthermore, the lines in gap planting are access lines and need not be very wide compared to line planting where the lines are for planting. Hence the 2-m width requirement. The lining can therefore be easier and faster for gap planting.

The cluster arrangement in gap planting also has another advantage. A gap can be considered a planting point. If eventually one out of three plants survives, the point is considered filled. The need for refilling which could be costly is avoided.

Recognizing the high cost associated with forest rehabilitation, especially during site preparation and planting and the hassle for legalized workers, a conscious decision was made at the start to keep the operations cost to a minimum at less than RM1 000 per hectare. This is possible by avoiding using contractors and to simplify most of the field operations so that the field crew are able to understand rapidly with some training and are able to effectively and accordingly implement these operations. Their basic tools are parangs, compasses, clinometers and tapes. Their crucial skills are tree species identification, and the ability to use the compasses and clinometers.

To date 3 500 ha have been planted for the project and another 90 ha silviculturally treated. The nursery has substantially expanded and has grown out of its dependence to buy planting stock towards self sufficiency.

REFERENCES

Adjers, G., Nuryanto, K. & Kuusipalo, J. 1996. Rehabilitation of degraded dipterocarp forests: results from South Kalimanta, Indonesia. *In* S. Appanah & K.C. Khoo, eds. *Proc. Fifth Round-Table Conference on Dipterocarps*, pp. 316–334. Chiang Mai, Thailand.

Appanah, S. & Weinland, G. 1993. *Planting quality timber trees in Peninsular Malaysia —a review*. Malayan Forest Records No. 38. Kepong, Forest Research Institute Malaysia. 221 pp.

Awang Mohdar, H. 1995. Forest plantation establishment in Sabah with special reference to Innoprise Corporation Sdn Bhd (ICSB). *In* R. Wickneswari, *et al.*, eds. *Proc. BIO-REFOR Workshop*, pp. 47–52. Kangar, Malaysia.

Martin, A.R., Daim, B. & Teo, Y.H. 2001. *Forest rehabilitation operation on Deramakot Forest Reserve*. 13th Malaysia Conference, 20–25 Aug. 2001, Johor Bahru, Johor.

Moura-Costa, P., Yap, S.W., Ong, C.L., Ganing, A., Nussbaum, R. & Mojiun, T. 1993. Large scale enrichment planting with dipterocarps as an alternative for carbon offset —methods and preliminary results. *In* S. Appanah & K.C. Khoo, eds. *Proc. Fifth Round-Table Conference on Dipterocarps*, pp. 386–409. Chiang Mai, Thailand.

Romell, E. 2002, *Artificial regeneration in logged and burned tropical rainforest: gap opening, light transmission and seedling establishment*. SLU. (Ph.D. thesis)

17 Using native tree species to restore degraded hillsides in Hong Kong, China

Billy C.H. Hau* and Ken K.Y. So**

ABSTRACT

The interest in restoring forest on degraded hillsides in Hong Kong for biodiversity conservation has been growing since the beginning of the last decade. This paper reviews the results of 8 planting trials conducted by different researchers on various scales in the last ten years using a total of 57 native tree and shrub[1] species with respect to early survival and growth. The performances of these seedlings were evaluated under the criteria of the framework species method of reforestation that was developed in North Queensland's wet tropics. Seedling performances were highly variable between species and sites. In general, a higher number of the native tree species showing early successional characters performed better on the exposed and eroded hillsides, such as Schefflera octophylla, Mallotus paniculatus and Zanthoxylum avicennae, while other early successional species performed badly, such as Sapium discolor. However, some late successional species also performed very well on the exposed hillsides, e.g. Cyclobalanopsis neglecta, C. edithiae and Syzygium hancei. Other late successional species performed very badly, such as Pygeum topengii. Only one of the 8 planting trials, also the latest one, used native shrub species. The preliminary results indicated that shrubs were doing very well even in very poor soil and on 55 degree cut slope surfaces. This suggests that the focus on planting tree seedlings for afforestation may have been misplaced in Hong Kong. The succession pathway from shrubland[1] to forest should be given more consideration and the first step of forest restoration projects may start with shrubs, followed by reinforcement with trees at a later stage. A list of potential framework species for restoring native, species-rich forest is prepared on the basis of this review.

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[1] Shrub is woody species that seldom exceeds 3 m in height in Hong Kong and vegetation formed by shrub species is referred to as shrubland.

INTRODUCTION

Tropical deforestation has been a major conservation issue for many years. Many efforts have been put to stop further deforestation on one hand and restore degraded forest land on the other. Exotic tree species are often used for plantation as well as environmental forestry. It is because exotic species have been tested, and seed sources selected and genetically improved to produce stocks of very high productive potential after many years of research (Haggar *et al.* 1998). In many cases, exotic species are also preferred because they grow faster than native species (Richardson 1998). They are also often better suited to planting on degraded land, where most afforestation is required. However, Butterfield (1993) points out that exotic tree species are rarely tested against local species that may be better adapted. With the rising concern for biodiversity conservation, habitat restoration is regarded a complementary measure to preserving existing habitats for native species (Jordan 1997). Reforestation aiming at restoring biodiversity has become a new trend and the planting of more native tree species is inevitable.

Currently, the problems with the wider use of native tree species in commercial and environmental forestry are yet to be overcome. There is a general lack of reliable knowledge of basic biology and nursery operations for native tree species in the tropics because of the large number of species and contradictory information from different areas (Richardson 1998). Information on seed collection, storage, germination and seedling growth conditions for many native tree species is not yet available (Blakesley *et al.* 2002). Native species are thus more difficult to manage silviculturally than the exotics. This makes the production of native seedlings more expensive (Elliott *et al.* 1995, Richardson 1998). Research on the use of native species, both in nursery production and planting method has already started throughout the tropics (Goosem & Tucker 1995, Forest Restoration Research Unit 1998, Hau 2000, Carnevale & Montagnini 2002). Some studies have already shown that certain native species are promising (Holl 1998, Blakesley *et al.* 2002).

Grasses and shrubs cover over 50% of the land area of Hong Kong, mostly on degraded hillside sites that formerly supported forest (ERM 2002). Forestry in Hong Kong has always been for environmental reasons, such as soil erosion control, watershed protection, landscape repair and more recently biodiversity conservation, rather than timber production (Corlett 1999). Despite the fact that the most commonly planted tree species in the early afforestation history of Hong Kong (1871–1965) was a native pine, *Pinus massoniana* (it lost its importance due to pest problems and its susceptibility to fire), Hong Kong has relied heavily on a limited number of exotic species in the 1970s and 1980s. Between 1871 and 1990, a total of 150 tree species were named in Hong Kong forestry reports, and only 33 were native species (Corlett 1999). After the Earth Summit in 1992, Hong Kong has declared its intention to follow the Convention on Biological Diversity. Since then, an increasing number of native species has been tried though a higher percentage of exotic trees are still used in reclamation projects on barren lands (Chong 1999, Lay *et al.* 1999). The percentage number of native trees planted in Country Parks, which cover the land area of Hong Kong, has increased from 38% (total 276 334) in 1994 to 59% (total 500 500) in 2001. However, most of these native tree species have been planted, albeit in the same way the exotics were, with little attempt to allow for the particular ecological characteristics of the species used. Most of these planting trials using native tree species have so far gained little success and are not well documented.

The aim of this paper is to review the performances of native tree species in eight planting trials in Hong Kong in which survival and growth data in the first two years are available. The performances and ecological characteristics of these native species were evaluated against the features of the framework species method of forest restoration, which was first developed in North Queensland's Wet Tropics (Goosem & Tucker 1995).

METHOD

The Hong Kong Special Administrative Region of the People's Republic of China (hereafter, Hong Kong) (22°N, 114°E), consists of a section of the Chinese mainland (Kowloon and the New Territories) and numerous islands, with a total land area of 1 100 km^2. The topography is mostly rugged, with the highest point at Tai Mo Shan (957 m above sea level) in the New Territories. The climate is subtropical monsoon, with a hot, wet summer and cool, dry winter. This climate would support tall, evergreen, fire-excluding forest, but this has been largely cleared within the last 1 000 years (Dudgeon & Corlett 1994). Today all flatland is urbanized, cultivated or abandoned cultivation. The remaining 80% of the land area is mostly steep hillsides covered in secondary grasslands and shrublands, maintained by anthropogenic fires, with an increasing area of secondary forest that has largely developed since 1945 (Zhuang & Corlett 1997). Some sites at high altitude may have escaped complete deforestation, although all forest patches have been disturbed.

The eight planting trials were conducted in various parts of Hong Kong ranging from 70 to 550 m above sea level by different institutions (Table 1). All except the Tai Lam site were typical degraded hillside sites covered with either or both common shrubs (e.g. *Rhodomyrtus tomentosa*, *Melastoma sanguineum*, *Baeckae frustescens* and *Litsea rotundifolia*) and grasses (e.g. *Arundinella*, *Ischaemum*, *Eulalia*, *Eragrostis*, *Cymbopogon* and *Miscanthus* species). Container-grown seedlings of 30–50 cm in height were planted in these seven sites. Grass was cut in advance and grass leaves were left on site as mulching. The Tai Lam site was man-made cut slopes where loosened topsoil was scraped off after landslip by engineering means. The soil condition was thus the worst amongst all sites. Commercial Bermuda grass seeds were applied on the slope by hydro-seeding prior to planting. After the grass cover was well developed (in a month), container grown tree and shrub seedlings were planted. Only small trees and shrubs were planted on these slopes because of safety concern. The total number of seedlings planted range from 300 in Tai Mo Shan 2 to over 1 000 in Hung Lung Hang and Tai Lam.

The raw data of these eight planting trials were extracted and only the first two-year growth and survival data were used in this review. However, only 18-month data were available in the Tai Lam cut slope site. The relative height increment per year (RHI) was calculated using RHI = [ln (H_2) – ln (H_1)] / time in years, where H_1 and H_2 were the initial and final seedling heights respectively (Coomes & Grubb 1998). The growth and survival of the seedling species were summarized and compared. Based on the already existing ecological information on the tree species planted, they were evaluated against the principles of the framework species method (Goosem & Tucker 1995).

RESULTS

A total of 51 native trees and 5 native shrubs were used in these 8 planting trials (Table 2). Most of them bear fleshy fruits that are dispersed by birds in the winter dry season. The tree species used have most of the ecological characteristics of the tree flora in Hong Kong including early pioneers, common secondary forest dominant species and remnant forest species. Thirty species were used only in 1 site; 12 in 2 sites and 14 in 3 or more than 3 sites (Table 3).

Of the 14 species that were planted in 3 or more sites, 5 species had consistently high survival (50–100%) across all the sites they were planted. They were *Schefflera octophylla* (5 sites), *Machilus breviflora* (5 sites), *Choerospondias axillaris* (4 sites), *Cinnamomum camphora* (4 sites) and *Schima superba* (4 sites). The rest of the 14 species

Table 1. Characteristics of the eight study sites in chronological order

Year	Site	Vegetation cover	District	Altitude (m)	Steepness	Slope orientation	Data source
89–91	Kwun Yam Shan 1	Scrubland	Central New Territories	200	Gentle	N facing	Zhuang & Corlett, 2000
95–98	Tai Mo Shan 1	Grassland	Central New Territories	550	Steep	NW facing	Hau, 1999
95–98	Ho Sheung Heung	Grassland	Northern New Territories	20	Gentle	SE facing	Hau, 1999
95–98	Kwun Yam Shan 2	Scrubland	Central New Territories	200	Gentle	NW facing	Hau, 1999
98–00	Nam Shan	Grassland	South Lantau	250	Gentle	NW facing	Unpublished data, KGBG[1]
00–02	Tai Mo Shan 2	Grassland	Central New Territories	550	Steep	N facing	Unpublished data, KGBG
00–02	Hung Lung Hang	Grassland	Northern New Territories	70	Very gentle	S facing	Unpublished data, KGBG
01–02	Tai Lam	Cut slope	Northwest New Territories	200	Very steep	NE facing	Unpublished data, KGBG & CED[2]

Note: [1] KFBG is Kadoorie Farm and Botanic Garden; [2] CED is Civil Engineering Department, Hong Kong SAR Government.

Table 2. Ecological characteristics of the native tree and shrub species used in the eight planting trials

Species	Growth form	Dry/wet season fruiting	Fruit type	Seed dispersal agent in Hong Kong	Ecological status in Hong Kong
Antirhea chinensis	Small tree	Dry	Drupe	Bird	Common in secondary forest and scrubland
Aporosa dioica	Small tree	Wet	Drupe	Bird	Common in secondary forest and scrubland
Aquilaria sinensis	Large tree	Wet	Capsule	Bird	Common in lowland forest
Archidendron lucidum	Shrub	Dry	Capsule	Bird	Common in scrubland & forest edges
Ardisia crenata	Shrub	Dry	Drupe	Bird	Common forest floor species
Bischofia javanica	Large tree	Dry	Drupe	Bird	Common in secondary forest
Bridelia tomentosa	Small tree	Dry	Drupe	Bird	Common in secondary forest and scrubland
Castanopsis fissa	Large tree	Dry	Acorn	Bird	Common in secondary forest
Celtis tetrandra	Large tree	Wet	Drupe	Bird	Common in secondary forest
Choerospondias axillaris	Large tree	Dry	Drupe	Bird & civet	Common in secondary forest
Cinnamomum camphora	Large tree	Dry	Drupe	Bird	Common in secondary forest
Cleistocalyx operculata	Medium tree	Wet	Drupe	Bird	Riparian species
Cordia dichotoma	Large tree	Wet	Drupe	Bird	Remnant forest species
Cratoxylum cochinchinense	Small tree	Dry	Capsule	Wind	Common in secondary forest and scrubland
Cryptocarya concinna	Large tree	Dry	Berry	Bird	Remnant forest species
Cyclobalanopsis edithiae	Large tree	Wet	Acorn	None	Remnant forest species
Cyclobalanopsis myrisinifolia	Small tree	Dry	Acorn	None	Localized distribution
Cyclobalanopsis neglecta	Large tree	Dry	Acorn	None	Remnant forest species
Cyclobalanopsis championii	Small tree	Dry	Acorn	None	Localized distribution
Daphniphyllum calycinum	Small tree	Dry	Drupe	Bird	Common in scrubland and forest edges

Species	Growth form	Dry/wet season fruiting	Fruit type	Seed dispersal agent in Hong Kong	Ecological status in Hong Kong
Diospyros morrisiana	Small tree	Dry	Berry	Bird	Common in secondary forest
Elaeocarpus chinensis	Large tree	Dry	Drupe	Bird & civet	Common in secondary forest
Gordonia axillaris	Small tree	Dry	Capsule	Wind	Common in secondary forest and scrubland
Ilex rotunda	Small tree	Dry	Berry	Bird	Common in secondary forest and scrubland
Liquidambar formosana	Large tree	Dry	Capsule	Wind	Common in secondary forest
Lithocarpus glaber	Medium tree	Dry	Acorn	None	Common in secondary forest
Lithocarpus harlandii	Large tree	Dry	Acorn	None	Remnant forest species
Litsea rotundifolia var. *oblongifolia*	Shrub	Dry	Drupe	Bird	Common in scrubland and forest edges
Machilus breviflora	Medium tree	Dry	Drupe	Bird	Common in secondary forest
Machilus chekiangensis	Medium tree	Dry	Drupe	Bird	Common in secondary forest
Machilus chinensis	Large tree	Dry	Drupe	Bird	Remnant forest species
Machilus oreophila	Large tree	Dry	Drupe	Bird	Remnant forest species
Machilus velutina	Medium tree	Dry	Drupe	Bird	Common in secondary forest
Mallotus paniculatus	Small tree	Dry	Capsule	Bird	Common in secondary forest and scrubland
Melicope pteleifolia	Small tree	Dry	Capsule	Bird	Common in scrubland
Myrsine seguinii	Small tree	Dry	Drupe	Bird	Common forest floor species
Ormosia emarginata	Small tree	Dry	Capsule	Bird	Common in secondary forest
Pinus massoniana	Large tree	Dry	Cone	Wind	Common in secondary forest
Psychotria asiatica	Shrub	Dry	Drupe	Bird	Common in scrubland and secondary forest
Pygeum topengii	Medium tree	Wet	Drupe	Bird	Common in secondary forest
Rauvolfia verticillata	Small tree	Dry	Drupe	Bird	Common in secondary forest

Species	Growth form	Dry/wet season fruiting	Fruit type	Seed dispersal agent in Hong Kong	Ecological status in Hong Kong
Reevesia thyrsoidea	Small tree	Dry	Capsule	Wind	Common in scrubland and forest edges
Rhaphiolepis indica	Shrub	Dry	Drupe	Bird	Common in scrubland
Sapindus mukorossi	Medium tree	Wet	Drupe	Bird	Common in secondary forest
Sapium discolor	Medium tree	Dry	Capsule	Bird	Common in scrubland and forest edges
Schefflera octophylla	Large tree	Dry	Berry	Bird	Common in secondary forest and scrubland
Schima superba	Large tree	Dry	Capsule	Wind	Common in secondary forest
Sterculia lanceolata	Medium tree	Wet	Capsule	Bird	Common in secondary forest
Styrax suberifolius	Medium tree	Dry	Capsule	Unknown	Common in secondary forest
Syzygium cuminii	Medium tree	Dry	Drupe	Bird	Common in secondary forest
Syzygium hancei	Medium tree	Dry	Drupe	Bird	Common in secondary forest
Trema tomentosa	Small tree	Dry	Capsule	Bird	Common in scrubland and forest edges
Tutcheria championii	Large tree	Dry	Capsule	Unknown	Remnant forest species
Viburnum odoratissimum	Medium tree	Dry	Drupe	Bird	Common in secondary forest and scrubland
Xylosma longifolium	Medium tree	Dry	Drupe	Bird	Remnant forest species
Zanthoxylum avicennae	Small tree	Dry	Capsule	Bird	Common in secondary forest and scrubland

Table 3. Percentage survival (% S) and relative height increment (RHI) of each species at each site. N is the sample size

Species	Kwun Yam Shan 1			Tai Mo Shan 1			Ho Sheung Heung			Kwun Yam Shan 2			Nam Shan			Tai Mo Shan 2			Hung Lung Hang			Tai Lam		
	N	RHI	% S	N	RHI	% S	N	RHI	% S	N	RHI	% S	N	RHI	% S	N	RHI	% S	N	RHI	% S	N	RHI	% S
Cyclobalanopsis neglecta	20	0.66	43.00	150	0.64	97.50	40	0.65	90.00	40	0.67	80.00	25	0.52	15.39	18	0.58	90.00	82	0.27	48.78			
Mallotus paniculatus	20	0.39	100.00	40	0.30	100.00	40	0.26	87.50	40	0.29	42.50	202	0.45	73.40				220	0.48	80.45			
Castanopsis fissa	20	0.27	10.00	150	0.26	82.00	50	0.42	74.00	100	0.39	26.00	174	0.27	22.29									
Cinnamomum camphora	19	0.82	100.00	40	0.13	95.00	40	0.12	97.50	40	0.19	100.00	30	0.18	69.70									
Machilus breviflora	19	0.85	85.00	40	0.68	87.50	40	0.63	95.00	40	0.50	70.00	142	1.07	64.42									
Schefflera octophylla	10	0.84	65.00	150	0.44	82.00	50	0.83	70.00	100	0.52	59.00										112	0.62	71.32
Sterculia lanceolata	20	0.30	100.00	440	0.38	92.50	40	0.44	87.50	40	0.34	20.00	65	0.57	19.69									
Choerospondias axillaris				40	0.38	97.50	40	0.29	100.00	40	0.41	97.50							140	0.40	100.00			
Cyclobalanopsis edithiae	10	0.40	82.00										6	0.27	14.29	20	0.77	85.00	200	0.23	47.50			
Sapium discolor	20	0.35	55.00	150	N.A.	24.00	50	N.A.	0.00	100	N.A.	0.00												
Schima superba				150	0.15	96.00	50	0.23	86.00	100	0.19	78.00	3	0.47	83.33									
Cyclonalanopsis championii	10	0.47	80.00										34	1.14	40.00	23	0.69	47.82						
Gordonia axillaria	19	0.69	45.00										18	0.65	73.68							226	0.59	84.84
Pyguem topengii	23	0.63	60.00													11	0.45	1.00	100	0.18	35.00			
Bischofia javanica	20	0.83	100.00										9	0.81	22.22									
Cleistocalyx operculata	20	0.62	100.00										36	0.57	97.22									
Cordia dichotoma																14	0.07	57.14	25	0.31	76.00			
Cratoxylum cochinchinense	10	0.93	100.00										16	0.21	21.21									
Cyclobalanopsis myrisinifolia	20	0.66	27.00										16	0.36	29.41									
Daphniphyllum calycinum	20	1.27	80.00																5	0.16	20.00			
Diospyros morrisiana	20	1.17	95.00																80	0.25	22.50			
Liquidambar formosana	20	0.44	95.00										15	0.02	6.25									
Lithocarpus glaber	20	0.55	18.00										62	0.39	28.57									
Myrsine seguinii													7	0.50	62.50				15	0.16	73.30			
Reevesia thyrsoidea	20	0.42	100.00																30	0.21	60.00			
Tutcheria championii																109	0.59	94.00	20	0.21	35.00			
Antirhea chinensis																			6	0.08	16.67			

Species	Kwun Yam Shan 1			Tai Mo Shan 1			Ho Sheung Heung			Kwun Yam Shan 2			Nam Shan			Tai Mo Shan 2			Hung Lung Hang			Tai Lam		
	N	RHI	% S	N	RHI	% S	N	RHI	% S	N	RHI	% S	N	RHI	% S	N	RHI	% S	N	RHI	% S	N	RHI	% S
Aporosa dioica																			100	0.18	73.00			
Aquilaria sinensis																			10	0.10	50.00			
Archidendron lucidum	20	0.79	89.00																					
Ardisia crenata																						98	0.40	79.39
Bridelia tomentosa	10	0.71	90.00																					
Celtis tetrandra	20	0.69	95.00																					
Cryptocarya concinna																			100	0.11	58.00			
Elaeocarpus chinensis																			100	0.30	31.00			
Ilex rotunda																10	0.06	60.00						
Lithocarpus harlandii																			50	0.21	70.00			
Litsea rotundifolia																						229	0.53	89.74
Machilus chekiangensis																			80	0.33	67.50			
Machilus chinensis	20	0.61	65.00																					
Machilus oreophila	20	0.31	80.00																					
Machilus velutina	20	0.92	65.00																					
Melicope pteleifolia																						145	0.64	86.41
Ormosia emarginata	20	0.45	28.00																					
Pinus massoniana	20	0.77	58.00																					
Psychotria asiatica																						114	0.46	91.58
Rauvolfia verticillata													3	0.26	75.00									
Rhaphiolepis indica																						140	0.38	56.49
Sapindus mukorossi	20	0.82	86.00																					
Styrax suberifolius																			50	0.13	42.00			
Syzygium cuminii													65	0.56	40.00									
Syzygium hancei																101	0.50	97.00						
Trema tomentosa	20	0.44	100.00																					
Viburnum odoratissimum																			24	0.30	79.16			
Xylosma longifolium																			70	0.19	78.57			
Zanthoxylum avicennae																						113	0.59	94.67

had variable survival in the sites planted. On the other hand, 4 species had consistently high growth (RHI > 0.4) in all sites they were planted. They were *S. octophylla* (5 sites), *M. breviflora* (5 sites), *Cyclobalanopsis championii* (3 sites) and *Gordonia axillaris* (3 sites). *Mallotus paniculatus* was planted in 6 sites and had consistently high survival in 5 sites. The rest of the 14 species had variable growth in the sites planted.

Seedling performances were variable at all sites except in the Tai Lam cut slope where the growth and survival were consistently high (RHI = 0.38–0.64; % S = 56.49–94.67).

A list of native tree species with high survival and growth in all sites planted, even if it is just one site, is selected according to the framework species criteria (Table 4).

Table 4. Selected Hong Kong native tree species according to the framework species criteria

Framework species criterion	Species
Toughness	*Schefflera octophylla, Machilus breviflora, Cyclobalanopsis championii, Gordonia axillaris, Schima superba*
Attractiveness to wildlife/ early production of wildlife resources	*Schefflera octophylla*, *Machilus breviflora, Ardisia crenata, Melicope pteleifolia, Zanthoxylum avicennae*
Regenerative ability/ease of germination	*Schefflera octophylla*, *Microcos paniculata, Choerospondias axillaris, Machilus breviflora*
Keystone species	*Schefflera octophylla, Ilex rotunda*
Architecture	*Choerospondias axillaris, Mallotus paniculatus*
Vigour	*Schefflera octophylla*, *Machilus breviflora, Gordonia axillaris*, *Cyclobalanopsis championii*
Species with limited dispersal mechanism	*Cyclobalanopsis championii*, *C. neglecta*

DISCUSSION

The results of the review show that most tree species performed differently at different sites. Nevertheless, two species, *S. octophylla* and *M. breviflora*, were found having consistently high survival and growth at all sites planted. Both species are common in secondary forests and *S. octophylla* is also common as seedlings in shrubland. It is thus considered an early pioneer species. They both bear fleshy fruits in the winter dry season that are dispersed by many bird species. *Schefflera octophylla* is particularly important in this respect because its fruit will last until the end of the dry season where fruit resources are scarce. However, not all early pioneer species performed well when planted in degraded sites. For example, *Sapium discolor* is very common in young secondary forests and shrubland in Hong Kong but its growth and survival in these planting trials were appalling. On the other hand, some remnant forest species, which are expected to be shade tolerant, performed unexpectedly well in at least some sites, for example, *Pygeum topengii*, *Tutcheria championii* and *Machilus chinensis*. Clearly, the results suggest that more screening trials are needed and future trials have to be further refined to match species with sites as well as microhabitats. Factors such as altitude, slope orientation, slope gradient, planting positions (i.e. ridges, gullies or slopes), degree of exposure to wind, existing vegetation cover (whether it is grass, shrub, fern or a mixture of these), and soil condition have to be tested.

The good performances of the species used in the Tai Lam cut slopes suggest that shrubs and small trees may play a significant role in very degraded sites. This fits in with the forest succession pathway whereby shrubs will establish prior to forest. Early studies in Hong Kong have already shown that in the absence of fire, degraded forest land with nearby seed sources will develop from grassland to shrubland in 5 to 10 years and to forest in another 20 to 30 years (Zhuang & Corlett 1997). The role of shrubs and small trees should be further studied in Hong Kong.

A list of framework tree species for Hong Kong, though short, is generated based on this review. A long-term demonstration plot, which is currently lacking, should be established in Hong Kong starting with this list of species and more species should be added pending the results of other planting trials.

This review also suggests that using native tree species to restore degraded hillsides in Hong Kong is possible. It is a matter of choosing the right species or the right mix of species for each site. Pending the results of more planting trials, this technical difficulty can be overcome. The experience in Hong Kong so far shows that the availability of tree seed is the limiting factor to wider use of native tree species. Seed collection is also time consuming and requires a certain degree of expertise. The silvicultural difficulties in the nursery propagation of native tree species are, however, low. For the 400 or so native tree species in Hong Kong, over 160 species have been successfully propagated in the Native Tree Nursery of the Kadoorie Farm and Botanic Garden in Hong Kong. Only a handful of species had germination problems in the nursery. A cost-effective approach from the nursery point of view is to concentrate on the production of ten or so framework species which have stable and abundant supply of seeds and to only produce other species in smaller quantities to enrich the diversity. In addition, high quality seedlings, good post-nursery care, good planting treatment and post-planting maintenance are all crucial to the success of any planting project.

Finally, the planting trials in Hong Kong so far are too small in scale. It is due to the high costs of planting in Hong Kong. Larger-scale planting trials should nevertheless be conducted and long-term monitoring is needed.

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REFERENCES

Blakesley, D., Elliott, S., Kuarak, C., Navakitbumrung, P., Zangkum, & Anusarnsunthorn S. 2002. Propagating framework tree species to restore seasonally dry tropical forest: implications of seasonal seed dispersal and dormancy. *Forest Ecology and Management* 164: 31–38.

Butterfield, R.P. 1993. *Tropical timber species growth in the Atlantic lowlands of Costa Rica and wood variation of two native species*. North Carolina State University, U.S.A. 76 pp. (unpublished thesis)

Carnevale, N.J. & Montagnini, F. 2002. Facilitating regeneration of secondary forests with the use of mixed or pure plantations of indigenous tree species. *Forest Ecology and Management* 163: 217–227.

Chong, S.L. 1999. Restoration of degraded lands in Hong Kong. *In* M.H. Wong, J.W.C. Wong & A.J.M. Baker, eds. *Remediation and management of degraded lands,* pp. 185–193. Boca Raton, London, New York, Washington, DC, Lewis Publishers.

Coomes, D.A. & Grubb, P.J. 1998. Responses of juvenile trees to above- and below-ground competition in nutrient-starved Amazonian rain forest. *Ecology* 79(3): 768–782.

Corlett, R.T. 1999. Environmental forestry in Hong Kong: 1871–1997. *Forest Ecology and Management* 116: 93–105.

Elliott, S., Anusarnsunthorn, V., Blakesley, D. & Garwood, N.C. 1995. Research needs for restoring the forests of Thailand. *Natural History Bulletin Siam Society* 43: 179–184.

ERM (Environmental Resources Management Hong Kong Ltd.). 2002. *Environmental baseline survey report: terrestrial habitat mapping and ranking based on conservation value*. Hong Kong, Environmental Protection Department, the Government of the Hong Kong SAR. 80 pp.

Forest Restoration Research Unit. 1998. *Forests for the future: growing and planting native trees for restoring forest ecosystems*. Thailand, Biology Department, Science Faculty, Chiang Mai University. 60 pp.

Goosem, S. & Tucker, N.I.J. 1995. *Repairing the rainforest, theory and practice of rainforest re-establishment in North Queensland's wet tropics.* Queensland, Australia, Wet Tropics Management Authority. 72 pp.

Haggar, J.P., Briscoe, C.B. & Butterfield, R.P. 1998. Native species: a resource for the diversification of forestry production in the lowland humid tropics. *Forest Ecology and Management* 106: 195–203.

Hau, B.C.H. 1999. The establishment and survival of native trees on degraded hillsides in Hong Kong. The University of Hong Kong, Hong Kong. 192 pp. (Ph.D. thesis)

Hau, B.C.H. 2000. Promoting native tree species in land rehabilitation in Hong Kong, China. *In* S. Elliott, J. Kerby, D. Blakesley, K. Hardwick, K. Woods & V. Anusarnsunthorn, eds. *Forest restoration for wildlife conservation,* pp. 109–120. International Tropical Timber Organization and The Forest Restoration Research Unit, Chiang Mai University, Thailand.

Holl, K.D. 1998. Tropical moist forest restoration on agricultural land in America. *In* B.C. Rana, ed. *Damaged ecosystems and restoration,* pp. 25-41. New Jersey, USA, World Scientific.

Jordan, III, W.R. 1997. Ecological restoration and the conservation of biodiversity. *In* M.L. Reaka-Kudla, D.E. Wilson & E.O. Wilson, eds. *Biodiversity II, understanding and protecting our biological resources,* pp. 371–387. Washington, D.C., Joseph Henry Press.

Lay, C.C., Chan, S.K.F. & Chan, Y.K., 1999. *The utilization of native species in local afforestation programme.* Hong Kong, Agriculture and Fisheries Department, the Government of the Hong Kong SAR. 31 pp. (unpublished)

Richardson, D.M. 1998. Forestry trees as invasive aliens. *Conservation Biology* 12(1): 18–26.

Zhuang, X.Y. & Corlett, R.T. 1997. Forest and forest succession in Hong Kong, China. *Journal of Tropical Ecology* 14: 857–866.

Zhuang, X.Y. & Corlett, R.T. 2000. Survival and growth of native tree seedlings in secondary forest of Hong Kong. *Journal of Tropical and Subtropical Botany* 8(4): 291–300. (in Chinese with an English abstract)

18 Forest rehabilitation case study: rehabilitation after bauxite mining in the jarrah (*Eucalyptus marginata*) forest of southwestern Australia

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ABSTRACT

Alcoa World Alumina Australia currently operates two bauxite mines in the jarrah (Eucalyptus marginata) forest of Western Australia. The jarrah forest is a multiple land-use system and Alcoa's rehabilitation objective is to return a self-sustaining jarrah forest ecosystem that fulfils all of the pre-mining land uses. The current rehabilitation procedure has evolved over the last 35 years with continual improvement in site preparation techniques following extensive research and monitoring projects. Today's programme is based on a sound knowledge of jarrah forest ecology and land rehabilitation fundamentals, and years of operational experience. Significant advances have been made in topsoil handling, ripping, breaking seed dormancy and planting of species that are difficult to establish. These practices are successful in establishing vegetation that reinstates floral diversity and ecosystem processes such as litter accumulation, redevelopment of nutrient pools and the successional development. The established forest ecosystem is also highly productive in terms of timber quantity and quality. Many of the techniques utilized in bauxite mine rehabilitation in Western Australia are applicable to the re-establishment of forest ecosystems in other parts of the world, and after other transient land uses besides mining.

INTRODUCTION

Logging, mining, shifting cultivation and frequent burning cause disturbance of forests in many parts of the world. Without appropriate management to restore ecological values and productivity, these forests can degrade, resulting in loss of future benefits. The

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degraded and often eroding areas can also contribute to off-site impacts to adjacent land and water resources. The science and technology of land rehabilitation and restoration ecology has advanced to a high level in some sectors, such as the mining industry, allowing disturbed lands to be rehabilitated to meet complex and multiple objectives (Gardner 2001).

This paper presents the case of Alcoa World Alumina Australia's mine rehabilitation programme in the jarrah (*Eucalyptus marginata*) forest of southwestern Australia. The paper briefly outlines the advanced techniques for land preparation, soil handling, seed treatment and plant propagation that are used to re-establish the native forest ecosystem and restore the multiple land-use objectives of the forest. These techniques reinstate the primary ecosystem processes that progress towards those of the unmined forest over time and re-establish a very productive forest community.

BAUXITE MINING IN THE JARRAH FOREST

The jarrah forest covers some 1.8 million hectares, most of which is publicly owned and managed as state forest. The vegetation community is tall open forest dominated by jarrah (*Eucalyptus marginata*) and marri (*Corymbia calophylla*). This community is botanically diverse with an estimated 780 plant species occurring in the forest region. Less than 15 percent of the forest remains in an old-growth condition. Under a current proposal, about 34 percent of the forest is to be placed in conservation reserves that sample the range of forest ecosystems and protect remaining old-growth areas (Conservation Commission of WA 2002). The forest is close to Perth, the capital of Western Australia, which has a population of over 1.5 million people.

Alcoa operates two bauxite mines at Huntly and Willowdale, approximately 90km and 135 km southeast of Perth respectively. A third mine at Jarrahdale ceased production in 1998 and has now been decommissioned and fully rehabilitated. Currently, about 550 ha are mined and rehabilitated annually. Since the commencement of mining, 13 400 ha have been cleared and 11 100 ha have been rehabilitated. Bauxite mining occurs in isolated pods of 1 to 100 ha in area, averaging 10 to 20 ha. Mining is shallow open cut that removes a layer of bauxite approximately 4 m thick.

REHABILITATION PROCESS

Site preparation

The first step in the current rehabilitation process is to batter down the pit walls (2–5 m high) and recontour the mines to blend into the surrounding forest areas, with maximum slope angles of 20 percent. Recontouring of the mined-out pits aims to mimic the original, natural landscape. The gravelly sand surface covering the bauxite is stripped before mining and used for rehabilitation. Usually it is removed in two layers (known as double stripping): the upper 10–15 cm is referred to as topsoil, and the remainder, usually about 40 cm, is known as overburden. Double stripping maintains the concentration of seeds and organic matter at the surface of the rehabilitated soil profile. The overburden is stockpiled alongside the pit. Ideally, the topsoil, which contains much of the soil organic matter, nutrients, micro-organisms and seeds, is used immediately after stripping to rehabilitate a nearby pit (known as direct return). Directly returned topsoil may contain over 50 percent of the original unmined forest topsoil seed reserve, compared to 15 percent when topsoil is stockpiled (Koch *et al.* 1996). Where logistics or forest disease considerations dictate, the topsoil is stockpiled. In rehabilitated bauxite pits, over 70 percent of plant species originate from the topsoil (Koch & Ward 1994).

The overburden and topsoil are returned in the correct sequence and the pit is then contour ripped to a depth of approximately 1.5 m using a winged ripping tine. Ripping with the winged tine relieves soil compaction that could restrict root growth, encourages water infiltration, and reduces the risk of erosion. Ripping is carried out in summer and autumn to maximize shatter of the compacted clayey subsoil. Contour lines at 3–5 m vertical intervals are surveyed and marked in the field and ripping accurately follows the contours. The ripping creates furrows approximately 0.4 m in height and 1.5 m wide. The contour furrows are critical for preventing rainfall runoff and soil erosion. Following ripping, a few tree stumps, logs and rocks are returned to the mined areas to provide habitat for fauna.

Following the earthworks but prior to the onset of winter rains, the areas are seeded with a seed mix that contains 70 to 100 local plant species. Seeding immediately after ripping maximizes plant establishment from the applied seed (Ward *et al.* 1996). Seed is either broadcast by hand or applied directly on to the freshly ripped ground by a seeding machine attached to the ripping bulldozer. The seed mix is applied at about 2 kg per hectare. Seed of the dominant tree species, jarrah and marri, are included in the mix. Only indigenous species are included in the seed mix, and all the seed are sourced from within 20 km of each mine to retain local genetic material in the rehabilitated areas. Plant species that cannot be established from topsoil or applied seed (known as recalcitrant species) are propagated at Alcoa's nursery and planted in rehabilitated areas in the first winter. Nursery plants are produced from treated seed, cuttings or tissue culture. In 2002, over 240 000 recalcitrant plants were planted at a rate of over 400 per hectare. Kangaroos graze some of the recalcitrant species and these plants are protected with tree guards. Finally, 500 kg ha^{-1} of a fertilizer mix based on di-ammonium phosphate with added potassium and micronutrients (16 percent P, 14 percent N, 5 percent K plus Cu, Zn, Mn and Mo) are applied by helicopter in spring.

Monitoring and research

To ensure that rehabilitated areas develop towards the identified rehabilitation objective, monitoring is conducted at an early stage and any unsatisfactory sites are remediated quickly. All rehabilitated pits are assessed at nine months for eucalypt, legume and weed density. Completion criteria specify that rehabilitation should contain 1 300 stems per hectare of eucalypts and one legume plant per square metre. Sites that contain less than 500 stems per hectare of eucalypts and less than 0.5 legume plants per square metre may need to be reseeded. Quality control during rehabilitation operations and reliable winter rainfall result in over 95 percent of rehabilitated areas meeting establishment standards. Occasional infestations of weed species are noted and sprayed.

When sites are 15 months old, plant species richness is measured. Completion criteria require that sites have greater than 50 percent of the understorey species richness of the unmined forest, but the company's internal objective is to average 100 percent across all sites. The average for all areas rehabilitated in 2000 at the two active mine sites achieved this target, and all individual sites exceeded 60 percent of the understorey species richness of the unmined forest.

The successional development of the plants and animals over time is assessed through long-term vegetation and fauna monitoring programmes (e.g. Nichols & Gardner 1998). Fauna monitoring has found that all jarrah forest mammal species, 95 percent of bird species and 87 percent of reptile species have recolonized the rehabilitated areas by the time they are 10 years old (Nichols 1998). Numerous other issues relating to the development of rehabilitated areas have been studied over the last 25 years including nutrient cycling, water use, timber quality, invertebrate recolonization and the reintroduction of various vertebrate species. Research projects have underpinned many of the advances in rehabilitation procedures that have been made over the last 35 years.

Ecosystem development

The rehabilitation procedure employed by Alcoa provides the building blocks of a sustainable ecosystem. However, many important processes take time to develop as the established vegetation matures, and other plants and animals recolonize over time. Some of the critical ecosystem processes include the accumulation of litter, redevelopment of nutrient pools and the successional development of the established vegetation. The contour furrowing that results from soil ripping aids these processes by ensuring that resources such as water, leaf litter and nutrients are captured and used *in situ* or recycled The furrows also concentrate the litter, allowing decomposition processes to commence earlier.

Litter reaccumulates rapidly in rehabilitated sites, sourced mainly from seeded eucalypt and legume species. Within 3 to 5 years, rehabilitated areas have accumulated the same amount of litter as unmined forest sites contain after the same period of time following burning (Ward 2000). Rehabilitated sites rapidly redevelop nutrient pools in the soil, litter and under-storey vegetation, but the pool contained within trees takes longer to develop (Ward & Koch 1996). High densities of legume species are established in rehabilitated areas to provide nitrogen fixation, water use and soil stabilization. These species are generally short-lived and their senescence leads to accumulation of highly flammable material that increases the risk of fire. Unmined jarrah forest is periodically burnt and a number of research projects have now investigated prescription burning in rehabilitated areas (Grant & Loneragan 1999, Smith 2001). Disturbance associated with fire is a critical stage in the development of the rehabilitated ecosystem, as it provides further opportunity for plant recolonization, regeneration and multiplication and for cycling of nutrients. Fire also modifies the structure of the young forests, leading to the development of a more clearly stratified, two-tiered structure of canopy and understorey, more similar to the natural forest.

Rehabilitated forest productivity

One of the identified land uses for the rehabilitated forests in southwestern Australia is timber production. A considerable amount of research and monitoring has been undertaken over the last 15 years investigating the growth and form of jarrah trees in rehabilitated areas compared to the unmined forest (e.g. Ward & Koch 1995). In 10- to 13-year-old rehabilitated sites with an average density of 1 750 stems ha^{-1}, the mean annual increment of basal area under bark (BAUB MAI) averaged 1.81 m^2ha^{-1} y^{-1} compared to the unmined forest with 0.19 m^2ha^{-1} y^{-1} at a lower tree density (Abbott & Loneragan 1986). However, even if the growth estimate figure is adjusted to include only 400 stems ha^{-1}, which is the crop tree density specified in the completion criteria (0.39 m^2ha^{-1} y^{-1}), the productivity of the rehabilitation is still much higher than the unmined forest, at least for the first 15 years after rehabilitation. Early assessment of small diameter timber from these areas has indicated that quality is also generally high. Rehabilitation operations in the jarrah forest have therefore been successful in re-establishing ecosystem processes and a productive forest environment.

CONCLUSION

Large mining operations, such as Alcoa's bauxite mines in Western Australia, are intensive and well resourced, and have the opportunity to develop advanced forest rehabilitation programmes based on scientific investigation, monitoring and adaptive management. Alcoa's rehabilitation programme has been recognized as being amongst the best in the world through the receipt of many awards, including a listing in 1990 on the UNEP Global 500 Roll of Honour. Each year, many scientists and land managers from the mining, agriculture and forestry sectors visit our operations, where we openly share our knowledge. Alcoa is currently working to transfer best practice rehabilitation expertise from Western Australia to its mining operations throughout the world and to implement the same rehabilitation principles and standards worldwide. There is much opportunity for large international companies to help with the improvement of environmental standards for mining and forestry around the globe and to promote capacity building in the regulatory, technical and academic communities in developing countries.

REFERENCES

Abbott, I. & Loneragan, O.W. 1986. Ecology of jarrah (*Eucalyptus marginata*) in the northern jarrah forest of Western Australia. *CALM Bulletin* 1: 25–59.

Conservation Commission of Western Australia. 2002. *Draft forest management plan*. Perth, Conservation Commission of Western Australia.

Elliott, P., Gardner, J., Allen, D. & Butcher, G. 1996. Completion criteria for Alcoa of Australia Limited's bauxite mine rehabilitation. *Proc. 3rd International and the 21st Annual Minerals Council of Australia Environmental Workshop.* Newcastle, 14–18 October 1996.

Gardner, J.H. 2001. Rehabilitating mines to meet land use objectives: bauxite mining in the jarrah forest of Western Australia. *Unasylva* 207: 3–8.

Grant, C.D. & Loneragan, W.A. 1999. The effects of burning on the understorey composition of 11–13-year-old rehabilitated bauxite mines in Western Australia: vegetation characteristics. *Plant Ecology* 145: 291–305.

Koch, J.M. & Ward, S.C. 1994. Establishment of understorey vegetation for rehabilitation of bauxite-mined areas in the jarrah forest of Western Australia. *Journal of Environmental Management* 41: 1–15.

Koch, J.M., Ward, S.C., Grant, C.D. & Ainsworth, G.L. 1996. Effects of bauxite mine restoration operations on topsoil seed reserves in the jarrah forest of Western Australia. *Restoration Ecology* 4: 368–376.

Nichols, O.G. 1998. The development of a rehabilitation program designed to restore a jarrah forest ecosystem following bauxite mining in south-west Australia. *In* Fox, Moore & McIntosh, eds. *Land reclamation: achieving sustainable benefits,* pp.315–325. Rotterdam, Balkema.

Nichols, O.G. & Gardner, J.H. 1998. Long term monitoring of fauna in bauxite mined areas of the Darling Range. *Proc. Australian Centre for Minesite Rehabilitation Research Workshop on Fauna Habitat Reconstruction.* Adelaide, Australia, 10–11 October 1997.

Smith, M.A. 2001. *Vegetation response to fire as an indicator of restoration success after bauxite mining in the Jarrah Forest of Western Australia*. University of Western Australia. (Ph.D. thesis)

Ward, S.C. 2000. Soil development on rehabilitated bauxite mines in south-west Australia. *Australian Journal of Soil Research* 38: 453–464.

Ward, S.C. & Koch, J.M. 1995. Early growth of jarrah (*Eucalyptus marginata* Donn ex Smith) on rehabilitated bauxite minesites in south-west Australia. *Australian Forestry* 58: 65–71.

Ward, S.C., Koch, J.M. & Ainsworth, G.L. 1996. The effect of timing of rehabilitation procedures on the establishment of a jarrah forest after bauxite mining. *Restoration Ecology* 4: 19–24.

19 Economic value of skid-track rehabilitation: a case study in Sabah, Malaysia

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ABSTRACT

Often soil rehabilitation research ends without considering if the increased timber production motivates the investments needed, with the result that the research is not practically applied. Therefore, in the context of Sabah Forest Industries Sdn Bhd plantation programme, this paper estimated the net present value (NPV) from a skid-track rehabilitation case study. Eight different management alternatives were considered, consisting of all combinations of 1) tracks rehabilitated or not rehabilitated, 2) areas outside tracks fertilized or not fertilized, and 3) tracks covering 10 or 30%. At 30% track cover without track rehabilitation or fertilization, the NPV outside tracks was negative at all relevant interest rates. Rehabilitation of tracks alone made this unprofitable plantation profitable to an interest rate of about 3.7%. Fertilization of areas outside tracks made the plantation profitable up to an interest rate of 16%, while additional track rehabilitation further increased this reference interest rate to 19%. At 10% track cover the increased benefits from tracks rehabilitation barely compensated for the costs. Fertilization of areas outside tracks, however, was now profitable to 20% interest rate. Most of the SFI concession area is within the studied growth range. Therefore, management should look into the need for rehabilitation, since all wood used for pulp production is going to be harvested from the plantations. This evaluation simplified the issue about soil degradation. In reality the values of goods and services from a system will consist of more values, e.g. risk reduction, recreational and different ecosystem values such as watershed protection and soil quality. One of the future challenges of resource management will be to develop assessment methods that can be used by policy-makers to apply such multi-dimensional value system.

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INTRODUCTION

The uniformity of raw material, reliability of supply, competitive pricing and relative proximity to centres of industry are factors that will increasingly favour industrial forest plantations as natural tropical forest resources become depleted owing to slow or no regeneration (e.g. Sayer *et al*. 1997). In the FAO Forest Resources Assessment, areas in Asia reported by country experts as forest plantations increased exponentially from 11 million ha in 1980 to 115 million ha in 2000 and there is not yet any sign of weakening in the trend (FAO 2001). In contrast, the 'Pan-tropical survey of forest cover changes', which is an independent and less subjective inventory based on LANDSAT images, estimated the area of plantations to be only 23.2 million ha in the total tropics compared to 187 million ha as reported by country experts (FAO 2001). This discrepancy may be explained by one or more of the following: 1) difficulty to detect plantations on LANDSAT images, 2) differences between official statistics and actual planting, and 3) conversion of planted areas into other land classes (e.g. fragmented forest, shrubland, fallows or other land uses).

Because of such uncertainties, wood production from tropical forests rests on a comparatively shallow scientific base. Despite high productivity in some well-maintained, often fertilized experimental plots, the long-term nutritional sustainability of short-rotation plantations is under debate (e.g. Sanchez *et al.* 1985, Nambiar & Brown 1997). It is also well documented that poor adaptation of logging systems like timber extraction with heavy machinery on humid tropical soils causes long-term degradation of soil physical properties and is detrimental to plant growth (e.g. Nussbaum *et al*. 1995, Woodward 1996). With these systems, skid tracks commonly cover up to 40% of the operation area (42%, Fox 1969; 24%, Malmer & Grip 1990; 30%, Nussbaum *et al*. 1995; 17%, Pinard *et al*. 2000). Because of the extent of selectively logged forests and forest plantations, rehabilitation of skid tracks has been assigned top priority for development research (Whitmore 1996).

However, despite the importance and extent of tractor disturbance, there have been few reported attempts to accelerate rehabilitation in humid tropical climates. In Sabah, Malaysia, there was a study, by Nussbaum *et al.* (1995), which found fertilization to significantly improve tree performance on timber landing sites, in contrast to mulching and loosening of soil, which had no effect. Woodward (1996) noted that fertilization, but not topsoil addition, increased plant growth in Amazonian Ecuador. In contrast to tree growth and soil physical properties, the effect of skid-tracks on soil chemical and biological properties has received little attention. This is despite that these factors could be equally responsible for the slow plant growth as the soil physical properties. Therefore, in the context of Sabah Forest Industries Sdn Bhd (SFI) plantation programme, an experiment was initiated to test if biological, chemical and physical properties of the soil could be improved on skid-tracks with additions of different combinations of commercial NPK-fertilizer, ash, and organic material (Ilstedt 2002). The organic material used was extracted from growing vegetation on the sides of the tracks and the ash was available from the SFI pulp-mill where it has been deposited and considered as waste. The main tree-growth related results so far from this study (Ilstedt 2002) showed that the total basal area of *Acacia mangium* at 24 months after planting increased from 2 to 14 m^2 ha^{-1} if tracks were tilled and fertilized. However, no effect on plant growth was found when either organic material or ash was added. Basal area outside tracks was 62% higher compared to untreated tracks.

It might seem like such result could be adopted into practical management. However, a large problem with management research at SFI and elsewhere has been that even though the increase in timber production can be quite marked, research often ends without properly considering if the increase is enough to justify the investments needed. Indeed, economic evaluations of rehabilitation studies are difficult to find in the literature. In their absence, an unmotivated fear for early investments might be a large contributor to why rehabilitation research is so seldom put into operational management. Furthermore, where the value of a new method actually has been assessed it has often been done without considering the effect of interest rate. Because two management options can both be the ‘best’ option depending on the interest rate, a better approach is to calculate the net present value (NPV) at a range of relevant interest rates (Duerr 1993). The higher the interest rate, the lower is the investor (or society) value future benefits. Thus, in forestry, a high interest rate favours short rotation times and small early investments. An increased expectancy of interest rate might also render a management option that was profitable at lower interest rates to be unprofitable. Since the choice of interest rate might differ with time and application, a range from 1% to the interest rate just above where the NPVs for all studied options are negative can be used. The interest rate when NPV is zero is often referred to as the ‘internal rate of return’ (IRR) (e.g. Duerr 1993). IRR can be seen as the interest rate that would be needed for an alternative investment (e.g. bank interest rate) or management option to be an economically competitive alternative. IRR and NPV have different advantages and shortcomings, and can therefore be seen as complementary ways to rank management options. IRR has an intuitive appeal, but if the objective of management is not to maximize the return of investments, the ranking might by misleading in some situations. Recent accounts on environmental and forestry investment analysis include those of Pearce (1990), Duerr (1993) and Klemperer (1996).

It might be tempting to evaluate the value of skid track rehabilitation by only comparing treated and untreated tracks. However, economic analysis of skid track rehabilitation should not be done in isolation from the management on areas outside tracks. For example, if skid track rehabilitation is profitable at high track cover, it is unlikely to be equally so if skid track cover is low. The lowest relevant skid track cover was considered here to be 10%, while 30% was considered normal. Furthermore, on tracks, tilling and fertilization were needed to achieve good rehabilitation of plant growth (Ilstedt 2002). Especially at high interest rates it can be asked whether a more economic option is to manage for a higher production by fertilizing just areas outside tracks, since this can be done without the extra cost of tilling.

Therefore, the objective of this paper, taking the results of a skid track rehabilitation experiment (Ilstedt 2002), was to estimate the NPV at a range of interest rates and at all combinations of,

1) tracks being rehabilitated or not rehabilitated;
2) areas outside tracks being fertilized or not fertilized;
3) 10 or 30% track cover.

METHODS

Study area

The project described in this paper was carried out in the Sabah Forest Industries Sdn. Bhd. (SFI) plantation concession. The concession consists of 289 000 ha of forest, including 17 990 ha of protected water catchment (SFI 2002). The SFI currently operates a pulp and paper mill as well as an integrated timber complex including a plywood mill and sawmill. The main objectives of forest management here are to provide the SFI mills with 750 000 m^3 y^{-1} of pulpwood and 339 000 m^3 y^{-1} of commercial wood. Today, most extracted pulpwood comes from the natural forests, but in the future, the raw materials should come entirely from the SFI plantations. The company started planting in 1985 and the present plantation comprises about 37 000 ha (SFI 2002), dominated mainly by acacia (mostly *Acacia mangium*) and eucalypts (above 800 m.a.s.l). However, on deep fine textured soils in the lowland, *Gmelina arborea* is planted. In 1998, large parts of the plantations were burned, and since then intensive efforts have been made to replant the affected areas. In addition to wood from the concession, villagers close to the concession area have been encouraged to establish smallholder plantations through agroforestry projects (Nykvist 1993) in which an area of about 1 699 ha has been established (SFI 2002). These villagers have been selling the wood to SFI since 1992.

The Mendolong research area and laboratory are run under a joint programme between SFI and the Department of Forest Ecology at the Swedish University of Agriculture Sciences. The skid track study is situated close to the Mendolong research area at an altitude of 580–620 m at the foothills of Mt. Lumaku, 35 km southeast of the coastal town of Sipitang (115.5°E, 5.0°N), Sabah, Malaysia (northern Borneo). In young plantations the monthly minimum temperatures generally vary between 20 and 22°C and maximum temperatures between 27 and 31°C (Malmer 1993). During the time of this study the annual precipitations were 1 840 and 3 290 mm in 1997 and 1998 respectively. The end of 1997 and the beginning of 1998 were unusual in that there were prolonged dry periods of several months in connection with the strong ENSO-event (El-Niño Southern Oscillations) of 1997/98.

The vegetation at the study site was formerly hill dipterocarp forest (Whitmore 1984), which was logged in 1988 and planted with *Acacia mangium*. The plantation was logged and residues were burned before the second generation planting in early 1998 (Figure 1). For this study an area with Haplic Acrisols (FAO 1988) developed on sandstones and shales was chosen because this soil type dominates large parts of Southeast Asia. Topsoil (0–5 cm) textures in Acrisols of the research area ranged from sandy loam to clay loam. Porosity in nearby undisturbed forest soil was high, up to 60–70% (Malmer & Grip 1990), bulk density was 0.83 (standard deviation, SD, 0.09) g cm^{-3} in the uppermost 5 cm of the soil (Malmer & Grip 1990) and the loss on ignition (LOI, %w/w) was in the range 5 to 15% (Malmer *et al*. 1998). Below this topsoil a 5 to 20 cm deep A/E horizon is generally found with lower organic matter content and bulk densities between 1.0 and 1.2 g cm^{-3} (Ohta & Syarif 1996). Below the A/E horizon there is a massive argillic Bt horizon with its lower boundary on about 1 to 2 m depth. Bulk densities in the Bt horizon are in the range 1.2 to 1.5 g cm^{-3} (Ohta & Syarif 1996). This profile development with depth is accompanied with increased exchangeable aluminum, and decreased nitrogen and phosphorous availability (Ohta & Syarif 1996). Crawler tractors used for skidding in the experimental area expose this Bt-horizon by moving the A/E horizon and parts of the B horizon to the side of the tracks.

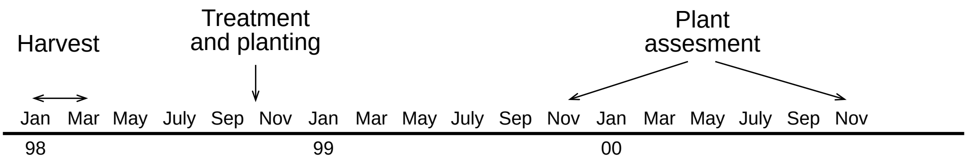

Figure 1. The timing for the treatments and assessments

Net present value analysis

The net present value (NPV) was calculated for an infinite number of rotations (1). The NPV in this case is often called 'land value', site value or 'soil value' and corresponds, in forest economics, to the well-known "Faustmann formula" (Faustmann 1995),

$$NPV = \sum_{t=1}^{n} [(B_t - C_t)\ (1+0.01*r)^{-t}] * (1+0.01*r)\ ((1+0.01*r) - 1)^{-1} \qquad (1)$$

B_t and C_t are the benefits and costs at t years respectively, and r the reference interest rate (%). The timing of benefits or costs even during one year can be important at high interest rates. To minimize this bias, all costs and benefits during one year were assigned to the middle of the year. Interest rates of 1, 3, 6, 9, 12, 15, 18, 21 and 24% rate were used to compare these alternatives and to estimate the internal rate of return (IRR; i.e. the interest rate when NPV is zero).

Management alternatives

Eight different management alternatives were studied (Table 1) consisting of all combinations of 1) tracks being rehabilitated (fertilized and tilled) or not rehabilitated, 2) areas outside tracks being fertilized or not fertilized, and 3) tracks covering 10 or 30%.

Table 1. The study alternatives and their mean annual volume increments

	Track cover (%)	**Tracks rehab.**	**Fertilized outside tracks**	**MAI ($m^3 ha^{-1} y^{-1}$)**
Rehab+fertil	30	yes	yes	23
Rehabilitated	30	yes	no	9
Fertilized	30	no	yes	18
Actual	30	no	no	4
Rehab+fertil	10	yes	yes	24
Rehabilitated	10	yes	no	6
Fertilized	10	no	yes	23
Actual	10	no	no	5

Table 2. The timing, costs and benefits used for the net present value calculations

Track cover	Management	Year	Cost / revenue (RM) [b]			
			Rehab+fertil	Rehabilitated	Fertilized	Actual
30%	Tilling	0.5	–173	–173	0	0
	Site preparation and planting	0.5	–1054	–1054	–1054	–1054
	Fertilization	0.5	–493	–148	–493	0
	Weeding and maintenance	0.5	–600	–600	–600	–600
	Weeding and maintenance	1.5	–340	–340	–340	–340
	Track maintenance	1.5	–50	–50	–50	–50
	Felling and extraction [a]	8	–7820	–3060	–6120	–1360
	Management overhead [c]	8	–300	–300	–300	–300
	Wood value (at mill gate)	8	17480	6840	13680	3040
10%	Tilling	0.5	–58	–58	0	0
	Site preparation and planting	0.5	–1054	–1054	–1054	–1054
	Fertilization	0.5	–493	–49	–493	0
	Weeding and maintenance	0.5	–600	–600	–600	–600
	Weeding and maintenance	1.5	–340	–340	–340	–340
	Track maintenance	1.5	–50	–50	–50	–50
	Felling and extraction [a]	8	–8160	–2040	–7820	–1700
	Management overhead [c]	8	–300	–300	–300	–300
	Wood value (at mill gate)	8	18240	4560	17480	3800

[a] Including transport within 50 km.

[b] US$1=RM3.80.

[c] Management overhead @ RM37.50 $ha^{-1}y^{-1}$ = RM300 ha^{-1} for 8 years.

In the NPV analysis the differences between the management alternatives were between the mean annual increment (MAI) and an additional cost for fertilization and tilling where applicable (Table 2). MAI (m^3 ha^{-1} y^{-1}) was calculated as BA*H *F, where BA was average yearly basal area increment, H was the average yearly height increment (Ilstedt 2002) and F a form factor of 0.4 (Nykvist *et al*. 1996).

Actual costs paid to contractors during all phases of plantation management (Table 2) were used. Work costs for plantation and maintenance were calculated assuming 1 111 trees ha^{-1}, which is the most common spacing at the SFI. The revenue of wood was calculated by multiplication of the MAI, the rotation age (8 years), and the market value of acacia wood at the mill gate (RM95 m^{-3}; US$1 = RM3.8). In the same way the SFI cost per hectare of harvesting and extraction was assumed at RM42.5 m^{-3} (within 50 km from the mill).

Rehabilitation treatments

The growth data for the study alternatives were taken from Ilstedt (2002). In October 1998 (Figure 1), the experimental plots (10 x 4 m) were laid out in the plantation on the tracks caused by skidding with crawler tractors (class D6). The amendments were additions (singly and in combination) of fertilizer, ash and green organic material (Table 3). There were 10 replicates of each combination resulting in 80 plots. The green organic material was extracted from slashed ground vegetation on the side of the plots. The added materials were mixed into the top 20-cm soil with a power tiller. The treatment combinations were randomly assigned to plots in order to test hypothesis about interaction effects of ash, fertilizer, and organic material. As an additional reference, 10 plots were put out at random positions outside the tracks.

Table 3. The amount of nutrients in the amendments

	C	N	P	K	Ca
			(kg ha^{-1})		
Fertilizer[a]	0.0	100	50	450	450
Ash[b]	n.d.	1	5	450	450
Organic[b]	940	26	1.0	24	4.0

[a] 0.4, 0.2, 1.8 and 1.8 kg per plot of urea, Christmas Island rock phosphate, K_2O and $CaCO_3$ respectively.

[b] 11 kg per plot.

[c] 25 kg fresh weght per plot.

Because only fertilization and tilling significantly affected growth on tracks, only untreated tracks, fertilized and tilled tracks (for the rehabilitated management option), as well as plots outside tracks were used for the net present value analysis in this paper. No data on growth outside tracks after fertilization were available for the study site. However, earlier experience from fertilization experiments in the SFI concession area (SFI 1991) suggests that for *A. mangium* a MAI of 25 m^3 $ha^{-1}y^{-1}$ can be expected on soil that is not disturbed by crawler tractors. Therefore this value was used to represent growth after fertilization outside tracks. This is also well within the range of 10–40 m^3 $ha^{-1}y^{-1}$ that is commonly reported for this species in the literature (e.g. Otsamo *et al*. 1995, Vichnevetskaia 1997, FAO 2001).

Assessment of plant growth

Plant growth was assessed by the average height and total basal area (at 1.3 m above the ground) per plot for five *A. mangium* seedlings, planted in October–November 1998. Height was measured 12 and 24 month after planting while basal area was measured at 24 month. According to routine nursery practices, seedlings were raised in seedling trays and were planted three months later (when 25–30 cm tall). In the nursery, 5 g Agroblen (NPK, 10:26:10) per seedling was mixed into the mineral soil used as potting medium. Agroblen is a fertilizer that is slowly released over about seven months. In the field, planting was carried out only during consecutive rainy days. On untilled tracks a spade was used to dig the planting holes (8 cm in diameter and 10 cm deep). Planted seedlings were inventoried two weeks after planting and dead seedlings were replaced. On each plot, five trees were planted with a spacing of 2 m. Plots were manually weeded using 'parangs' (machetes) at three-month intervals during the full study period. All plots were fenced to avoid human disturbance. Plots outside tracks were planted one month after the plots on the tracks.

RESULTS AND DISCUSSION

Profitability of the management alternatives

The 'actual' management resulted in negative NPV at all interest rates if track cover was assumed to be 30% (Figure 2). Since this is the management presently performed around the study site, the area should be regarded as economic impediment if it is not rehabilitated. However, not all areas in the concession perform as equally poorly as the 4 $m^3 ha^{-1}y^{-1}$ that was the average at the study site. During the first rotation in nearby experimental catchments, the MAI was 6.9 $m^3 ha^{-1}y^{-1}$ in tractor-logged and burned areas (Nykvist *et al.* 1996). As a comparison, in an unburned area that was logged without tractors, the MAI was 12.4 $m^3 ha^{-1}y^{-1}$ (Nykvist *et al.* 1996). If a MAI of 6.9 $m^3 ha^{-1}y^{-1}$ was used instead of 4 $m^3 ha^{-1}y^{-1}$ in the 'actual 30% track cover' alternative, the IRR increased from below zero to about 3.5%, and if the MAI was 12.4 $m^3 ha^{-1}y^{-1}$ the corresponding IRR was about 12% (data not shown). Small variations in track cover could make a substantial difference to the total MAI. However, it appears possible that the nutrient removal from harvest and burning, which were repeated for the second-generation plantation, has further depleted the already low nutrient capital, and therefore is responsible for at least a part of the lower growth at the study site. The area was also severely weed infested, which is a common phenomenon after shifting cultivation with repeated burnings at short intervals (Garrity *et al.* 1996, Goldammer 1997) as well as in plantations (Nykvist *et al.* 1996). Increased competition of weeds might therefore also be partly responsible for the lower growth.

Behind the collective term 'site preparation and planting', there are activities like track construction, culvert maintenance, burning, under-brushing, boundary maintenance, and planting. Therefore the cost of tilling and fertilization was only a small fraction of the total cost that is needed for site preparation, planting and maintenance (Table 2). This resulted in a small interaction between interest rate and management option (i.e. the differences in slope for the alternatives in Figures 1 and 2 were similar). Therefore the relative ranking of the options was the same at interest rates when the NPVs were positive, which means that the following discussion regarding the ranking of the

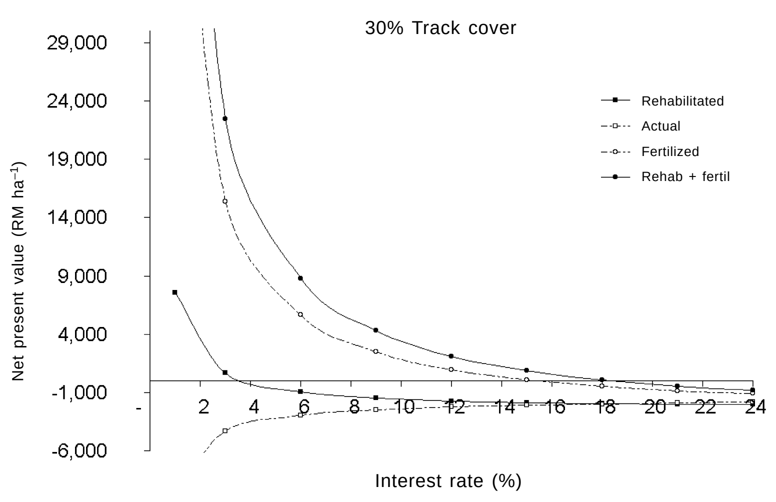

Figure 2. The net present value at 30% track cover as a function of interest rate (US$1 = RM3.8)

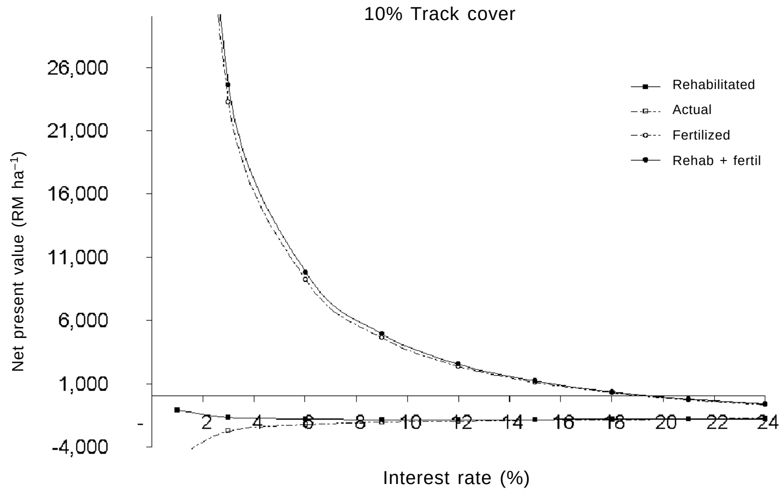

Figure 3. The net present value at 10% track cover as a function of interest rate (US$1 = RM3.8)

management options can be simplified to IRR. The IRR increased from below zero to about 18% in the best of the studied option, i.e. tilling of tracks and fertilization of the whole area (Figure 2). However, fertilization of just areas outside tracks increased the IRR to 16%, which might be a preferred alternative if there are constraints on workforce or cost. Given the sensitivity of the economic outcome to the MAI, more site-specific management should be considered. If there are constraints to costs or workforce, these might include avoiding low productivity sites. Otherwise improved stand and soil management should be the preferred options. This study showed that despite higher costs for fertilization and tilling of tracks, these were more than compensated for by increased benefits.

The cost for tilling was estimated during the end of establishment of the experiment when the workers were used to the machines and productivity had levelled to a constant length of tracks tilled per working day. However, other equipment and situations might result in higher or lower costs. It is therefore valuable to calculate the break-even cost for tilling. That is how much the cost of tilling could be for the alternatives with and without rehabilitation to have equal NPV. Assuming 30% track cover and areas outside tracks fertilized, the break-even was about RM690 ha^{-1} at 16% interest rate (i.e. IRR for fertilization only), RM2 500 ha^{-1} at 9% interest rate and about RM3 000 ha^{-1} at 6% interest rate. Therefore, since the cost for tilling was estimated to RM173 ha^{-1}, there seems to be a considerable marginal before track rehabilitation becomes unprofitable.

It appears that 10% track cover was very close to the limit for when rehabilitation no longer is worth the cost (Figure 3). However, 10% track cover is very low, and track cover lower than this might be associated with increased costs in equipment, planning, education and salaries, which have not been considered in this paper. For example, cable systems might reduce the need of track cover to about 10%. Since the NPVs for 10% track cover without tilling are very close to the NPVs with tilling at 30% track cover, the cost of, for example cable systems, could be compared to the break-even costs for tilling (see above). If the total cost for the cable system is lower than the break-even costs for tilling, the cable system should be preferred.

It should be recognized that the economic model is sensitive to changes in wood market value. If the wood price changes, the absolute NPV might change dramatically. However, the relative ranking between the alternatives should not change within reasonable market changes. The conclusions made about skid-track rehabilitation in this paper were based on results two years after treatment and planting. This represents ‘only’ 25% of a normal rotation. Therefore it can be asked whether the growth rates noted after fertilization in this study will be maintained during the rotation and if the growth on untreated tracks will be restored to the next generation. Furthermore, at present there are no published studies in the tropics following productivity from natural forest to second generation of plantation. Therefore extrapolations of economic costs and incomes in subsequent rotations as done here should be interpreted with care (cf. Sanchez *et al.* 1985, Nambiar & Brown 1997). However, the ranking of the management options does not change if one or several rotations are considered.

Research needs

The large variation of productivity in tropical plantations is coupled both to management and inherent soil fertility, but the knowledge of the interaction between site management and productivity is not very good for most tropical conditions (Binkley *et al*. 1997, Fölster & Khanna 1997). Obviously, the knowledge of the interaction between site management and economic profitability is then even less developed. This was exemplified in the present study, and if the study site of this thesis is representative of a larger area much work is presently done without sufficient economic return. Unbiased inventories of actual productivity at a larger scale would therefore be of high value. There is a need for accurate and easily used site-indices to predict wood production as well as responses of the soil to management. Examples of applications where good indicators could improve management are site selection, choice of soil preparation, fertilizer optimization and site–species matching. The perfect setting for such a study would be comprehensive factorial fertilizer trails stratified for important site factors (including site history such as type and degree of disturbance). However, in line with the above reasoning research proposals should already from the start include a component making economic evaluation of the results possible.

Application of the research to society

The discussion of degradation has evolved from economical production to also cover ecosystem structure (e.g. diversity) and ecosystem function (biomass and nutrients) (Bradshaw 1990, Lamb 1994b) as well as other social services and goods (Sayer *et al.* 1997). Degradation is usually defined as a reduction in some or all of these values permanently (Lovejoy 1985) or temporally (Bradshaw 1990, Lamb 1994a, FAO 2001). However, for a farmer with limited recourses, an increase in the amount of inputs in the form of time, work or money is just as severe as a reduction in crop productivity. A deficiency of most definitions of degradation is therefore the neglect to take into account the input of energy and resources needed to get access to the values and services of a system. The concept of net present value does this partly, since an increase in cost will decrease the net present value. However, if there are no constraints on the amount of costs for a given management alternative, the 'best' NPV might be the one that the land user can not afford. In a more general assessment of the effects of degradation and rehabilitation, we therefore suggest that the different social values (including net present value) as well as the costs are analysed as separate 'sub-variables' of the total degradation. For each sub-variable the socially relevant range is then determined, and optimization can be restricted to this range.

This paper only analysed one of the many aspects of soil degradation. In reality the values of goods and services from a (management) system will consist of even more values, for example, risk reduction, recreational values as well as different ecosystem values such as watershed protection and soil quality. Each of these groups can consist of several more or less useful indicator variables. However, it is likely that many of these values (or variables) are related and therefore can be reduced to fewer components by available multivariate statistical methods. One of the future challenges of soil science and forestry is in our opinion to develop such indicator variables that can be used by social scientists and policy-makers to apply a multi-dimensional value system on regions and countries. The only way to achieve this is by close interaction between different groups of scientists and the stakeholders to which the model is applied.

CONCLUSION

For a 30% track cover, tilling and fertilization of skid tracks made this unprofitable humid tropical plantation profitable to a reference interest rate of about 3.4%. Fertilization of areas outside tracks made the plantation profitable up to a reference interest rate of 16%, while additional tilling and fertilization of skid tracks further increased the expected rate of return to 19%.

The general implication of this study is that the break-even between uneconomical and economically competitive plantations is very dependent on soil management, as manifested in the resulting effect on stand growth. Therefore, even seemingly large costs might be motivated by increased growth rates. Much of the SFI concession as well as other humid tropical forest plantations might have growth rates close to what is economically viable. Therefore, sound inventories are needed and the rehabilitation of skid tracks should be incorporated into the management if, as is often stated, most of the wood used for pulp and paper production is going to be harvested from the plantations in the future.

REFERENCES

Binkley, D., O'Connell, A.M. & Sankaran, K.V. 1997. Stand development and productivity. *In* E.K.S. Nambiar & A.G. Brown, eds. *Management of soil, nutrients and water in tropical plantation dorests,* pp. 219–442. Canberra, ACIAR.

Bradshaw, A.D. 1990. The reclamation of derelict land and the ecology of ecosystems. *In* W.R. Jordan, E. Gilpin & J.D. Aber, eds. *Restoration ecology: a synthetic approach to ecological research*, pp. 53–74. Cambridge University Press.

Duerr, W.A. 1993. *Introduction to forest resource economics*. New York, McGraw-Hill. 485 pp.

FAO. 1988. *FAO–UNESCO soil map of the world. Revised legend*. Rome. 119 pp.

FAO. 2001. *Global forest resources assessment 2000—Main report*. Rome. 119 pp.

Faustmann, M. 1995. Calculation of the value which forest land and immature stands possess for forestry. Reprinted and translated from: Allgemeine Forst- und Jagd-Zeitung v. 15, 1849. *Journal of Forest Economics* 1: 7–44.

Fölster, H. & Khanna, P.K. 1997. Dynamics of nutrient supply in plantation soils. *In* E.K.S. Nambiar & A.G. Brown, eds. *Management of soil, nutrients and water in tropical plantation forests,* pp. 339–378. Canberra, ACIAR.

Fox, J. 1969. Soil damage factor in present day logging in Sabah. *Sabah Society Journal* 5**:** 43–52.

Garrity, D.P., Soekardi, M., Van Noordwijk, M., De La Cruz, R., Pathak, P.S., Gunasena, H.P.M., Van So, N., Huijun, G. & Majid, N.M. 1996. The *Imperata* grasslands of tropical Asia: area, distribution, and typology. *Agroforestry Systems* 36: 3–29.

Goldammer, J.G. 1997. Overview of fire and smoke management issues and options in tropical vegetation. *In* H.A. Hassan, D. Taha, M.P. Dahalan & A. Mahmud, eds. *Transboundary pollution and sustainability of tropical forests: towards wise forest fire management*, pp. 189–217. Kuala Lumpur, ASEAN Institute for Forest Management.

Ilstedt, U. 2002. *Soil degradation and rehabilitation in humid tropical forests (Sabah, Malaysia).* Department of Forest Ecology, Swedish University of Agricultural Sciences, Umeå. 38 pp. (Ph.D. thesis)

Klemperer, W.D. 1996. *Forest resource economics and finance*. New York-London, McGraw-Hill. 551 pp.

Lamb, D. 1994a. Forest rehabilitation in the Asia-Pacific region: past lessons and present uncertainties. *Journal of Tropical Forest Science* 7: 157–170.

Lamb, D. 1994b. Reforestation of degraded tropical forest lands in the Asia-Pacific region. *Journal of Tropical Forest Science* 7: 1–7.

Lovejoy, T.E. 1985. Rehabilitation of degraded tropical forest lands. *The Environmentalist* 5: 1–8.

Malmer, A. 1993. *Dynamics of hydrology and nutrient losses as response to establishment of forest plantation. A case study on tropical rainforest land in Sabah, Malaysia*. Department of Forest Ecology, Swedish University of Agricultural Sciences, Umeå. 54 pp. (Ph.D. thesis)

Malmer, A. & Grip, H. 1990. Soil disturbance and loss of infiltrability caused by mechanized and manual extraction of tropical rainforest in Sabah, Malaysia. *Forest Ecology and Management* 38: 1–12.

Malmer, A., Johansson, E. & Kluge, M. 1998. Natural rehabilitation of disturbed tropical rainforest soils in Sabah, Malaysia. *In* A. Schulte & D. Ruhiyat, eds. *Soils of tropical forest ecosystems: characteristics, ecology and management*, pp. 199–204. New York, Springer-Verlag.

Nambiar, E.K.S. & Brown, A.G. 1997. Towards sustained productivity of tropical plantations: science and practice. *In* E.K.S. Nambiar & A.G. Brown, eds. *Management of soil, nutrients and water in tropical plantation forests*, pp. 527–557. Canberra, ACIAR.

Nussbaum, R., Anderson, J. & Spencer, T. 1995. Factors limiting the growth of indigenous tree seedlings planted on degraded rain-forest soils in Sabah, Malaysia. *Forest Ecology and Management* 74**:** 149–159.

Nykvist, N. 1993. An even better compromise! An interesting agroforestry system used by Sabah Forest Industries in Malaysia. *Forest, trees and people*, p. 15.

Nykvist, N., Sim, B.L. & Malmer, A. 1996. Effects of tractor logging and burning on biomass production and nutrient accumulation in *Acacia mangium* plantations in Sabah, Malaysia. *Journal of Tropical Forest Science* 9: 161–183.

Ohta, S. & Syarif, E. 1996. Soils under dipterocarp forests—characteristics and classification. *In* A. Schulte & D. Schöne, eds. *Dipterocarp forest ecosystems: towards sustainable management*, pp. 29–51. Singapore, World Scientific Publishing.

Otsamo, A., Adjers, G., Hadi, T.S., Kuusipalo, J., Tuomela, K. & Vuokko, R. 1995. Effect of site preparation and initial fertilization on the establishment and growth of four plantation tree species used in reforestation of *Imperata cylindrica* (L) Beauv dominated grasslands. *Forest Ecology and Management* 73: 271–277.

Pearce, P.H. 1990. *Introduction to forestry economics*. Vancouver, University of British Columbia Press. 226 pp.

Pinard, M.A., Barker, M.G. & Tay, J. 2000. Soil disturbance and post-logging forest recovery on bulldozer paths in Sabah, Malaysia. *Forest Ecology and Management* 130: 213–225.

Sanchez, P.A., Palm, C.A., Davey, C.B., Szott, L.T. & Russell, C.E. 1985. Tree crops as soil improvers in the humid tropics? *In* M.G.R. Cannell & J.E. Jackson, eds. *Attributes of trees as crop plants*, pp. 327–358. Penicuik, UK, Institute of Terrestrial Ecology.

Sayer, J.A., Vanclay, J.K. & Byron, N. 1997. *Technologies for sustainable forest management: challenges for the 21st century*. CIFOR occasional paper. Bogor.

SFI. 1991. *Sabah Forest Industries Sdn. Bhd. biannual research report* (Soil & hydrology) 1990/91. Vol. 3/8.

SFI. 2002. *Forest management plan 2001–2010*. Sabah Forest Industries Sdn. Bhd.

Vichnevetskaia, K. 1997. *Global fibre supply study*. FAO, Rome.

Whitmore, T.C. 1984. *Tropical rainforests of the Far East*. Oxford, Clarendon. 352 pp.

Whitmore, T.C. 1996. *Swedish–Malaysian research cooperation on tropical rain forest management systems*. Stockholm, SIDA, Department for Research Cooperation, SAREC. 51 pp.

Woodward, C.L. 1996. Soil compaction and topsoil removal effects on soil properties and seedling growth in Amazonian Ecuador. *Forest Ecology and Management* 82: 197–209.

SESSION V

20 Institutional financing of forestry programmes including afforestation of wastelands in India: some issues and options

Kulbhushan Balooni* and Katar Singh**

ABSTRACT

India has vast tracts of wastelands, which have been lying barren for ages. Most of such lands are suitable for growing trees and thus could be put to socially productive uses. Growing trees, or afforestation of wastelands, is also economically viable but requires massive investment of funds, which is beyond the means of most of the land owners. The budgetary allocations of the government for afforestation are also inadequate. Institutional credit is therefore needed. In recognition of this need, the National Bank for Agriculture and Rural Development (NABARD) of India provides refinance facilities to individuals and organisations for forestry activities under a number of different schemes. Although the number of forestry schemes refinanced by the NABARD was high in the past, they currently constitute only about 1% of the total number of loans sanctioned and account for only about 2% of the cumulative loan disbursements made by the NABARD so far. In fact, since 1992, their share has declined. Major constraints on the pace of expansion of forestry programmes include non-availability of degraded land, technical information not available to potential tree growers, delays in sanctioning and disbursement of bank credit, low prices for tree products, and policies of the Indian state forest departments unfavourable to tree growers. Unless these constraints are overcome, the NABARD cannot effectively speed up the refinancing of developmental programmes in the forestry sector. The authors believe that most of the constraints on institutional credit for wasteland afforestation can be removed/relaxed.

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INTRODUCTION

India has vast tracts of wastelands extending over 100 million ha. Tree plantation is considered both a socially optimal and an ecologically sound use of such lands. However, restoration and afforestation require huge investment (Kapoor 1992, World Bank 1993), beyond the means of local landowners and the government forest sector. Therefore access to external funds, preferably from institutional sources, is a prerequisite for afforestation of wastelands in India. The National Bank for Agriculture and Rural Development (NABARD) of India could play an important role in providing credit for the wasteland afforestation schemes.

Rural credit

The NABARD has, since its inception in 1982, emphasized the need for increasing the productivity of the forest sector. Prior to the establishment of the NABARD, the policy, planning and operational aspects of rural credit came under the Agricultural Refinance and Development Corporation (ARDC) and the Rural Credit Planning Division of the Reserve Bank of India. In the late 1980s, from providing support to activities leading to commercial exploitation of forest resources the NABARD's lending priority in the forestry sector shifted to schemes of tree plantation on private and community lands. In fact, during its very first year (1982–83) of operation, the NABARD decided to consider refinancing farm forestry development schemes for private lands and the planting of trees on degraded lands belonging to the government and leased to farmers, either individually or in groups (NABARD 1983).

This article first examines the role played by the NABARD and other financial institutions under its aegis in financing forestry programmes, including wasteland afforestation in India. The article then identifies various constraints on wasteland afforestation through institutional financing and related issues involved. Options and alternatives to resolve these constraints are briefly outlined.

THE ROLE OF THE NABARD IN REFINANCING OF WASTELAND AFFORESTATION PROJECTS

The NABARD provides refinancing assistance to financial institutions like scheduled commercial banks, state cooperative banks, state land development banks and regional rural banks with respect to loans advanced by them to individuals and groups of individuals for undertaking afforestation of private wastelands. Projects for the development of wastelands can also be formulated by forest-based industries, corporations and non-governmental organisations (NGOs) engaged in the promotion of wasteland development. The NABARD also provides funds, on a selective basis, for capacity building of NGOs (NABARD 2000). In its first years of operation, the NABARD placed more emphasis on refinancing afforestation of private wastelands undertaken by individual landowners than on supporting corporations or other organisations. However, after the promulgation of the National Forest Policy of 1988, its priority focus has shifted to forest-based industries, corporations and organizations such as state forest development corporations and NGOs undertaking wasteland development at the grassroots level.

In order to boost the development of forestry and wasteland afforestation programmes in the country, the NABARD identified six activities as main thrust areas (Sharma 1993). Most of these activities were directed towards development of wastelands, both degraded forests and non-forested lands. Many innovative schemes were sanctioned by the NABARD for refinancing of plantation programmes. One of them is the Margin Money Assistance Scheme/Investment Promotion Scheme, sponsored by the Department of Land Resources of the Ministry of Rural Development and refinanced by the NABARD. The main objective of this scheme is to encourage the flow of low-cost institutional funds to socially beneficial afforestation and wasteland development projects in non-forest areas; the Ministry of Environment and Forests, Government of India, is responsible for the rehabilitation of degraded forests in India. This is sought to be achieved by extending the central assistance so that such schemes could meet the economic viability criteria of the NABARD. Under this scheme, the central promotional grant/subsidy to individuals/ groups is limited to Indian rupees (INR) 2.5 million or 25 percent of the project cost, whichever is less subject to the condition that the promoters' contribution in the project shall not be less than 25% of the project cost (Government of India 2002a). Similar schemes providing subsidy for the social forestry sector are also promoted in other countries. For example, in Colombia, the Government promotes reforestation through subsidies financed with loans from the Inter-American Development Bank (IDB), the German Reconstruction Credit Institution (KfW) and the World Bank (Gaviria 1997).

The NABARD is somewhat similar to BANRURAL (National Bank for Rural Credit), which is the largest agricultural bank in Mexico owned by the government, with an extensive presence in the country through its regional offices. In Mexico, the Bank of Mexico is the trustee for agricultural funds administered by the Trust Fund for Agriculture (FIRA). The other trust funds and banks engaged in financing the forestry sector are FICART (Trust Fund for Credit in Rainfed and Irrigated Area), FODEF (Trust Fund for Forestry Development) and BANRURAL. Even the disbursement of funds from the World Bank forestry development loans are routed through these trust funds and banks to private and commercial banks for on-lending to the ultimate beneficiaries (*ejidos* [public land], *comunidades* [communities]) and small producers (Weaver 1996). Of late, the NABARD has also been involved in implementing externally aided innovative projects with the objective of poverty alleviation through resource development and people's participation in management of common property resources (NABARD 1999). For example, a rubber development project assisted by the World Bank has been under implementation with assistance of SDR14.59 million. The money is routed through the Government of India and the NABARD and is used for providing loans to rubber growers to create on-farm and off-farm employment opportunities (NABARD 2000).

THE NABARD'S REFINANCING OF FORESTRY SCHEMES

During the period 1983/1984 to 1991/1992, the number of forestry schemes, including wasteland afforestation, refinanced by the NABARD grew at an annual compound rate of 21.66 percent (Table 1). This compares well with the overall average growth rate of 4.09 percent for all the categories of schemes refinanced by the NABARD over the same period of time. However, the average proportion of forestry sector schemes is only 0.61 percent of the total number of schemes sanctioned by the NABARD in the same time period; the highest yearly percentage being 1.22 percent in 1986–1987 (Figure 1). At the national level, theNABARD's cumulative disbursement of funds[1] under schematic lending[2] to the forestry sector at the end of March 1992 amounted to INR1 343.9 million, which is 0.82 percent of the total cumulative disbursement of INR163 640 million under all the categories of schemes. Though the annual compound growth rates of forestry schemes (21.66 percent) and of disbursement (21.95 percent) in various years have been higher as compared with those of all the schemes taken together, the share of forestry schemes in the total schemes refinanced by the NABARD is still less than 2 percent. In view of the fact that the entire amount of funds disbursed to the forestry sector does not go to afforestation of wastelands, the NABARD's contribution to this important activity in India has been paltry. This is also reflected by the fact that the Government of India's contribution to afforestation of wastelands in the Seventh Five-Year Plan, 1985–90, was INR24 266.3 million (Indian Council of Forestry Research and Education 2000). As against this, the disbursements by the NABARD to the forestry sector during the same period of time amounted to only INR661.3 million, which is only 2.73 percent of the former (Table 1).

Table 1. Forestry schemes refinanced by the NABARD from 1982–83 to 1992–93[a,b]

Year	Number of schemes		Disbursement (INR million)	
	Forestry	Total including forestry	Forestry	Total including forestry
1982–83[c]	5	24 410	98.8	34 921.2
1983–84	15	4 866	45.8	8 841.1
1984–85	22	5 446	23.5	10 512
1985–86	49	7 835	96.6	11 916.5
1986–87	123	10 068	91.8	13 342
1987–88	73	9 995	191.3	14 819.1
1988–89[d]	48	7 037	110.5	12 701.5
1989–90	64	9 211	171.1	17 021.3
1990–91	62	10 650	290.5	19 021.7
1991–92	72	6 706	224	20 543.6
Total	583	96 219	1 343.9	163 640
Annual compound growth rate (%) (1983–84 to 1991–92)	21.66	4.09	21.95	11.11

[a] Source: Annual Reports of the NABARD for the respective years.

[b] All the figures refer to the NABARD's schematic lending.

[c] Figures for 1982–83 are cumulative up to the year including ARDC sanctions.

[d] For the year 1988–89, the figures relate to 9 months period (July–March).

[1] This includes disbursement of funds by erstwhile Agricultural Refinance and Development Corporation.

[2] The NABARD has stipulated certain guidelines for preparing applications by banks for loans refinanced by them. The loan applications are verified by the NABARD officials for financial viability and other aspects. Such loans with project duration of more than three years refinanced by the NABARD come under the category of schematic lending. The appraisal of such projects is done by the NABARD according to pre-determined parameters.

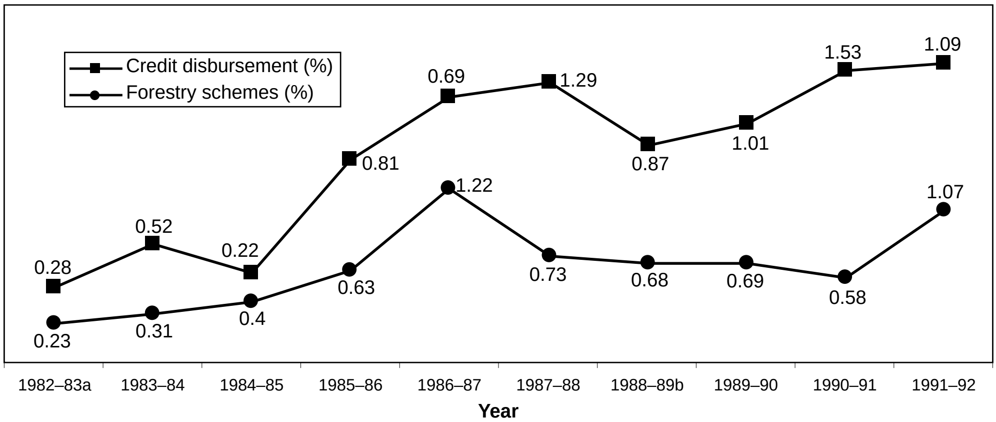

Figure 1. Proportions of schemes sanctioned and credit disbursed in the forestry sector under schematic lending to total schemes sanctioned and credit disbursed by the NABARD respectively from 1982–83 to 1991–92 (Based on Annual Reports of the NABARD)

[a] Figures for 1982–83 are cumulative up to the year including sanctions of erstwhile Agricultural Refinance and Development Corporation.

[b] For the year 1988–89, the figures relate to 9 months period (July–March).

Moreover, in recent years also, the amount refinanced by the NABARD to financial institutions and disbursed by financial institutions to wasteland schemes has declined considerably; it was INR290.5 million in 1990–91 (Table 1) as compared with INR90 million in 1998–99 (Table 2). The share of the forestry sector in the total disbursement by the NABARD was 1.53 percent in 1990–91 as compared with 0.2 percent in 1998–99. During 1992–96, under the *Investment Promotion Scheme* promoted by the Government of India and the NABARD, only four projects were sanctioned in the country. And during 1998–1999, three projects were sanctioned and an amount of only INR0.22 million was released as subsidy (Government of India 2002a). The main reason for the decline in the demand of credit and/or disbursement of credit by financial institutions for forestry schemes seems to be the dilution of focus of the government on farm forestry since 1991, as observed by the Planning Commission of India (Government of India 2002b). Besides, the macro-indicators also corroborate the decline in investments in the forestry sector. For example, in the Eighth Five-Year Plan, 1992–97, the proportion of forestry sector's outlay to total public sector outlay was 1.13percent, which has been reduced to 0.84 percent in the Ninth Five-Year Plan, 1997–2002.

Table 2. The NABARD's disbursement to forestry schemes during 1997–98 and 1998–99[a] (INR million)

	Forestry	Total including forestry	% of forestry to total
1997–98	110	39 220	0.30
1998–99	90	45 210	0.20

[a] Source: Annual Report of the NABARD for 1998–99.

THE NABARD'S REFINANCING OF FORESTRY SCHEMES BY AGENCY

Of all the financial institutions, which were provided refinance facility by the NABARD, the share of scheduled commercial banks in the total number of forestry schemes sanctioned (70.67%) and the total disbursement of funds (93.20%) until March 1992 (including the share of the ARDC) was highest (Table 3). The state land development banks together ranked second with their shares in the forestry schemes sanctioned and the total credit disbursed being 25.04% and 6.28% respectively. The state cooperative banks and the regional rural banks played a less significant role in the financing of forestry schemes. To involve them more effectively, a specific target amount for financing afforestation programmes should be assigned to each bank for each year. There are 32 232 rural and semi-urban branches of scheduled commercial banks and 196 regional rural banks with their 14 539 branches in India (NABARD 1993). Besides, there are 97 122 cooperative credit societies including state cooperative banks (Central Statistical Organisation 1998). With this kind of widespread network of bank branches and adoption of the *service area approach*, banks could and should play an important role in the development of forestry by financing afforestation programmes with funds provided by the NABARD. *Service area approach* is an effort towards decentralization of credit planning for the rural sector in India. Under this approach, the entire responsibility of assessing and meeting the credit needs of all the approximately 600 000 villages in India has been assigned to the branches of commercial banks and cooperative banks (a cluster of 15–20 villages served by one branch).

Table 3. Forestry schemes refinanced by the NABARD in India from 1982–83 to 1992–93 by agency[a,b]

Agency	Number of schemes		Disbursement (INR million)	
	Forestry	% of forestry to total	Forestry	% of forestry to total
State land development banks	146 (25.04)[c]	0.46	84.4 (6.28)	0.15
Scheduled commercial banks	412 (70.67)	0.73	1 252.5 (93.20)	1.58
State cooperative banks	6 (1.03)	0.21	28 (0.01)	0.04
Regional rural banks	19 (3.26)	0.40	42 (0.01)	0.02
Total	583	0.61	1 343.9	0.82

[a] Source: Annual Reports of the NABARD for the respective years.
[b] The figures are inclusive of the cumulative sanctions of ARDC till 1982 and refer to schematic lending.
[c] Figures in parentheses are the percentages of the respective column totals.

CREDIT DISBURSEMENTS BY THE NABARD FOR AFFORESTATION BY REGION

The NABARD has divided its area of operation into six regions (Table 4). Among all the regions, the share of the Central Region was highest in terms of both the number of forestry schemes sanctioned (35.42%) and the disbursement of funds (34.33%) under schematic lending (Table 4 and Figure 2). The Southern Region ranked second with its share in the number of schemes sanctioned being 34.17% and in the disbursement of funds being 23.36%. When we compare regionwise forestry schemes with regionwise total forest degraded land and non-forest degraded land (Figure 2), we find that, by and large, the NABARD's allocation of forestry schemes to different regions is positively correlated with the extent of total degraded lands available for afforestation in the regions. But when we compare the NABARD's regionwise disbursement of credit for forestry schemes with the regionwise availability of total forest degraded land and non-forest degraded land, we find that the former is not commensurate with the latter except for the Central Region, which has the highest disbursement of credit and the highest degraded land in the country. In all the regions, the number of schemes under forestry (accounting for 0.20 to 2.32%) and disbursement of credit for forestry schemes (accounting for 0.06 to 1.70%) are abysmally low as compared with the total number of schemes refinanced and total disbursements made by the NABARD during the period 1987–92.

Table 4. Extent of wastelands and the NABARD's refinancing of forestry schemes in India from 1987–88 to 1991–92 by region[a,b]

Region	Forest degraded land and non-forest degraded land[c] (Million hectares)	Number of schemes		Disbursement (INR million)	
		Forestry	% of forestry to total	Forestry	% of forestry to total
Northern	27.17	38	0.71	176.8	1.30
North-eastern	7.45	4	0.82	1.2	0.06
Eastern	14.66	26	1.04	11.3	0.11
Central	28.2	113	2.32	339	1.69
Western	22.24	29	0.20	228.4	1.70
Southern	26.26	109	0.69	230.7	0.92
Total	125.98[d]	319	0.73	987.4	1.17

[a] Source: Annual Reports of the NABARD for the respective years.
[b] All the figures refer to the NABARD's schematic lending.
[c] Source: Society for Promotion of Wasteland Development, New Delhi.
[d] The total figure for Column 2 excludes the degraded forest area and non-forest degraded area in the Union Territories.

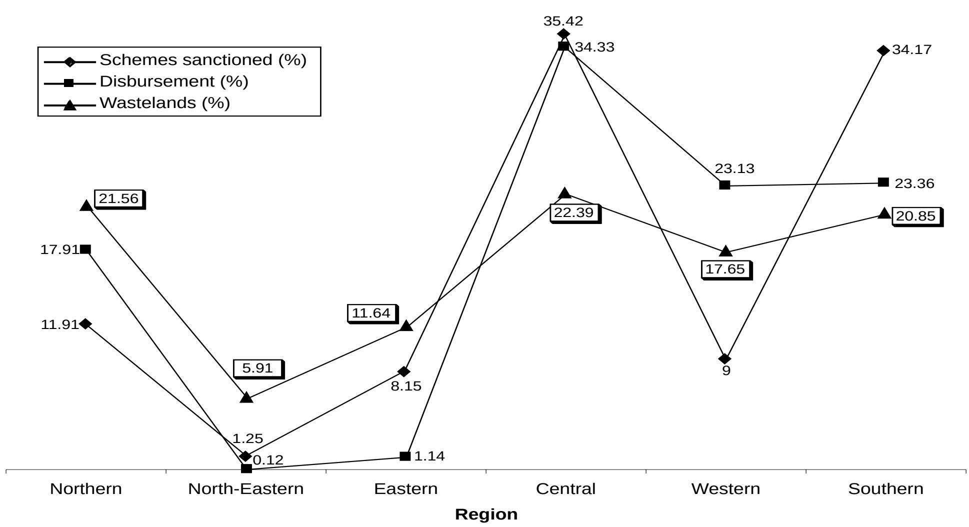

Figure 2. The NABARD's disbursement to forestry schemes in India from 1987–88 to 1991–92 *vis-à-vis* extent of wastelands in India[a]

[a] Source: Annual Reports of the NABARD for the respective years.

CONSTRAINTS ON INSTITUTIONAL FINANCING OF WASTELAND AFFORESTATION PROGRAMMES

There are quite a few physical, technical, financial, and institutional/organizational constraints on promoting wasteland afforestation in India. A brief description of each of them follows.

Problems in availability of degraded land for tree plantation

The information needed for assessing the potential of non-forest and cultivated lands, like ownership, extent and type of degradation, and present and future uses, has never been collected on a systematic basis for the entire country (Romm 1981a,b). This lack of ground-level data/information has dampened the progress of formulation and implementation of bankable plantation programmes. However, some initiatives have been taken to improve the availability of grassroots level data for this purpose. Now there are many NGOs and tree growers' cooperative societies involved in providing institutional finance for afforestation of wastelands in India. But most of them face the problem of non-availability of degraded forest lands for afforestation programmes due to a variety of procedural and legal complications. Such complications need to be removed.

The financial institutions also face difficulty in identification of compact blocks of wasteland for sanctioning the credit in the case of private landowners (Sreenivasan 1992). The scattered landholdings make the tasks of project formulation and close supervision by the field staff of financing institutions difficult. There is a need to consolidate the scattered landholdings in rural India. This can be done by implementing the already existing land reform laws to facilitate tree plantation with the help of institutional credit in the regions where there exists vast potential for tree cultivation.

Moreover, most of the revenue wastelands and degraded forests are in remote rural areas, far away from the area of the operation of rural branches of commercial banks and Regional Rural Banks. This makes it difficult for bank personnel to access the tree growers and the tree plantations.

Lack of information and technical support to tree growers

Most of the tree growers in India are poor, small-scale operators, unorganized and illiterate. They do not have access to the latest technical information about farm forestry nor can they afford fertilizers and pesticides. A large volume of information about the latest developments in technical aspects of growing trees is now available in India with various organizations. But the typical potential tree grower in India is still ignorant about fast-growing species and techniques of cultivating them. There is a need to make tree growers aware of those new species which are most likely to thrive in local conditions and generate higher profit than the existing crops. This information needs to be disseminated to potential tree growers using appropriate mass media tools and techniques. Provision of information will need to be supplemented by training tree growers in the latest techniques of tree plantation. Many institutions, both at the national and state levels, have been established within the last decade to overcome the technical constraints in tree growing and to disseminate the latest information to farmers under various social forestry programmes. These need to play a greater role in the future.

Unless the tree growers are aware of the various aspects of tree growing, the NABARD and the financial institutions refinanced by it cannot increase institutional financing for wasteland afforestation programmes.

Delays in sanctioning and disbursing credit and long gestation

The lack of adequate expertise in forestry and of infrastructure with financial institutions dissuades the banks from taking up afforestation projects. There is also a long time lag between the date of submission of application by the beneficiary and the final sanction of loan. This dampens the interest of potential beneficiaries (Pethiya 1993, Sharma 1993). The interest rates charged by the NABARD for various categories of tree growers and for various types of forestry projects are the same. There is a need for financing the forestry projects at differential rates of interest by the NABARD based on classification of farmers into small, medium and large farmers, and on the potential of their land (Kant & Saxena 1993, Pethiya 1993). Financial institutions should also work towards rationalizing credit delivery and recovery systems for afforestation of wastelands, particularly in view of the fact that trees mature slowly, and consequently investors have to wait for many years for the returns on their capital invested. Moreover, some institutional arrangements need to be made to provide adequate and assured income earning opportunities to tree growers during the long gestation period.

Institutional, organizational and legal constraints

The state governments in India need to take some concrete steps for the benefit of tree growers like modifying legal provisions so that tree growers can freely harvest trees grown on their own farms. In several states, provisions of the Forest Law discourage farm forestry by imposing restrictions on felling, and transportation and sale of timber standing on private lands. For example, in Gujarat, there are restrictions on felling of twenty-six tree species including teak (Professional Assistance for Development Action 1990). Further, the farmers have to seek permission for felling trees from the Revenue Department before harvesting trees on their private lands. It could take a year or two before the farmer gets the requisite permission (National Tree Growers' Co-operative Federation 1998). The Andhra Pradesh Forest Produce Transit Rules of 1970 regulate the transit of forest produce into or from or within any area in the State of Andhra Pradesh. According to Balaji (1997), "at policy level (in the State of Tamilnadu) the cultivation of trees is inhibited by a number of *archaic acts* and rules that restrict felling and transport of timber."These restrictions erode the value of produce for the farmers and dissuade them from taking up plantations. This ultimately dampens tree grower's interest in approaching commercial banks for credit.

According to Guha (1994), even the proposed new forest act, which is to be called the 'Conservation of Forests and Natural Ecosystems Act' and is to replace the Indian Forest Act of 1927, stipulates unnecessary and irksome interference by the state in the affairs of the tree growers. It claims that it will facilitate tree farming, but at the same time it places numerous hurdles in the path of farmers who might actually want to plant trees on their own lands. It also requires that every tree grower registers with the local state forest department, and informs it when trees planted and nurtured by him are to be felled or sold. This would be a great deterrent to farmers who might otherwise like to plant trees on their land. This draft act, which generated a lot of debate, is still to be presented in the Indian Parliament. In the mean while, the old Indian Forest Act of 1927 with subsequent amendments continues to be in operation (Kulkarni 2000).

To substantiate the above-mentioned facts, we reproduce a part of a recent notification by the Ministry of Environment and Forests (Government of India 2001): *"Trees: There shall be no felling of trees whether on Forest, Government, Revenue or* *private land within the Eco-Sensitive Zone, without the prior permission of the State Government in the case of forest land, and the respective District Collector in the case of Government, Revenue and private land, as per procedure which shall be prescribed by the State Government, provided that the District Collector shall not delegate this power to any subordinate officer below the rank of Sub-Divisional Officer".*

There are many other constraints, which impede the development of afforestation of wastelands, and which need to be resolved. For example, the present policy of the Government of India that forest lands should not be leased out to private entrepreneurs for raising plantations to meet their raw material needs is a big hurdle in attracting private investment in tree plantations. Also, the preference of some of the state governments for community forestry schemes over farm forestry schemes reduces the number of financially viable farm forestry schemes being referred to the NABARD.

Given the above-mentioned context, there is a need for the government and financial institutions to encourage NGOs and tree growers' cooperative societies through financial, technical, and legal support to take up afforestation activities.

Non-remunerative prices and lack of marketing facilities

Poor infrastructure and the lackadaisical approach to marketing of farm forestry products followed in the past have led to tree growers receiving unrewarding prices for their products. This has dampened the interest of present tree growers as well as potential tree growers in planting trees and approaching financial institutions for loans even when many schemes for tree plantation are available (Chambers *et al.* 1989, Saxena 1992, Singh 1993). This situation has been more or less the same for decades now. In many places where transport and communication facilities are lacking, middlemen and local entrepreneurs who come over to villages to procure trees and pay very low prices for them often cheat the tree growers. This can be attributed to the lack of knowledge on the part of tree growers regarding prevailing market prices and their inability to go to the distant markets. There is a need for the state governments' intervention to provide the requisite information about markets and prices and to purchase the harvested produce at a reasonable price, if necessary.

A CASE STUDY

To complement the discussion presented in the preceding sections, a case study was undertaken to find out the constraints in financing afforestation programmes by financial institutions at the grassroots level. The present case study evaluates the performance of some representative banks in Gujarat State, in financing afforestation of wastelands, namely the regional office of the NABARD in Ahmedabad, the zonal office of the State Bank of India (SBI) in Ahmedabad; and the Agricultural Banking Division of the Mehmedabad Branch of SBI. These financial institutions are mentioned in descending order in terms of quantum of refinanced credit sanctioned by the regional office of the NABARD to a financial institution disbursing credit to beneficiaries at the grassroots level.

It has been shown that financial institutions in India have disbursed a rather small quantum of credit for afforestation programmes. The case study on institutional financing revealed that the same scenario prevailed in the State of Gujarat, despite the fact that the state was a pioneer in India in implementing social forestry programme. The pattern of refinance allocation of forestry schemes by the regional office of the NABARD, Ahmedabad, to financial institutions in Gujarat, and disbursement of credit by these financial institutions for the years 1991–92 and 1992–93 is presented in Table 5. This table shows that among all the financial institutions, which were offered refinance by the NABARD, only a few scheduled commercial banks had disbursed credit for forestry schemes, amounting to only 1.67% of the total credit disbursed by them during 1991–93. Even after the sanction of credit by financial institutions for afforestation schemes in Gujarat, many of the schemes were abandoned. During 1989–92, six major wasteland development schemes were sanctioned by the NABARD for refinance in Gujarat, but by March 1992, loans had been disbursed to only three of them. These six schemes are profiled in Table 6. One of the reasons behind the failure of three plantation schemes to take off as revealed by the officials of the NABARD was the long gestation period.

Table 5. The NABARD's refinance allocation to forestry schemes and actual disbursement of credit in Gujarat State during 1991–92 and 1992–93[a] (INR million)

Financial institution		Refinance allocation by NABARD		Disbursement	
		Forestry	Total including forestry	Forestry	Total including forestry
Scheduled commercial banks[b]	1991–92	11.80	521.34	8.64	518.12
	1992–93	11.05	599.66	5.29	522.77
Regional rural banks[c]	1991–92		81.53		77.55
	1992–93		96.91		95.85
State land development bank[d]	1991–92	15	295		321.46
	1992–93	20	550		525.02
State cooperative bank[e]	1991–92		101.02		88.85
	1992–93		100		124.55

[a] Source: The NABARD, regional office, Ahmedabad.

[b] Includes nineteen scheduled commercial banks.

[c] Includes nine regional rural banks.

[d] Gujarat State Cooperative Agriculture and Rural Development Bank Ltd.

[e] Gujarat State Cooperative Bank.

Now, we shall discuss one such scheme, which could not take off. A major scheme for the cultivation of *Salvadora persica* on private marginal lands in 275 villages in the Bhal region of Gujarat, involving a refinance of INR46.27 million by the NABARD, was abandoned (Table 6). This scheme was sponsored by the Mumbai-based Lauric Oilseed Company, engaged in the extraction of lauric and myristic fatty acids from the seeds of *Salvadora* for industrial use. These fatty acids are used particularly in pharmaceutical and chemical industries. *Salvadora* is considered suitable for arid and semi-arid zones and is also drought resistant and salt tolerant. Farmers of the region were to raise these trees in collaboration with the industry. The scheme was to be financed by a consortium of nine scheduled commercial banks and was approved in 1991. However, the farmers did not show any interest in raising the *Salvadora* trees as they were also not convinced about the projected benefits from the plantation. The company tried in vain to motivate the farmers and promised to provide quality planting material. On the other hand, the bankers were also hesitant in providing loans to farmers, despite the NABARD's willingness to refinance such loans.

Table 6. Wasteland development schemes sanctioned and refinanced by the NABARD for Gujarat State from 1989–90 to 1991–92[a] (INR million)

Wasteland development scheme	Financing agency	Refinance sanctioned	Disbursement up till March 1992
Salvadora persica plantation in Ahmedabad district	Bank of Baroda[b]	1.1	0.006
Wasteland development through afforestation of 324 ha in Valsad and Bharuch districts	Gujarat State Cooperative Agricultural and Rural Development Bank Ltd. (GSCARDB)	3.14	0.18
Wasteland development through social forestry plantation on 80 ha in Dabhoi in Baroda district	State Bank of India[b]	0.66	
Schemes for plantation of fuel trees in Bhavnagar district	GSCARDB	0.51	
Scheme for cultivation of *Salvadora persica* in 275 villages in Bhal region comprising the districts of Ahmedabad, Surendranagar, Bhavnagar and Kheda.	Consortium of nine scheduled commercial banks	46.27	
Scheme for *Zizyphus* sp. cultivation on wastelands	Dena Bank[b]	0.39	0.31

[a] Source: The NABARD, Regional Office, Ahmedabad.

[b] Scheduled commercial bank.

Discussions with the officials of the Mehmedabad Branch of the Agricultural Banking Division, the State Bank of India, revealed that the lack of expertise of bank officials was one of the major constraints to the financing of forestry schemes. Such failures and constraints in delivering credit by financial institutions at the grassroots level are also reported in Latin American countries (Weaver 1996). Recently, the NABARD has tried to remove these constraints by commissioning selected NGOs to train its officials in forestry to process forestry loan applications. Uvin *et al*. (2000) reported that MYRADA, a reputed NGO from India, specializing in organizing self-help groups (SHGs) among small farmers to save money and help one another by advancing loans out of the savings credit, has trained hundreds of the NABARD officers in the use of their model.

A SYNTHESIS

The above discussion reveals that most of the constraints hampering the progress of disbursement of credit for wasteland development through afforestation can be traced to the state governments and their forest departments. The Government of India has stipulated an enhanced role for the NABARD in refinancing the wasteland development programmes. But it is quite evident from our study that its own rigid policies have thwarted such programmes and are likely to jeopardize various wasteland afforestation schemes unless some radical steps are taken by the government to simplify its own rules and regulations and make them tree-grower friendly. If the aforesaid constraints are not overcome, the NABARD would not be successful in achieving its mandated targets of disbursement of credit for wasteland development programmes.

On other hand, it has also been argued that subsidized credit is not a proper incentive mechanism as it leads to decapitalization of the financial institution advancing such loans. Moreover, directed credit is difficult to administer. Haltia and Keipi (1997) have analysed this situation with reference to Latin American countries. Besides, Weaver (1996) pointed out that in Mexico, the rural poor and Indian people could not make proper use of credit for productive purposes due to the lack of the requisite knowledge about banking and the banks were urban based and urban biased. A similar situation occurs in India wherein the NABARD is directing subsidized credit for forestry schemes through financial institutions to ultimate beneficiaries, a large majority of whom are illiterate and hence lack banking knowledge and aptitude. One solution for these two situations lies in the direct incentive administered by governments though co-financing of inputs such as seedlings and provision of extension services. The golden era of *Eucalyptus* plantations on private lands during the late 1970s and early 1980s under the auspices of social forestry programme in India was an outcome of this strategy. This strategy has also been successful in the ongoing joint forest management programmes to rehabilitate government-owned degraded forests (common lands) in India along with one more crucial input, the people's participation.

CONCLUSION

The restoration and afforestation of wastelands require huge investment, which is beyond the reach of owners of such lands and the budgetary resources of the government. Therefore, availability of external funds, preferably from institutional sources, is a pre-requisite for afforestation of wastelands in India. The NABARD can play an important role in refinancing the wasteland afforestation schemes. It has already accepted this role and provides refinance facility to state land development banks, scheduled commercial banks, state cooperative banks and regional rural banks for the purpose. Its contribution so far has, however, been meagre —less than 2 percent. There are many physical, technical, financial and institutional constraints on refinancing of wasteland afforestation schemes by the NABARD. But many of these constraints can be removed/relaxed and the NABARD could and should play a bigger role in future.

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REFERENCES

Balaji, S. 1997. Forestry extension in Tamil Nadu—approaches and challenges ahead. *Proc. 2nd IUFRO Forestry Extension Working Party S6.06-03 Symposium*. Nairobi, Kenya, 7–12 September. (Available at http://iufro.boku.ac.at/iufro/iufronet/d6/wu60603/proc1997/balaji.htm).

Central Statistical Organisation. 1998. *Statistical pocket book, India 1998.* New Delhi, India, Department of Statistics, Ministry of Planning and Programme Implementation.

Chambers, R., Saxena, N.C. & Shah, T. 1989. *To the hands of the poor.* New Delhi, India, Oxford & IBH Publishing.

Gaviria, D. 1997. Economic and financial instruments for sustainable forestry in Colombia. *Unasylva* 48: 32–35.

Government of India. 2001. *Mahableshwar Panchgani, notification, 17 January 2001 [No. J-20011/7/98/IA-III].* New Delhi, India, Ministry of Environment and Forests. (Available at http://164.100.10.135/divisions/iass/notif/mahap.htm).

Government of India. 2002a. *Investment promotional scheme.* New Delhi, India, Ministry of Rural Development. (Available at http://www.rural.nic.in).

Government of India. 2002b. *Approach paper to the Tenth Five-Year Plan (2002–2007).* New Delhi, India, Planning Commission. (Available at http://planningcommission.nic.in/leasef1.htm).

Guha, R. 1994. Forestry debate and draft forest act: who wins, who loses? *Economic and Political Weekly* 29: 2192–2196.

Haltia, O. & Keipi, K. 1997. *Financing forest investments in Latin America: the issue of incentives.* 12/97, ENV-113. Washington, DC, The Inter-American Development Bank.

Indian Council of Forestry Research and Education. 2000. *Forestry statistics.* Dehradun, India.

Kant, S. & Saxena, R. 1993. An overview. *In* S. Kant & R. Saxena, eds. *Proc. National Seminar on Tree Growers' Cooperatives.* New Delhi, India, ISO/Swedforest.

Kapoor, R.P. 1992. Investments in afforestation: trends and prospects. *In* A. Agarwal, ed. *The price of forests.* New Delhi, India, Centre for Science and Environment.

Kulkarni, S. 2000. The flight of the tribal. *Seminar* (Protecting Nature, a symposium on some legal issues concerning the environment) August, 492. (Available at http://www.india-seminar.com/semframe.htm).

NABARD. 1983. *Annual report 1982–83.* Mumbai, India, National Bank for Agriculture and Rural Development.

NABARD. 1993. *Annual report 1992–93.* Mumbai, India, National Bank for Agriculture and Rural Development.

NABARD. 1999. *Annual report 1998–99.* Mumbai, India, National Bank for Agriculture and Rural Development.

NABARD. 2000. *Annual report 1999–2000.* Mumbai, India, National Bank for Agriculture and Rural Development.

National Tree Growers' Co-operative Federation. 1998. *Annual report 1997–98.* Anand, India.

Pethiya, B.P. 1993. Financial issues in farm forestry. *In* S. Kant & R. Saxena, eds. *Proc. National Seminar on Tree Growers' Cooperatives.* New Delhi, India, ISO/Swedforest.

Professional Assistance for Development Action. 1990. *Access to government wastelands for afforestation: legal provisions in Andhra Pradesh, Bihar, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Orissa, Rajastham, Tamil Nadu and Uttar Pradesh.* New Delhi, India.

Romm, J. 1981a. The uncultivated half of India (Part-I). *Indian Forester* 107: 1–23.

Romm, J. 1981b. The uncultivated half of India (Part-II). *Indian Forester* 107: 69–85.

Saxena, N.C. 1992. Farm forestry and land use in India: some policy issues. *Ambio* 21: 420–425.

Sharma, M.R. 1993. Role of National Bank in forestry and wastelands development. *In* T.H. Babu, ed. *Proc. National Workshop on Farm Forestry Management.* Bhopal, India, Indian Institute of Forest Management.

Singh, S. 1993. Policy of NWDB regarding tree growers' cooperatives. *In* S. Kant & R. Saxena, eds. *Proc. National Seminar on Tree Growers' Cooperatives.* New Delhi, India, ISO/Swedforest.

Sreenivasan, P.B. 1992. Credit and institutional finance for afforestation. *In* A. Agarwal, ed. *The price of forests.* New Delhi, India, Centre for Science and Environment.

Uvin, P., Jain, P.S. & Brown, L.D. 2000. Think large and act small: toward a new paradigm for NGO scaling up. *World Development* 28: 1409–1419.

Weaver, T. 1996. Mapping the policy terrain: political economy, policy environment, policy, environment, and forestry production in Northern Mexico. *Journal of Political Ecology* 3: 37–68.

World Bank. 1993. World Bank strategy for development of the forest sector in Asia. *Wastelands News.* 8: 6–16.

21 Forest rehabilitation and forest genetic diversity—management implications and research needs

Jarkko Koskela*, Percy Sajise* and L.T. Hong*

ABSTRACT

There is increasing scientific evidence that forest rehabilitation and restoration are technically feasible through silvicultural interventions in degraded tropical forests and lands. In tropical Asia and the Pacific alone, there are several million hectares of degraded forests and land areas that can be restored for biodiversity conservation or rehabilitated for tree-based production systems, such as agroforestry or tree plantations. Traditionally, reforestation efforts have attempted to re-establish tree cover with any suitable species regardless of the original tree species composition at a given site. The term 'forest rehabilitation' is commonly used for reforestation and other related techniques like assisted natural regeneration when the goal is to re-establish the original forest cover with native tree species. After forest rehabilitation, the aim is often to manage and utilize the rehabilitated forests to fulfil various human needs. 'Forest restoration', on the other hand, attempts to re-establish the original forest ecosystems with complex interaction and it often emphasizes habitat and wildlife conservation instead of human utilization as a management target. While evaluating whether reforestation, rehabilitation and restoration efforts have been successful or not, the output is commonly measured in terms of hectares or number of reintroduced species while less attention is paid for analysing the long-term sustainability of these efforts. In this regard, forest genetic diversity has an important role to play in maintaining the rehabilitated forests under changing climate and against the potential risks this role will bring along. Already under the present environmental conditions, narrow genetic diversity makes the rehabilitated forests vulnerable to pest and disease outbreaks, for example. Very little information is available on the level of genetic variation in rehabilitated forests, i.e. how well various rehabilitation efforts have been able to restore forest genetic diversity. This information is not only relevant for sustainable forest management but also for future conservation efforts as natural

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production forests can significantly contribute to conservation of forest genetic resources if managed properly. In this paper, we provide an overview to the various forest rehabilitation efforts in the Asia Pacific region and discuss their sustainability from the forest genetic diversity point of view. Based on this and the likely effects of relevant genetic processes, we also highlight some management implications for future rehabilitation efforts and identify research needs.

INTRODUCTION

In the tropical Asia Pacific region alone, there are millions of hectares of degraded forests and unproductive land areas that could be rehabilitated or developed to tree-based production systems, such as agroforests, intensively managed natural forests or tree plantations. Similarly, large parts of these areas could also be turned back into original forest ecosystems through restoration efforts. Several scientific studies have indicated that forest rehabilitation and restoration are technically feasible through silvicultural interventions in degraded tropical forests and lands (e.g. Kuusipalo *et al*. 1995, Ashton *et al*. 1997, Oberhauser 1997, Chapman & Chapman 1999, R. Otsamo 2000a, Yirdaw 2001, Bebber *et al*. 2002). These efforts, if implemented together with revised policies on natural resources management, could significantly improve the livelihood of rural people and enhance conservation of biological diversity.

Biological diversity consists of variation in all species of plants and animals, their genetic material and the habitats in which they occur. Subsequently, diversity occurs at genetic level (variation in genes and genotypes), species level (species richness) and ecosystem level (communities of species) (e.g. Ramanatha Rao & Hodgkin 2002). Biological diversity and its sustainable use provide numerous benefits for human well-being and therefore the importance of conserving this diversity is well recognized. A lot of efforts have been put to conserve genetic diversity of domesticated crop species in particular whereas less attention is given to conserving forest genetic diversity. Unlike crop genetic resources, long-term conservation of tropical forest genetic resources in seed banks is problematic in many forest species as they have recalcitrant seed behaviour and therefore their long-term conservation is mostly dependent on conserving forest ecosystems.

Degraded forests and land areas are often results of human interventions. Mining activities often leave behind totally barren soils. Areas cleared for agriculture are commonly abandoned when they become unproductive and these may develop into grasslands or forest fallows. Selective logging leaves behind secondary forests, which still have adequate canopy cover (more than 10%) to be classified as forests but their biodiversity is often deteriorated considerably. In general, three broad approaches are used for overcoming forest and land degradation (Lamb 1994). Traditionally, reforestation efforts have attempted to re-establish forest cover with exotic tree species with no attempt to bring back the original, native tree species composition at a given site (*reclamation*). In *rehabilitation*, native tree species are used for reforesting a site with or without exotic species but the management goal is not to recreate the original and often complex forest ecosystem. After forest rehabilitation, the aim is to manage and utilize the rehabilitated forests to fulfil various human needs. The most ambitious approach is *restoration*, attempting to recreate the original ecosystem with complex interaction of plants and animals that once occupied the site. Thus the management objective in restoration emphasizes habitat and wildlife conservation prior to utilization for human needs.

The reclamation–rehabilitation–restoration sequence is a continuum of different approaches and techniques, ranging from simple to complex, from less expensive to more expensive and from necessity to 'luxury' (Lamb 1994). Social and economic conditions influence the selection of the management goal and the subsequent decision as to which part of this continuum is applied to a certain situation. Several countries in the Asia Pacific region have both practical experience and scientific knowledge on different parts of the continuum. However, many countries have chosen to emphasize the first step of the continuum, i.e. reclamation, which can rapidly provide social and economic return even if the available resources would be limited. On the other hand, the pressure of human populations does not often allow establishment and occupation of large areas solely for wood production purposes without the option to produce food and income-generating cash crops. It should be kept in mind that the reclamation–rehabilitation–restoration continuum is also a reflection of another continuum ranging from sole utilization of forest genetic resources to conservation of overall biological diversity in forest ecosystems.

In this paper, we provide a short overview of various forest rehabilitation efforts in selected countries in the Asia Pacific region and discuss their sustainability from the forest genetic diversity point of view. We also discuss how reforestation and rehabilitation efforts could increase the use of forest genetic diversity and the role of these efforts in conserving forest genetic resources. Based on this and the likely effects of relevant genetic processes, we also highlight some management implications for future rehabilitation efforts and identify research needs.

REHABILITATING AND RESTORING TROPICAL FORESTS IN THE ASIA PACIFIC REGION

Forest rehabilitation and restoration include a wide range of different conceptual frameworks and techniques, which aim at regenerating logged-over and secondary forests or establishing tree cover in degraded lands using native or exotic species. This range starts at planting with native or exotic species using high human input, and ends at 'pure', assisted natural regeneration without tree planting using low human input. The term 'assisted natural regeneration' often refers only to rehabilitation or restoration efforts on secondary forests or degraded lands with some trees, apart from various well-established silvicultural systems that aim to ensure forest regeneration immediately after logging in tropical forests.

The ratio of natural regeneration to tree planting varies from zero (intensive tree planting) to one (assisted natural regeneration) within the above-mentioned range of methods available (Hardwick *et al*. 2000). Between these two methods, there are several others that apply a mixture of enrichment planting and natural regeneration. Basically all conceptual frameworks and methods rely on assisting or manipulating the natural process of ecological succession. In the following chapters we shall shortly highlight some experiences and results from different methods in selected Southeast Asian countries before discussing the genetic implications of these methods in forest rehabilitation.

Malaysia

On average, some 235 000 and 175 000 ha of natural forests are harvested annually in Peninsular Malaysia and Sabah respectively, and about one-third of the area harvested is likely to become degraded (see Nik Mohd. & Mohd. Zaki 1995). In addition to this, there are large areas of ex-tin mining areas (tin tailings), about 205 000 ha in Peninsular Malaysia (Ang 1987, cited by Awang & Venkateswarlu 1992) and 250 000 ha in Sabah (Lim *et al*. 1981, cited by Nik Mohd. & Mohd. Zaki 1995). Rehabilitation efforts in Malaysia have focused mainly on planting indigenous tree species in logged-over or secondary forests (Tang & Chew 1980, Ang *et al*. 1992, Maswar *et al*. 2001, Mohamad Azani *et al*. 2001) and multipurpose exotic tree species in old tin mining areas (Awang & Venkateswarlu 1992). Planting of native species has also been tested under fast-growing exotic tree plantations (Ueda *et al*. 1995).

Rehabilitation in logged-over tropical rain forests has emphasized enrichment planting with commercially important indigenous tree species, mainly dipterocarps. The potential of several native species for tree plantations is also well known but these species have never been planted on a large scale. The major problem has been species selection for given site conditions as seedlings of most dipterocarp species are very specific to light conditions. In various planting experiments, dipterocarps have shown a wide rage of survival rates and generally seedlings planted under partial shade survive better than those planted in open areas (Abdul Rahman *et al*. 1992, Ang *et al*. 1992, Nik Mohd. & Mohd. Zaki 1995, Mohamad Azani *et al*. 2001). Both line planting and gap planting are suitable methods but it has been suggested that line planting provide less favourable light conditions for seedling growth as compared to gap planting (Bebber *et al*. 2002). Gap planting has also been found more efficient and effective than line planting in terms of costs and keeping the undergrowth suppressed (Maswari *et al*. 2001).

In the case of tin tailing areas, multipurpose tree species, such as *Acacia* and *Leucaena* spp., have been used for rehabilitation to improve site conditions and provide multiple products (Awang & Venkateswarlu 1992). The results of these efforts are very promising and have a potential to pave the way for developing more diverse production systems or accelerating recovery of native forest species. At a later phase, narrow strips or small gaps could be opened within the exotic plantations to promote further rehabilitation and even restoration through planting of carefully selected dipterocarp species (cf. Ueda *et al*. 1995).

Indonesia

Similarly to Malaysia, increasing efforts to rehabilitate logged-over rain forests have taken place in Indonesia (e.g. Mori 2001). The present logging practices have considerably reduced dipterocarp seed production and regeneration in and altered the responsiveness of these forests to the El-Niño Southern Oscillations (ENSO) by disrupting edaphic conditions or causing extended drought stress (Curran *et al*. 1999). Logged-over forests are expected to develop into the original primary forests through natural succession and post-logging silvicultural operations are often conducted to speed up this process. However, these techniques may not guarantee that this objective is achieved. For example, Kuusipalo *et al*. (1996) reported that liberation cutting of pioneer or secondary forest tree species to favour dipterocarp species did not enhance the succession in logged-over areas after a short (2 years) or long (12 years) period of time. Instead of large-scale liberation cuttings, Tuomela *et al*. (1996) reported that the fastest early growth of dipterocarps is achieved by opening up artificial gaps less than 500 m^2 in size in logged-over forests. The results can be further enhanced by opening the gaps in places where an abundant ephemeral seedling stock of dipterocarps is present (Tuomela *et al*. 1996).

In addition to logged-over rain forests, there are considerably large areas of degraded land in Indonesia. Degraded, low-volume (≤30 m^3 ha^{-1}) humid lowland rain forests covered about 16 million hectares in the country at the end of the 1980s (ITTO 1990) and presumably the figure is much higher today as deforestation has been continuing despite the increasing efforts to promote sustainable forest management (cf. FAO 2001). Mega-level *Imperata* grasslands cover 8.5 million hectares, equalling 4% of the total land area of Indonesia, and this figure does not include smaller grasslands (Garrity *et al*. 1997). Fast-growing tree plantations of *Acacia crassicarpa*, *A. mangium*, *Gmelina arborea* and *Paraserianthes falcataria*, for example, have been successfully used to shade out the *Imperata* grass while transferring the unproductive grasslands into industrial wood production (e.g. A. Otsamo *et al*. 1995, 1997). These plantations also enhance natural regeneration of native forest tree species in their understorey (Kuusipalo *et al*. 1995, R. Otsamo 2000a). As an additional management objective, tree plantations can be diversified with silvicultural interventions such as gap opening to facilitate rehabilitation or even restoration process (R. Otsamo 1998, 2000b).

Thailand

Thailand, like several other Southeast Asian countries, has struggled with large-scale deforestation during the past decades. Presently, the total forest area is about 14.7 million hectares, covering 28.9% of the total land area (FAO 2001). Traditionally, reforestation efforts have promoted establishment of tree plantations mainly with exotic tree species. As a result of these efforts, there are some 4.9 million hectares of tree plantations in Thailand (FAO 2001) but the establishment of tree plantations has not been able to stop deforestation or deterioration of biodiversity in the remaining natural forests. Simultaneously with reforestation efforts increasing research efforts have been carried out to gain better understanding on the natural forests and their regeneration processes, especially in seasonally dry northern Thailand (e.g. Elliott *et al*. 1989, Koskela *et al*. 1995, Maxwell *et al*. 1995, Hardwick *et al*. 1997, Oberhauser 1997).

The drawbacks and limitations of traditional reforestation methods have initiated the development of alternative methods in Thailand. Some tree plantations, like the ones established using native *Pinus kesiya*, have shown great potential to facilitate forest restoration. Oberhauser (1997) reported that native vegetation was regenerating better beneath the pine plantations than abandoned agricultural fields in northern Thailand. Although some plant species are able to regenerate in open clearings, in many cases seed dispersal and germination face serious obstacles even in relative small clearings (<1 ha) in the seasonally dry tropical forests of northern Thailand (Hardwick *et al*. 1997).

To increase ecological restoration, the framework species method, originally developed for restoring humid tropical rain forests in Queensland, Australia, was introduced to Thailand and experiments are underway to test its applicability in restoring seasonally dry tropical forests (e.g. Elliott *et al*. 2000). The concept involves planting of fast-growing, native tree species with a dense canopy so that these can shade out weeds and attract seed-dispersing wildlife to promote further regeneration of native species. Nearly 400 native tree species have been screened for their potential usefulness in forest restoration (Blakesley *et al*. 2000) and a total of 45 species have been recommended for forest restoration in northern Thailand (FORRU 2000). Seed germination and dormancy studies have also been conducted in 36 potential framework species (Blakesley *et al*. 2002). The preliminary results from field experiments indicate that selected framework species such as *Erythrina subumbrans*, *Melia toosendan* and *Prunus ceradoides*, for example, perform well in terms of early survival and growth (Elliott *et al.* 2000). Thus, the framework species method seem to have potential even for large-scale forest rehabilitation and restoration efforts, provided that some problems in seed and seedling supply can be solved.

Philippines

The conceptual framework of assisted natural regeneration (ANR) was specifically developed to restore vast areas of *Imperata* grasslands in the Philippines and it has also been successfully applied elsewhere. Basically ANR is based on the ecological principles of community succession (e.g. Sajise *et al*. 1976) and is most applicable if there are patches of natural forests or trees mixed within the grasslands. ANR relies on natural regeneration, either from natural seedlings or planted wildings, and prevention of fire in the grasslands. ANR can also include enrichment planting of tree species that match a given site. The subsequent successional development increases shading, which suppresses *Imperata* grass and facilitates invasion of other native tree and plant species into the rehabilitated areas.

Since ANR does not necessarily require nurseries, it is a cost-efficient way to carry out forest restoration. It also has a number of other advantages, such as maintaining the original vegetation and corresponding ecosystem function, promoting biodiversity conservation and the use of indigenous knowledge, and providing employment for local people (Sajise 1989). On the other hand, labour intensity can also become a constraint for ANR and similarly inadequate extension, insecure land and tree tenure, and poverty may prevent a proper use of ANR (Friday *et al*. 1999). ANR, like any other forest restoration frameworks, has technological, biophysical and socio-cultural dimensions, which need to be included in a complementary manner to ensure the successful outputs (Sajise 2002).

FOREST GENETIC DIVERSITY IN REHABILITATION PROCESS

Genetic diversity in degraded forests

Logging in tropical forests tends to reduce biodiversity in all its different levels and only very low-intensity timber harvesting has the potential to maintain biodiversity (see Putz *et al*. 2001). Logging not only reduces population size but also causes structural alterations that are likely to change the complex ecological interactions between trees and various animals necessary for maintaining the genetic processes (Bawa & Seidler 1998, Wickneswari & Boyle 2000). The way in which logging is implemented has major impact on regeneration potential of the remaining stand, i.e. how much physical damage is caused to remaining trees and seedlings. Similarly to timber harvesting, collection of non-timber forest products may also reduce species diversity and especially genetic diversity if the harvesting is focused on reproductive parts, e.g. flowers or fruits (Wickneswari & Boyle 2000).

Lee *et al*. (2002) studied the effect of selective logging on the genetic diversity of *Scaphium macropodum* in Peninsular Malaysia. They found no negative immediate reduction in genetic diversity when logging reduced the density of the species from 10 to of 8 trees ha^{-1} (>20 cm in diameter). Similarly, Wickneswari and Boyle (2000) observed that a single low-intensity logging event did not cause adverse reduction in genetic diversity of *Parkia speciosa*, *Shorea leprosula*, *Garcinia malaccensis*, *Daemonorops verticillaris* and *Labisia pumila*. However, Lee *et al*. (2002) also reported that, as a result of logging in low-abundant *S. macropodum* stands (about 2 trees ha^{-1}), a significant loss in genetic diversity still prevailed 40–50 years after logging. Thus the effects of logging on forest genetic diversity depend not only on harvesting intensity but also on the density of harvested tree species and more importantly, the number of reproducing individuals in a stand.

Logging not only reduces the overall number of trees but it may also cause spatial isolation of the remaining tree populations and thus fragmentation. However, after logging activities have opened access to a given forest area, the subsequent development often leads to the conversion of the forest to other land uses such as agriculture or pasture and this is likely to cause more fragmentation than logging as such. As fragmentation proceeds, its genetic effects also become more obvious, including loss of genetic diversity, change in interpopulation structure and increased inbreeding (Young & Boyle 2000). In India, for example, genetic diversity of *Santalum album* (sandal) decreased in terms of heterozygosity along an extraction pressure gradient from the core zone of a protected area to buffer and periphery zones (see Nageswara Rao *et al*. 2001). Fragmentation also tends to reduce the activity of animal vectors contributing to gene flow among and between populations in tropical tree species, which are predominantly outcrossing. However, despite fragmentation, some fragments may still be linked by gene flow in case the distances between the fragments are short or if there are individual trees between facilitating the movement of pollinators (see Young & Boyle 2000).

Intensive selective logging, however, is not likely to maintain links in the form of individual trees between forest fragments. Condit *et al*. (2000) analysed spatial patterns in the distribution of tropical tree species from dry deciduous to humid evergreen forests in Asia and Central America. They found that most tree species were aggregated than random and that rare tree species were more aggregated than common ones. Thus intensive selective logging may remove entire clusters or leave behind unproductive individuals and cut off possible links between clusters or subpopulations. This will obviously lead to serious long-term genetic consequences in the remaining fragmented and often small tree populations.

Several plant species have low net seed or fruit production in small fragments, like on the mallee woodlands of Australia (Cunningham & Duncan 2001). In northern Thailand, Ghazoul (2001) also observed considerably lower fruit set in *Shorea siamensis* at logged sites as compared to unlogged sites. In Costa Rica, Rocha and Aguilar (2001) compared the reproductive biology of *Enterolobium cyclocarpum*, a predominantly outcrossing and insect pollinated dry forest species, between trees found in pastures and in continuous forests. They found that trees in continuous forests were more likely to set fruits and more seeds per fruit than trees in pastures. Rocha and Aguilar (2001) also reported that the vigour was higher in seedlings originating from continuous forests than in those from pastures.

These findings demonstrate that seed or fruit production will be reduced far before any long-term genetic consequences take place in fragmented forests. Inbreeding can also result in deleterious alleles, which further reduce survival and reproduction potential even in relatively large populations, depending on the level of inbreeding depression in a given species. However, small population size does not necessarily indicate low levels of genetic variability although species with narrow distributions have often less variability than widely distributed species (Savolainen & Kuittinen 2000). In forest fragments, genetic drift can considerably change allele frequency already over a few generations although usually the genetic effects take place slowly. For the management of forest fragments, the major genetic concern is to increase population sizes large enough so that mutation and recombination can generate enough variability within populations to respond to selection pressures (Savolainen & Kuittinen 2000).

Forest genetic diversity in rehabilitation process

As discussed above, there is increasing scientific evidence that forest rehabilitation and restoration are technically feasible through silvicultural interventions in degraded tropical forests and lands. However, what remains unclear is the effect of these interventions on forest genetic diversity, i.e. how well the diversity can be recovered and maintained in rehabilitated forests. To our knowledge, very few scientific studies have been carried out in the Asia Pacific region to find answers specifically for these questions and to provide management guidelines for practical work. Despite the very little specific information available, some conclusions for rehabilitation work can be drawn based on the above-mentioned genetic studies and guidelines developed for managed natural forests and protected areas (FAO, DFSC, IPGRI 2001) and seed handling (Schmidt 2000).

The way a rehabilitation process is initiated, i.e. how degraded forests are regenerated, has a crucial effect on long-term productivity and sustainability of rehabilitated forests. It also determines the later value of these forests in conserving genetic resources of selected priority species, if the forests are managed for production purposes or biodiversity conservation. From the genetic processes point of view, rehabilitation efforts can be classified into three broad categories, 1) silvicultural interventions after selective logging in well-stocked natural forests or in secondary forests, 2) assisted natural regeneration in landscape where only forest fragments and individual trees still exit, and 3) seriously degraded landscapes where only a few trees are left.

For the rehabilitation efforts in recently logged natural forests or secondary forests, the following general guidelines are applicable (FAO, DFSC, IPGRI 2001):

- Local seed sources should be used as a source for the next generation (applies for both natural regeneration and possible enrichment planting).
- To maintain (or enrich) genetic diversity, a sufficient number of seed trees should contribute to regeneration or, if direct seeding or planting is applied, seeds should be collected from a larger number of individuals and pooled.
- Silvicultural interventions should avoid creating neighbourhoods of related trees which might lead into inbreeding and growth depression in subsequent generations in species with mixed mating systems.

As we have discussed above, the effects of logging on forest genetic diversity are highly site and species specific; so it is difficult to define exactly what is a sufficient number of seed trees. If no detailed genetic studies have been carried out, as many seed trees as it is practically feasible should be left or used for collecting seeds after logging. For moist tropical forests, for example, it has been suggested that 6–10 seed trees per hectare and species would probably be sufficient and when genetic conservation is included as a management objective, the total number of individuals within a larger area should be kept relatively high (>150) (FAO, DFSC, IPGRI 2001).

In the case of secondary forests, rehabilitation efforts have to rely on what is left, and it is likely that genetic diversity has decreased considerably. To enhance the recovery of genetic diversity, seeds or wildings of a given species could be collected from several local stands and from as many individuals as possible and pooled to be used in the rehabilitation process within a limited local area. For highly endangered species, gene pools could be even pooled over larger geographical regions, as suggested within the concept of forest genebanks (Uma Shaanker & Ganeshaih 1997, Uma Shaanker *et al*. 2002). However, it should be kept in mind that this kind of pooling over large geographical regions may cause loss of rare alleles, disrupt adaptation to local conditions and prevent new genotypes from having desirable and valuable quantitative traits.

In fragmented landscapes where forests occur in isolated patches, maintaining and enriching genetic diversity during the rehabilitation process require special attention. Assisted natural regeneration can be used for creating links or 'ecological corridors' between fragments but the reduced capacity of fragments to produce viable seeds and vigorous seedlings is likely to hinder these efforts. In some species, long-distance gene flow may maintain genetic diversity even in small fragments, depending on their pollination vectors and seed dispersers. However, to facilitate the recovery of genetic diversity assisted natural regeneration efforts in fragments and surrounding degraded areas should include direct seeding or tree planting efforts using germplasm from other local sources.

In seriously degraded landscapes, assisted natural regeneration is not a feasible means for rehabilitation as it is likely that isolated trees are not producing viable seeds and vigorous seedlings. In degraded areas like *Imperata* grasslands, it is also difficult for many tree species to regenerate naturally and initiate the succession even if seed production would be adequate. Therefore rehabilitation efforts in seriously degraded sites commonly include artificial regeneration, which makes the efforts more costly than other methods relying on natural regeneration. When the management objective is to restore the original forest ecosystem, the framework species method seems to be highly applicable. If the management objective is to rehabilitate forest cover and simultaneously support rural livelihood or local industrial activities, establishment of tree plantations or agroforests would be desirable. In both cases, it is essential that potential tree species for these specific purposes have been identified and tested in various sites and environmental conditions before using them for rehabilitation.

When collecting seeds (or wildings) for rehabilitation of seriously degraded landscapes, germplasm should be obtained from several adjoining areas or forest fragments with similar environmental conditions, if possible. This will ensure that the material is adapted to local conditions. Seed collection efforts should also follow the following guidelines to ensure that genetic diversity is enriched or maintained in rehabilitated forests (Schmidt 2000, FAO, DFSC, IPGRI 2001):

- Collect seed or wildings from a large number of trees (preferably more than 50) with a minimum distance of 100 meters between seed trees.
- Collect an equal amount of seed from each tree and keep the seed separate by tree until sowing or propagate separately and mix prior to planting.
- Collect seed during years of mast flowering and fruiting to enhance the likelihood of high levels of outcrossing.
- Collect seed several times a year for species that flower and fruit sporadically throughout the year.

In addition to these guidelines, there are several points that need to be considered during the seed handling process to avoid loss of genetic diversity and these are presented in detail by Schmidt (2000).

In degraded landscapes with forest fragments, it is obvious that the requirements for the number of seed trees and the minimum distance between seed trees are difficult to follow due to small fragment size and low number of individuals per species left in the fragments. Therefore, these requirements need to be adjusted and applied according to species and local conditions to maximize the amount of genetic diversity among collected seed or wildings under the existing constraints. Most tropical tree species have aggregated spatial distribution (Condit *et al*. 2000) and neighbouring trees in natural stands are often related to each other (Griffin 1991); so the purpose is to avoid collecting seed and wildings from related individuals or inbred populations. When rehabilitation efforts aim at establishing forests for production rather than conservation purpose, seed can be collected from only 25 or even as low as 15 individual trees (see Schmidt 2000).

Well before a rehabilitation (or restoration) process and planning of seed or wildling supply are initiated, the ultimate management goal should be clearly identified. The long-term management goal can be to 1) restore a site for conservation of forest genetic resources or biodiversity in general, 2) rehabilitate a site for short-term production purposes with native or exotic species and after the first rotation period, shift the focus towards restoration taking a full advantage of the succession bringing in more native forest species, and 3) rehabilitate a site for long-term production purposes and manage native or exotic forest species to meet human needs while simultaneously providing environmental services. The identification of the management goal will not only facilitate decision-making during the rehabilitation process (e.g. how many seed trees should be used) but also determine the value of rehabilitated sites for genetic conservation and their usefulness to be used as seed sources in the future. Obviously, the selected management goal and subsequent activities during a rehabilitation process, including seed or wilding collection, should be well documented and records maintained properly. Documentation also enables later analyses on how much various man-made inputs attract natural recovery of species and genetic diversity.

Research needs

A lot of studies have been done to analyse various methods for reclamation, rehabilitation and restoration. While the existing information can already provide a rather sound basis for large-scale implementation of more ecological reforestation and rehabilitation, there are still gaps in our understanding, especially on how to manage forest genetic diversity during the rehabilitation process. Some research topics specifically relevant for rehabilitation include:

- selecting and testing native tree species for rehabilitation;
- assessing and locating genetic diversity of potential native tree species;
- genetic diversity of forests rehabilitated with various methods;
- gene flow between fragments and rehabilitated forests in degraded landscapes.

Although increasing efforts have been put on assessing usefulness of native tree species for rehabilitation, there is a need to test more species for different site and environmental conditions. This work should also include development of appropriate propagation methods and collection of indigenous knowledge. Information on genetic diversity of potential native tree species is needed to identify the most diverse populations of fragments for genetic conservation and to be used as seed sources. There is very little information available on how well various methods have been able to restore genetic diversity. Therefore, genetic studies are needed to analyse some successful methods and to provide guidelines for managing forest genetic diversity during the rehabilitation process. Tree plantations and the framework species method, for example, can significantly facilitate natural regeneration of native species but it is unclear how well the process can restore genetic diversity. Much of the additional geneflow into rehabilitated areas occurs in the form of seeds but in some cases, pollen movements may also have a significant role.

In addition to the above-listed topics, there are several broader research topics that are also relevant for managing forest genetic diversity during rehabilitation efforts (Ramanatha Rao & Koskela 2001):

- improving methods for surveying, sampling and assessing inter- and intraspecific diversity;
- ethnobotany and socio-economics to better understand the role of local communities in conservation;
- population genetics and conservation biology to better understand dynamics of forest genetic diversity;
- development of improved *ex situ* conservation methods;
- improving information and documentation methods;
- economic studies on the benefits from conservation and use of forest genetic resources.

SOCIO-ECONOMIC CONSIDERATIONS IN FOREST REHABILITATION

As mentioned earlier, any forest rehabilitation effort has technological, biophysical and socio-economic dimensions (Sajise 2002). More efforts are often put on understanding technological and biophysical aspects of a given rehabilitation intervention as compared to socio-economic aspects. However, the success or failure of any forest rehabilitation or biodiversity conservation project is strongly dependent on how the needs of local people are taken into account while planning and implementing the activities (e.g. Enters 2000). Thus forest rehabilitation process should not only promote biodiversity conservation but also bring benefits to rural communities and provide them a channel to participate in this process. Obviously, the socio-economic dimension has a strong influence on how the long-term management goal is identified for a given rehabilitation or restoration effort.

Many Asian countries have recognized the importance of involving local people in forest conservation and subsequently participatory approach is increasingly applied to forest conservation and management (e.g. Isager *et al*. 2002). However, there still is a need to enhance the creation of enabling environments for participatory process in the Asia Pacific region. These include appropriate institutional and regulatory framework, secure land tenure and various forms of capacity building (Isager *et al*. 2002). In general, policies for forest rehabilitation and conservation need to be based on a wider recognition of various interests and rights which makes the development of such policies a more demanding task than developing the technical parts of conservation and use policies (Kanowski 2000).

As we move into the new millennium, there is an increasing demand for wood and non-wood products in both industrial and local sectors. In forest rehabilitation point of view, this demand has to be taken into account and activities balanced between production of forest-based goods and biodiversity conservation. Therefore forest geneticists and others should not only conserve genetic diversity of indigenous forest species in rehabilitation process but also promote its increasing use.

CONCLUDING REMARKS

Forest rehabilitation and restoration in degraded tropical lands have great potential to enhance sustainable forest management, contribute to biodiversity conservation, increase food security and provide income for rural people. Several countries in the Asia Pacific region have both practical experience and research results on various methods for forest rehabilitation and restoration but it seems that their large-scale implementation is still waiting for its turn. Therefore, it is important that policy-makers in different countries support increasingly rehabilitation and restoration while formulating or updating national forest policies and offer appropriate incentives.

Conservation and wise use of forest genetic resources are a corner stone for truly sustainable forest management. In this paper, we have provided some guidelines for managing genetic resources in forest rehabilitation and restoration process but there are gaps in common understanding of how genetic processes operate in natural tropical forests, both in intact and degraded ecosystems. Also, national programmes on forest genetic resources are weak in many countries in the Asia Pacific region. Thus more research and management capacity on forest genetic resources needs to be built at national and regional levels to alleviate these problems and to enhance sustainable forest management.

BIBLIOGRAPHY

Abdul Rahman, K., Azman, H., Shahrulzaman, I. & Appanah, S. 1992. Results of 15-year-old treatment trial in Tapah Hills Forest Reserve, Perak, Peninsular Malaysia. *In* M. Nik Muhamad, A.M. Ismail Adnan, H. Mohd Zaki & J. Kamaruzaman, eds. *Proc. International Symposium on Rehabilitation of Tropical Rainforest Ecosystems: Research and Development Priorities*, pp. 173–182. Serdang, Malaysia, Universiti Pertanian Malaysia.

Ang, L.H., Maruyama, Y., Wan Razali, W.M. & Abdul Rahman, K. 1992. The early growth and survival of three commercial dipterocarps planted on decking sites of a logged-over hill forest. *In* M. Nik Muhamad, A.M. Ismail Adnan, H. Mohd Zaki & J. Kamaruzaman, eds. *Proc. International Symposium on Rehabilitation of Tropical Rainforest Ecosystems: Research and Development Priorities*, pp. 147–156. Serdang, Malaysia, Universiti Pertanian Malaysia.

Appanah, S. & Nair, C.T.S. 2001. FORSPA initiative for rehabilitation of tropical forests in the Asia Pacific region. *In* S. Kobayashi, J.W. Turnbull, T. Toam, T. Mori & N.M.N.A. Majid, eds. *Rehabilitation of Degraded Tropical Forest Ecosystems*, pp. 219–225. Bogor, Indonesia, Center for International Forestry Research.

Applegate, G.B. & Robson, K.J. 1994. Establishment of mixed rainforest species on degraded land—a case study from the coastal lowlands of northeastern Australia. *Journal of Tropical Forest Science* 7: 8–17.

Arunachalam, A. & Arunachalam, K. 2002. Evaluation of bamboos in eco-restoration of 'jhum' fallows in Arunachal Pradesh: ground vegetation, soil and microbial biomass. *Forest Ecology and Management* 159: 231–239.

Ashton, P.M.S., Gunatilleke, C.V.S. & Gunatilleke, I.A.U.N. 1997. Restoration of a Sri Lankan rain forest: using Caribbean pine (*Pinus caribaea*) as a nurse for establishing late successional tree species. *Journal of Applied Ecology* 34: 915–925.

Awang, K. & Venkateswarlu, P. 1992. Rehabilitation of tin tailing using multipurpose tree species. *In* M. Nik Muhamad, A.M. Ismail Adnan, H. Mohd Zaki & J. Kamaruzaman, eds. *Proc. International Symposium on Rehabilitation of Tropical Rainforest Ecosystems: Research and Development Priorities*, pp. 127–135. Serdang, Malaysia, Universiti Pertanian Malaysia.

Bawa, K.S. & Seidler, R. 1998. Natural forest management and conservation of biodiversity in tropical forests. *Conservation Biology* 12: 46–55.

Bebber, D., Brown, N., Speight, M., Moura-Costa, P. & Wai, Y.S. 2002. Spatial structure of light and dipterocarp seedling growth in a tropical secondary forest. *Forest Ecology and Management* 157: 65–75.

Blakesley, D., Anusarnsunthorn, V., Kerby, J., Navakitbumrung, P., Kuarak, C., Zangkum, S., Hardwick, K. & Elliott, S. 2000. Nursery technology and tree species selection for restoring forest biodiversity in northern Thailand. *In* S. Elliott, J. Kerby, D. Blakesley, K. Hardwick, K. Woods & V. Anusarnsunthorn, eds. *Forest restoration for wildlife conservation*, pp. 207–222. Thailand, International Tropical Timber Organisation and the Forest Restoration Research Unit, Chiang Mai University.

Blakesley, D., Elliott, S., Kuarak, C., Navakitbumrung, P., Zangkum, S. & Anusarnsunthorn, V. 2002. Propagating framework tree species to restore seasonally dry tropical forest: implications of seasonal seed dispersal and dormancy. *Forest Ecology and Management* 164: 31–38.

Chapman, C.A. & Chapman, L.J. 1999. Forest restoration in abandoned agricultural land: a case study from East Africa. *Conservation Biology* 13: 1301–1311.

Condit, R., Ashton, P.S., Baker, P., Bunyavejchewin, S. *et al*. 2000. Spatial pattern in the distribution of tropical tree species. *Science* 288: 1414–1418.

Cunningham, S.A. & Duncan, D.H. 2001. Plant reproduction in a fragmented landscape. *In* K.N. Ganeshaiah, R. Uma Shaanker & K.S. Bawa, eds. *Tropical ecosystems: structure, diverstiy and human welfare. Proc. International Conference on Tropical Ecosystems*, pp. 93–96. New Delhi, India, Oxford-IBH.

Curran, L.M., Caniago, I., Paoli, G.D. *et al*. 1999. Impact of El-Niño and logging on canopy tree recruitment in Borneo. *Science* 286: 2184–2188.

Elliott, S.E., Maxwell, J.F. & Prakobvitayakit Beaver, O. 1989. A transect survey of monsoon forest in Doi Suthep-Pui National Park. *Nat. Hist. Bull. Siam Soc.* 37: 137–171.

Elliott, S.E., Navakitbumrung, P., Zangkum, S., Kuarak, C., Kerby, J., Blakesley, D. & Anusarnsunthorn, V. 2000. Performance of six native tree species, planted to restore degraded forestland in northern Thailand and their response to fertilizer. *In* S. Elliott, J. Kerby, D. Blakesley, K. Hardwick, K. Woods & V. Anusarnsunthorn, eds. *Forest restoration for wildlife conservation*, pp. 245–256. Thailand, International Tropical Timber Organisation and the Forest Restoration Research Unit, Chiang Mai University.

Enters, T. 2000. Rethinking stakeholders involvement in biodiversity conservation projects. *In* A.Young, D. Boshier & T. Boyle, eds. *Forest conservation genetics: principles and practice*, pp. 263–273. Collingwood, Australia, CSIRO Publishing.

FAO. 1999. *State of world's forests 1999*. Rome. 154 pp.

FAO. 2001. *State of world's forests 2001*. Rome. 181 pp.

FAO, DFSC, IPGRI. 2001. Forest genetic resources conservation and management. Vol. 2. *In Managed natural forests and protected areas* (*in situ*). Rome, Italy, International Plant Genetic Resources Institute. 90 pp.

FORRU [Forest Restoration Research Unit]. 2000. *Tree seeds and seedlings for restoring forests in northern Thailand*. Thailand, Biology Department, Science Faculty, Chiang Mai University. 151 pp.

Friday, K.S., Drilling, M.E. & Garrity, D. 1999. *Imperata grassland rehabilitation using agroforestry and assisted natural regeneration*. Bogor, Indonesia, International Centre for Research in Agroforestry, Southeast Asian Regional Research Programme. 167 pp.

Garrity, D.P., Soekardi, M., van Noordwijk, M., de la Cruz, R., Pathak, P.S., Gunasena, H.P.M., van So, N., Huijun, G. & Majid, N.M. 1997. The *Imperata* grasslands of tropical Asia: area, distribution and typology. *Agroforestry Systems* 36: 3–29.

Ghazoul, J. 2001. Direct and indirect effects of human disturbance on the reproductive ecology of tropical forest trees. *In* K.N.Ganeshaiah, R. Uma Shaanker & K.S. Bawa, eds. *Tropical ecosystems: structure, diverstiy and human welfare. Proc. International Conference on Tropical Ecosystems*, pp. 97–100. New Delhi, India, Oxford-IBH.

Griffin, A.R. 1991. Effects of inbreeding on growth of forest trees and implications for management of seed supplies for plantation programmes. *In* K.S. Bawa & M. Hadley, eds. *Reproductive ecology of tropical forest plants*, pp. 355–374. Paris and Carnforth, Man and Biosphere Series, Vol 7. UNESCO/Parthenon Publishing.

Hardwick, K., Healey, J. & Blakesley, D. 2000. Research needs for the ecology of natural regeneration of seasonally dry tropical forests in Southeast Asia. *In* S. Elliott, J. Kerby, D. Blakesley, K. Hardwick, K. Woods & V. Anusarnsunthorn, eds. *Forest restoration for wildlife conservation*, pp. 165–179. Thailand, International Tropical Timber Organisation and the Forest Restoration Research Unit, Chiang Mai University.

Hardwick, K., Healey, J., Elliott, S., Garwood, N. & Anusarnsunthorn, V. 1997. Understanding and assisting natural regeneration processes in degraded seasonal evergreen forests in northern Thailand. *Forest Ecology and Management* 99: 203–214.

Isager, L., Theilade, I. & Thomson, L. 2002. People's participation in forest conservation: considerations and case studies. *In* J. Koskela, S. Appanah, A.P. Pedersen & M.D. Markopoulos, eds. *Proc. Southeast Asian Moving Workshop on Conservation, Management and Utilization of Forest Genetic Resources*, pp. 177–190. 25 February–10 March 2001, Thailand. FORGENMAP/IPGRI/FORSPA/ DFSC/RFD, FORSPA Publication No. 31, Bangkok, Thailand.

ITTO. 1990. *Rehabilitation of logged-over forests in Asia/Pacific region*. Draft project report. Yokohama, Japan, International Tropical Timber Organization/Japan Overseas Forestry Consultants Association (JOFCA).

Kanowski, P. J. 2000. Politics, policies and the conservation of forest genetic diversity. *In* A. Young, D. Boshier & T. Boyle, eds. *Forest conservation genetics: principles and practice*, pp. 275–287. Collingwood, Australia, CSIRO Publishing.

Koskela, J., Kuusipalo, J. & Sirikul, W. 1995. Natural regeneration dynamics of *Pinus merkusii* in northern Thailand. *Forest Ecology and Management* 77: 169–179.

Kuusipalo, J., Ådjers, G., Jafarsidik, Y., Otsamo, A., Tuomela, K. & Vuokko, R. 1995. Restoration of natural vegetation in degraded *Imperata cylindrica* grasslands: understorey development in forest plantations. *Journal of Vegetation Science* 6: 205–210.

Kuusipalo, J., Jafarsidik, Y., Ådjers, G. & Tuomela, K. 1996. Population dynamics of tree seedlings in a mixed dipterocarp rainforest before and after logging and crown liberation. *Forest Ecology and Management* 81: 85–94.

Lamb, D. 1994. Reforestation of degraded tropical forest lands in the Asia-Pacific region. *Journal of Tropical Forest Science* 7: 1–7.

Lee, C.-T., Wickneswari, R., Mahani, M.C. & Zakri, A.H. 2002. Effect of selective logging on the genetic diversity of *Scaphium macropodum*. *Biological Conservation* 104: 107–118.

Maswar, Mokhtaruddin, A.M., Nik Muhamad, M., Faridah Hanum, I., Kamil Yusoff, M., Azani, A.M. & Kobayashi, S. 2001. Evaluation of methods for rehabilitation of logged-over lowland forest in Pasoh, Negeri Sembilan, Malaysia. *In* S. Kobayashi, J.W. Turnbull, T. Toam, T. Mori & N.M.N.A. Majid, eds. *Rehabilitation of Degraded Tropical Forest Ecosystems Workshop,* pp. 135–139. Bogor, Indonesia, Center for International Forestry Research.

Maxwell, J.F., Elliott, S., Palee, P. & Anusarnsunthorn, V. 1995. The vegetation of Doi Khuntan National Park, Lamphun-Lampang Provinces. *Nat. Hist. Bull. Siam Soc.* 43: 185–205.

Mohamad Azani, A., Nik Muhamad, M. & Meguro, S. 2001. Rehabilitation of tropical rainforests based on indigenous species for degraded areas in Sarawak, Malaysia. *In* S. Kobayashi, J.W. Turnbull, T. Toam, T. Mori & N.M.N.A. Majid, eds. *Rehabilitation of Degraded Tropical Forest Ecosystems Workshop,* pp. 141–147. Bogor, Indonesia, Center for International Forestry Research.

Mori, T. 2001. Rehabilitation of degraded forests in lowland Kutai, East Kalimantan, Indonesia. *In* S. Kobayashi, J.W. Turnbull, T. Toam, T. Mori & N.M.N.A. Majid, eds. *Rehabilitation of Degraded Tropical Forest Ecosystems Workshop,* pp. 17–26. Bogor, Indonesia, Center for International Forestry Research.

Nageswara Rao, M., Ganeshaiah, K.N. & Uma Shaanker, R. 2001. Mapping genetic diversity of sandal (*Santalum album* L.) in south India: lessons for *in-situ* conservation of sandal resources. *In* R. Uma Shaanker, K.N. Ganeshaiah & K.S. Bawa, eds. *Forest genetic resources: status, threats and conservation strategies*, pp. 49–67. New Delhi, India, Oxford & IBH Publishing.

Nik Mohd., M. & Mohd. Zaki, H. 1995. Rehabilitation of degraded forest land in Malaysia. *In* A.M. Abdul Rashid, N. Abdul Rahim, S.S. Lee, A.H.H. Wong & K.C. Khoo, eds. *Proc. Third Conference on Forestry and Forest Products Research*, Vol. 2, pp. 68–77. Kuala Lumpur, Forest Research Institute Malaysia.

Oberhauser, U. 1997. Secondary forest regeneration beneath pine (*Pinus kesiya*) plantations in the northern Thai highlands: a chronosequency study. *Forest Ecology and Management* 99: 171–183.

Otsamo, A., Ådjers, G., Sasmito Hadi, T., Kuusipalo, J., Tuomela, K. & Vuokko, R. 1995. Effect of site preparation and growth of four plantation tree species used in reforestation of *Imperata cylindrica* (L.) Beauv. dominated grasslands. *Forest Ecology and Management* 73: 271–277.

Otsamo, A., Ådjers, G., Sasmito Hadi, T., Kuusipalo, J. & Vuokko, R. 1997. Evaluation of reforestation potential of 83 tree species planted on *Imperata cylindrica* dominated grasslands. *New Forests* 14: 127–143.

Otsamo, R. 1998. Removal of *Acacia mangium* overstorey increased growth of underplanted *Anisoptera marginata* (Dipterocarpaceae) on an *Imperata cylindrica* grassland site in South Kalimantan, Indonesia. *New Forests* 16: 71–80.

Otsamo, R. 2000a. Secondary forest regeneration under fast-growing forest plantations on degraded *Imperata cylindrica* grasslands. *New Forests* 19: 69–93.

Otsamo, R. 2000b. Early development of three planted indigenous tree species and natural understorey vegetation in artificial gaps in an *Acacia mangium* stand on an *Imperata cylindrica* grassland site in South Kalimantan, Indonesia. *New Forests* 19: 51–68.

Putz, F.E., Blate, G.M., Redford, K.H., Fimbel, R. & Robinson, J. 2001. Tropical forest management and conservation of biodiversity: an overview. *Conservation Biology* 15(1): 7–20.

Ramanatha Rao, V. & Hodgkin, T. 2002. Genetic diversity and conservation and utilization of plant genetic diversity. *Plant Cell, Tissue and Organ Culture* 68: 1–19.

Ramanatha Rao, V. & Koskela, J. 2001. Action plans and research needs to conserve forest genetic resources in Asia. *In* R. Uma Shaanker, K.N. Ganeshaiah & K.S. Bawa, eds. *Forest genetic resources: status, threats and conservation strategies*, pp. 283–301. New Delhi, India, Oxford & IBH Publishing.

Rocha, O.J. & Aguilar, G. 2001. Reproductive biology of the dry forest tree *Enterolobium cyclocarpum* (guanacaste) in Costa Rica: a comparison between trees left in pastures and trees in continuous forest. *American Journal of Botany* 88(9): 1607–1614.

Sajise, P.E. 1989. *Assisted natural regeneration (ANR) as an approach to reforestation. Assisted natural regeneration training manual*. DENR, Quezon City, Philippines. (unpublished)

Sajise, P.E. 2002. *Working with nature: technical and social dimensions of assisted natural regeneration*. Paper presented at the FAO/DENR/IPGRI/Bagong Pag-asa Foundation sponsored workshop and study tour on 'Assisted Natural Regeneration in the Philippines', Manila and Puerto Princesa City, April 22–26, 2002.

Sajise, P.E., Orlido, N.M., Lales, J.S., Castillo, L.C. & Atabay, R. 1976. The ecology of Philippine grasslands: I. Floristic composition and community dynamics. *Philippine Agriculturist* 59: 317–334.

Savolainen, O. & Kuittinen, H. 2000. Small population processes. *In* A. Young, D. Boshier & T. Boyle, eds. *Forest conservation genetics: principles and practice*, pp. 91–100. Collingwood, Australia, CSIRO Publishing.

Schmidt, L. 2000. *Guide to handling of tropical and subtropical forest seed*. Humlebaek, Denmark, Danida Forest Seed Centre. 511 pp.

Tang, H.T. & Chew, T.K. 1980. Preliminary results of two six-year-old under-planting trials at Tapah Hills Forest Reserve, Perak. *Malaysian Forester* 43: 193–211.

Tuomela, K., Kuusipalo, J., Vesa, L., Nuryanto, K., Sagala, A.P.S. & Ådjers, G. 1996. Growth of dipterocarp seedlings in artificial gaps: an experiment in a logged-over rainforest in South Kalimantan, Indonesia. *Forest Ecology and Management* 81: 95–100.

Ueda, K., Kimura, K., Matsumoto, Y., Samsudin, S. & Mangsor, M.F. 1995. Survival and growth of three dipterocarp species line planted under *Acacia mangium*. *In* A.M. Abdul Rashid, N. Abdul Rahim, S.S. Lee, A.H.H. Wong & K.C. Khoo, eds. *Proc. Third Conference on Forestry and Forest Products Research*, pp. 87–98. Kuala Lumpur, Forest Research Institute Malaysia.

Uma Shaanker, R. & Ganeshaiah, K.N., 1997. Mapping genetic diversity of *Phyllanthus emblica*: forest gene banks as a new approach for *in situ* conservation of genetic resources. *Current Science* 73: 163–168.

Uma Shaanker, R., Ganeshaiah, K.N., Nageswara Rao, M. & Ravikanth, G. 2002. Forest genebanks: a new approach to conserving forest tree genetic resources. *In* J.M.M. Engels, V. Ramanatha Rao, A.H.D. Brown & M.T. Jackson, eds. *Managing plant genetic diversity*, pp. 229–235. International Plant Genetic Resources Institute, and Wallingford, CABI.

Wickneswari, R. & Boyle, T.J.B. 2000. Effects of logging and other forms of harvesting on genetic diversity in humid tropical forests. *In* A. Young, D. Boshier & T. Boyle, eds. *Forest conservation genetics: principles and practice*, pp. 115–122. Collingwood, Australia, CSIRO Publishing.

Yirdaw, E. 2001. Diversity of naturally-regenerated native woody species in forest plantations in the Ethiopian highlands. *New Forests* 159–177.

Young, A.G. & Boyle, T.J. 2000. Forest fragmentation. *In* A. Young, D. Boshier & T. Boyle, eds. *Forest conservation genetics: principles and practice*, pp. 123–134. Collingwood, Australia, CSIRO Publishing.

22 The rehabilitation of the poorly-stocked hill forests in Peninsular Malaysia: crucial for timber production

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ABSTRACT

Hill forests will continue to be an important source of the future timber supply in Peninsular Malaysia. This is true when most of the lowland forests have largely been converted for other land-based development. Hill forests occur on mountain terrain of the country that ranges from 300 to 800 m above mean sea level and are categorized into lower and upper dipterocarp forests. These forests are generally managed for productive and protective functions. A considerable portion of the production forests has been allocated for sustainable production of timbers, while the remaining is set aside as protection forest for the conservation of biodiversity, forest recreation, water catchment, Virgin Jungle Reserve (VJR), wildlife sanctuary, amenity, education and research. In the production forests, the distribution of timber trees, however, is generally scattered, richer on the ridge tops and lower slopes, but poorer on the steeper slopes. The forest stands are also dominated largely by tree species in the emergent and main storey but fewer trees in the understorey and in the lower part of the main storey. Intensive rehabilitation efforts through tree planting programmes are therefore necessary to increase the productive capacity of the hill forests as well as to ensure that the timber trees are well distributed in the stand. This paper highlights several issues and challenges encountered in the implementation of forest rehabilitation activities in the hill forests. It also attempts to outline important policies and strategies emphasizing the importance of hill forests under the Sustainable Forest Management practices in Peninsular Malaysia.

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INTRODUCTION

Peninsular Malaysia is fortunate to have a large tract of rich tropical rain forest. This forest has long been valued as a source of food, fuel, medicine and materials for shelter and livelihood. It continues to play an important role in the rural economy and influences significantly the socio-economic development, community welfare and the people's quality of life. In Peninsular Malaysia, the forestry sector continues to be one of the important sectors contributing to the national economy. In terms of timber production, for example, the forest industry has contributed significantly to the total value of export of the country. In 2002, the annual export earning of Peninsular Malaysia from processed timber and medium density fiberboard (MDF) was RM21.2 billion (USD5.5 billion).

Recognizing the crucial role of the forest and to ensure its sustainable contribution to the socio-economic development of the country, a Permanent Reserved Forest (PRF) has been gazetted under the National Forestry Act 1984 to be managed under the sustainable forest management practices. In terms of timber production, sustainable production from the PRF areas is essential to provide sufficient raw material for the domestic wood-based industries. In order to achieve this, the Selective Management System (SMS) has been introduced and practised for the timber harvesting in Peninsular Malaysia. Under this system, only selected timber trees within the prescribed cutting limit timber are tagged and harvested (for logging). The bulk of the future long-term timber production in Peninsular Malaysia, however, is largely dependent on the availability of the hill forests. The supply of timber from these forests has been very restricted by the availability of sufficient stand stocking as well as the extent of the said forests particularly for timber production.

Hill forests occur on mountain terrain that ranges from 300 to 800 m above sea level. These forests are generally managed for productive and protective functions. A considerable portion of the production forests has been allocated for sustainable production of timbers, while the remaining is set aside as protection forests for the conservation of biodiversity, forest recreation, water catchment, Virgin Jungle Reserve (VJR), wildlife sanctuary, amenity, education and research.

Floristically, hill forests are characterized by several unique timber tree species and differ from lowland forests in the floristic composition of the dominants in the upper and main tree storeys. Several large trees in the hill forests are generally slightly smaller and shorter than the tallest trees in the lowland forest, except for the big trees that grow on the ridge tops.

This paper, therefore, attempts to highlight several issues and challenges encountered in the implementation of forest rehabilitation activities in the hill forests in contributing to the effective implementation of Sustainable Forest Management, particularly for the purpose of continuous timber production through the implementation of enrichment planting programme. It also attempts to outline important policies and strategies emphasizing the importance of hill forests in Peninsular Malaysia.

FOREST COVERS

The total area of forests in Peninsular Malaysia as at the end of 2001 was estimated to be 5.97 million hectares or 45.4 percent of the total land area. The majority of these forests areas comprise the Dry Inland Forest (5.49 million hectares), Peat Swamp Forest (0.30 million hectares), Mangrove Forest (0.11 million hectares) and the planted forest

(0.07 million hectares). Out of these, a total of 4.84 million hectares or 36.8% of the total forested land in Peninsular Malaysia have been secured in their tenure and gazetted in accordance with the National Forestry Policy 1984 as PRF. For management purposes, the PRF has been classified into production and protection forests. Approximately 1.90 million hectares or 39.2 percent of the total PRF in 2001 are protection forest while the remaining 2.94 million hectares are production forest. The PRF forms the most important forest resource under the custodian of the Forestry Department of Peninsular Malaysia, through the respective State Forestry Departments and continues to be sustainably managed under the Sustainable Forest Management (SFM) system.

The long-term timber supply (production) under the sustainable forest management practices in Peninsular Malaysia will always be largely dependent on the availability of the productive Permanent Reserved Forest (PRF). Dipterocarps remain an important group of timber species extracted during timber harvesting (logging). The opening of the PRF for timber harvesting (logging) is largely governed by the annual coupe (or annual allowable cut) approved and endorsed by the National Forestry Council (NFC). Generally, the PRF covers the three major forest types, *vis-à-vis* the Dry Inland Forests, Peat Swamp Forests and Mangrove Forests. In terms of Dry Inland Forests, the proportion of PRF currently comprises about 10 percent lowland and 90 percent hill forests. While, there has been a gradual reduction of lowland forests (Lowland Dipterocarp Forests) in the Dry Inland Forests for the past many years, the future forest areas for timber harvesting (or logging), therefore, will be largely confined to the hill forest (Hill Dipterocarp Forests).

In terms of long-term forest resource security, the Government has formulated and implemented the Land Capability Classification (LCC) since in 1967 (Haron & Abdul Rahman 1991). The LCC serves as a guideline which indicates the purpose for which given areas of land should be used, in order to make the best use of the inherent resources (Anonymous 1967). This guideline thus facilitates the objective to maximize the benefits derived from any form of land use. Through the LCC, 1967, land has been classified into 5 classes, viz. Class I (land suitable for mining), Class II (land suitable for agriculture), Class III (land suitable for agriculture), Class IV (land suitable for forestry), and Class V (land suitable for forestry). In terms of forestry, Class IV land is to be used for productive forests and Class V land to be used for protective forests.

FOREST MANAGEMENT PRACTICES IN THE DRY INLAND FORESTS

The earliest forest management system was the “Departmental Improvement Felling or Regeneration Improvement Felling (RIF)”. Introduced and implemented in the early 1920, it aimed mainly at improving the existing stand stock through the removal of inferior species (tree-girdling) in stages. This system particularly promotes the establishment of improved existing stands of the preferred species having actual or potential market value, such as cengal (*Neobalanocarpus heimii*). RIF was actually designed to establish natural regeneration of mainly the naturally durable heavy hardwood species particularly in the lowland forests. At the same time, “Commercial Regeneration Felling” was also practised in areas having demands for firewood and poles by the mining industry. This involved a 5-year regeneration period coupled with several felling operations for the extraction of selective highly marketable timber species.

After the Second World War, the number and processing capacity of wood-based processing mills, such as sawmills, as well as the demand for timber as raw materials increased. More forest areas were opened for logging to support these demands. The RIF management system was found to be unsuitable to cope with the increasing demand for timber by these processing mills. This led to the discontinuation of the RIF management and the implementation of the Malayan Uniform System (MUS) from 1948 onwards. The MUS was then formulated and implemented for the purpose of converting the virgin tropical lowland forests to more or even-aged forests, while removing a reasonable volume of timber from the stand for the wood-based processing mills. The MUS was timely and crucial to ensure a sufficient number of residual stocking for the next harvesting.

By the end of 1970s, however, most of the lowland forests have generally been harvested and the hill forests then constituted the bulk of the productive forests for the subsequent harvesting operation. The MUS cannot be universally applicable to both the lowland forests and the hill forests. The Selective Management System (SMS) was then formulated and introduced in Peninsular Malaysia in 1978. Currently, the production forests are managed under this system. The SMS allows for more flexible timber harvesting regimes consistent with the need to safeguard the environment and at the same time to take advantage of the demands in the timber markets. The SMS is polycyclic in nature. Felling limits are determined from a pre-felling inventory, catering for the dipterocarp and non-dipterocarp components of the forests. This system seems to be well adapted to the hill forests.

For the purpose of timber management, the Selective Management System (SMS) is implemented. The SMS involves the following (Shaharuddin 1997):

(a) pre-harvesting (pre-F inventory and prescribing the minimum cutting limit);
(b) during harvesting (implementation of reduced impact logging, determination of felling direction, implementation of timber tagging); and
(c) post-harvesting (post-F inventory, prescribing suitable silvicultural treatments).

In practice, the SMS adopts a modest cutting cycle of 25–30 years after the first logging with an expected net economic outturn of 40–50 $m^3 ha^{-1}$ enriched with dipterocarp species. No clear felling is involved. The following prescriptions have been adopted for the implementation of the SMS in Peninsular Malaysia (Thang 1997):

- The cutting limit prescribed for the group of dipterocarp species should not be less than 50 cm dbh, except for chengal (*Neobalanorcarpus heimii*) where the cutting limit prescribed should not be less than 60 cm dbh.
- The cutting limit prescribed for the group of non-dipterocarp species should not be less than 45 cm dbh.
- The difference in the cutting limits prescribed between the dipterocarp species and the non-dipterocarp species should be at least 5 cm.
- The residual stocking should have at least 32 sound commercial trees per hectare in the dbh class from 30 to 45 cm or its equivalent. The adequacy of residual stocking for the next cutting cycle and the number of residual stems in the higher dbh classes are deemed to have an equivalent value to the proportion of stems required by the standards of the next lower dbh class, as illustrated in the following table.

Table 1. Minimum residual stocking standards

Class	Size	Number of trees per hectare at the next cut	Tree(s) equivalent to number of trees in the 30–45 cm dbh class
Exploitable	+45 cm dbh	25	2
Ingrowth	30–45 cm dbh	32	1
Small trees	15–30 cm dbh	96	(1/3) (trees below 30 cm dbh are not generally considered for the next cut)

- The percentage of the dipterocarp species in the residual stand for trees having dbh of 30 cm and larger should not be less than that in the stand prior to harvest (original stand).

FOREST REHABILITATION ACTIVITIES FOR SUSTAINABLE TIMBER PRODUCTION

The dipterocarps remain the important timber-producing trees in Malaysia (Saw & Sam 1999). They may comprise over 30% of the basal area of the trees in both the lowland and hill forests or close to or over 40% of the emergents (Manokaran & Swaine 1994). The composition of natural regenerations of dipterocarps in the hill forests, however, is not as abundant or widely distributed as in the lowland forests. While the topographical condition of the hill forest has also a significant effect on the distribution of commercial timber tree species, the importance to enrich the forests seems to be more critical particularly when the hill forests have been opened for logging. The damage to the residual stand after any harvesting operation (or logging) normally depends on the volume of timber removed which creates large crown gaps in the forest. For example, the more bigger trees are harvested, the greater is the damage to the stand. In addition, there is reason to believe that the potential for environmental damage to the residual stand may also increase as the slope increases. It is in this context that normally after harvesting (or logging), the composition of the residual stand for the subsequent cut in the next harvesting rotation is relatively poor in stocking for the next cut. Therefore, the forest stand needs to be artificially regenerated through vigorous planting operation with suitable selected timber tree species. Hence enrichment planting is very crucial particularly for the poorly-stocked hill forests.

Generally, a poorly-stocked stand may be attributed to the following:

- uncontrolled timber harvesting resulting in insufficient availability of commercial sized trees in the residual stand for the next cut; and
- degraded land resulting from the opening of forest areas for forest road (feeder roads and skid trails), logging camp (or matau) or log yard.

Poorly-stocked stands need to be enriched (or to increase its productivity) through tree planting programmes or 'artificial regeneration' or 'enrichment planting' of suitable/ selected indigenous timber species. Silvicultural treatments are therefore crucial to rehabilitate (or to increase stand productivity) poorly-stocked forests. Forest rehabilitation in the PRF may involve two major approaches. These may include 'natural regeneration' and 'artificial regeneration'. Both of these approaches have been undertaken as an important rehabilitative measure to varying extents for poorly-stocked logged-over forests in Peninsular Malaysia. For an example, during the 'gutta-percha era (1900–1922)', silvicultural operations were only confined to the establishment of stands for selective commercial species, such as taban (*Palaquium gutta*), para rubber (*Hevea brasiliensis*) and chengal (*Neobalanocarpus heimii*). These forest resources were naturally abundant and easily available; hence natural regeneration approach seemed to be more suitable than artifical regeneration. Under this approach, sufficient mother trees were left in the residual stand for the purpose of liberation of seeds.

Enrichment planting or artificial regeneration, on the other hand, has been defined as the introduction of valuable selected timber species into degraded forest areas without eliminating the existing timber trees in any single forest stand. In other words, it is essentially a process of supplementing the natural regeneration where it is insufficient, with seedlings of commercial species (preferably indigenous) (Appanah & Weinland 1993). Enrichment planting activities were seriously introduced in the mid-1960s when more timber species were needed by the processing industries in tandem with the increasing demand for wood-based products. Species such as meranti tembaga (*Shorea leprosula*), meranti sarang punai (*S. parvifolia*), meranti bukit (*S. platyclados*), mersawa (*Anisoptera* spp.), kapur (*Dryobalanops aromatica*) and jelutong (*Dyera costulata*) were selected to be planted under encrichment planting activity, particularly for the logged-over forest areas with relatively low residual stocking.

In the current management sequence of the SMS, enrichment planting has been considered as an essential and important silvicultural component for the purpose to enrich poorly-stocked logged-over forest in Peninsular Malaysia (Singh 1970, Thang 1997). This is particularly crucial for the successful implementation of Sustainable Forest Management (SFM) in the hill forests. Some of the significant roles of enrichment planting are summarized as follows:

(i) introduction of selected and desired good quality timber species into the forest stand;
(ii) manipulation of stocking through specified planting distance;
(iii) enhancement of the rate of recovery of a poorly-stocked logged-over forest;
(iv) improving residual stocking of a poorly-stocked logged-over forest for the next cut.

The implementation of enrichment planting programmes under the MUS and SMS in the past many years has provided a lot of experience and knowledge as well as training ground for the foresters. Some of the information gained was in the areas related to selection of planting materials, proper planting techniques, handling of planting materials and tending of planted trees. Through years of experience and with the information and knowledge gained in the field, the Silviculture Unit at the Forestry Department Headquaters of Peninsular Malaysia has produced a practical guide to enrichment planting entitled 'Handbook on enrichment planting' in 1978 for the planning and execution of enrichment planting programmes in the country. This served as a first guide to enrichment planting practice by the Forestry Department, which has been continuously reviewed. This guideline was further revised and 'Panduan aktiviti tanaman mengaya' (*Guideline for the enrichment planting activity*) was produced on 1 March 1996 as the Circular of the Director-General of Forestry No: 2/96. This guideline serves as an important reference to many aspects related to the implementation of enrichment planting in Peninsular Malaysia, covering the key areas such as factors governing selection of species, areas to be planted, aspects of field operation to be addressed and tending of planted areas.

During the early implementation of the enrichment planting, the main focus was in the form of 'taungya system' practices, which form one of the models available under 'agroforestry' land-use practice. It is basically referred to as raising of forest tree species together with agriculture crops. This system focused on reforestation, especially small patches around forest fringes in the Permanent Reserved Forests (PRF) which had long been encroached into by illegal agricultural farmers. Under this system, participating farmers were given a special forest permit to allow them to cultivate the degraded land with agriculture crops such as banana and tapioca. In return the farmers planted tree seedlings supplied by the Forestry Department. Through this system large patches of degraded forests had been successfully rehabilitated with both exotic and indigenous timber species such as pine (predominantly *Pinus caribaea*), kapur, meranti tembaga, balau kumus (*S. laevis*), meranti seraya and mahogany (*Swietenia macrophylla*). The oldest of taungya planting was recorded in Perlis, in which a total of 133 ha of the degraded forests has been cultivated with teak (*Tectona grandis*) and mainly intercropped with hill paddy and tobacco.

Other than the planting approach under the 'taungya system', early enrichment planting project embarked on by the Forestry Department was the planting under 'single cropping' of indigenous timber species such as meranti sarang punai (*Shorea pavifolia*) through strip/line-planting technique in a poorly-stocked forest area at Bukit Tapah Forest Reserve, Perak. The result was very promising. The annual mortality rate was seen to be decreasing as the planted trees grew older. The annual mortality rate decreased from 10% at one year after planting to 5% in the following three years after planting. The mean annual height increment was generally between 1.2 and 1.5 m and mean annual diameter increment was between 1.3 and 1.5 cm (Tang & Chew 1980). These initial findings showed that enrichment planting under 'single cropping' could be extended on a larger scale. Subsequently, more enrichment planting activities were implemented on a relatively bigger scale in poorly-stocked forest areas of the PRF throughout Peninsular Malaysia. As at the end of year 2001, a total of 24 441 ha had been planted under the enrichment planting programme with dipterocarp and non-dipterocarp timber species throughout Peninsular Malaysia, as shown in the Table 2.

Large tracks of successfully established enrichment planting plots are available in the State of Perak, followed by Selangor, Kelantan, Pahang, Johor, Kedah, Melaka, Terengganu and Negeri Sembilan. Almost 79.3% of the species planted under the enrichment planting programmes throughout Peninsular Malaysia are mainly focussed on the dipterocarps especially the genera *Shorea* and *Dipterocarpus*, while about 17.4% are mixed dipterocarps and non-dipterocarps. The main timber species planted are commercially preferred species such as *Shorea leprosula, S. parvifolia, S. acuminata, Dryobalanops aromatica, Hopea odorata, S. pauciflora, S. ovalis, Dipterocarpus cornutus* and *Anisoptera* spp. Most of the species of interest are covered in the 'Regeneration sampling (RS) list of 1974', of the FDPM (Anonymous 1974) and '*Panduan aktiviti tanaman mengaya, 1996*'.

Table 2. Areas planted through enrichment planting in Peninsular Malaysia

State	Area planted (ha)			Total area planted (ha)	Planting spacing (line planting)
	Dipterocarps	Non-dipterocarps	Mixed		
Johor	1 804	–	–	1 804	3 × 3 m 3 × 10 m
Kedah	1 030	23	553	1 606	3 × 10 m
Kelantan	3 505	66	190	3 761	6 × 10 m 5 × 10 m
Melaka	399	–	–	399	3 × 3 m
Negeri Sembilan	832	–	126	958	5 × 4 m 3.3 × 3.3 m 3 × 5 m 3 × 10 m
Pahang	4 733	10	220	4 963	3 × 10 m 5 × 10 m 7 × 11 m
Perak	4 426	489	435	5 350	3 × 10 m 3 × 3 m
Selangor	3 636	25	–	3 661	3 × 10 m
Terengganu	1 779	–	–	1 779	3 × 10 m
Total	22 304	614	1 524	24 441	
%	91.3	2.5	6.2	100	

ISSUES AND CHALLENGES

Continuing to explore the complexity of the hill forests

The complexity of the hill forests remains a unique feature. Forest management in the hill forests particularly for timber production must therefore continue to take corrective measures in tandem with the availability of new research findings (Appanah *et al*. 1997). For an example, in relation to the poor regeneration capability in the hill forests, Thang (1987) has emphasized that the success of the SMS would depend on growth and mortality rates, logging damage to residual stand and adequacy of residual stock to ensure sustainability as well as ingrowth. Updated information is thus crucial to unsure successful implementation of the SMS while further refining various assumptions and theories that were outlined earlier (Abd. Rashid & Moktar 1997). Hence continuous research is necessary.

Overcoming the poor stocking of regeneration in the logged-over hill forest stand

Adequacy of the naturally residual stocking and its species composition after logging need to be further explored to ensure in particular adequate dipterocarp timber species for the next cut. The existing silvicultural prescriptions on the residual stand after logging give more emphasis on immediate trees (Abd. Rashid & Mokhtar *et al*. 1997). It is acknowledged that dipterocarp and non-dipterocarp timber species have different growth rates (Nussbaum *et al*. 1996, FDPM/PSFD/JICA 1999). Hence, if blanket prescriptions are applied for the whole forest stand, for both the dipterocarps as well as non-dipterocarps, they will have an unpleasant impact on the growth of both groups of species. Again, the silvicultural prescriptions given are to assist the growth of residual stands of higher diameter classes for the next cut. The effect on the rate of growth of residual stands of lower diameter class would be much affected. Rehabilitation effort through enrichment planting has a great potential to enrich or increase the residual stocking of the logged-over forest stand (Azahar 1997).

Exploring suitable species for planting programme

Rehabilitation of poorly-stocked forests is seen to be mandatory in order to ensure forest stand productivity regains for the next cut or at least a reversion to the original state. Enriching the poorly-stocked stand through artificial tree planting is thus necessary. In relation to the hill forests, however, selection of suitable indigenous species for effective rehabilitation would need, for example, to take cognizance of the following (Zuhaidi & Weinland 1993, Wan Yusof & Abdul Rahman 1997):

- easy handling of the species in the nursery;
- high rate of germination;
- regular flowering and fruiting;
- higher growth rate, particularly at the initial stage of planting;
- shade tolerance; able to withstand competition between trees on planting sites;
- good self pruning (if possible);
- low susceptibility to diseases, insect and fungal attacks.

Post-planting tending operations not properly implemented

Post-planting treatments are critical for the successful establishment of planted seeding (Raja Barizan & Shamsuddin 1997). Tending operations after planting as well as the maintenance of enrichment planting areas, however, are not properly implemented and are of very limited scope. Due to manpower and cost limitations, the tending operations are seen to be confined only to canopy manipulations at different levels after planting to ensure sufficient sunlight for planted seedlings to grow. It has been recommended that overhead shade should be removed within three to six months after planting, as delays would reduce height increments of planted seedling (Tang & Chew 1980). A prolonged treatment of removing overhead shade to 15 years after planting improved the percentage of survival and diameter increments of planted trees (Azman *et al*. 1991). Record keeping and mapping (if possible) are essential in order to facilitate the monitoring as well the implementation of rehabilitation programmes. This is crucial to attain the objective of the tree planting programme.

Requirement of comprehensive ‘site–species matching’ outputs

Comprehensive ‘site–species matching’ is necessary for effective implementation of enrichment planting. Site–species matching enables large-scale establishment of commercial tree plantations to be successfully achieved. At the moment, site–species matching is still limited to certain species and certain sites. Thus coordinated and aggressive R&D should be undertaken.

High cost of enrichment planting programme

Financial constraints for effective implementation of enrichment planting remain as it is costly to embark upon commercial tree planting (Awang Noor *et al*. 1997). This is a challenge for future enrichment planting activities in Peninsular Malaysia.

STRATEGIES FOR THE WAY FORWARD

The tropical rain forests of Peninsular Malaysia will continue to be managed sustainably. Thus more research, particularly for hill forests, is required to further appraise and unveil the complexity of the forests. This information is essential for effective timber production planning.

Planting should be done immediately after timber harvesting (or logging) with priority given to dipterocarp timber species where minimum canopy opening and line clearing are required. However, sufficient funds are needed for the effective implementation of enrichment planting, particularly in the poorly-stocked forests. In this regard, sufficient forest development funds, such as from the silvicultural cess, are very essential for forest rehabilitation in the poorly-stocked forests.

Artificial regeneration through enrichment planting will continue to be important in the silvicultural practices (or forest rehabilitation) of the poorly-stocked forest. In the past, it has often been shown that enrichment planting is an essential silvicultural treatment in order to enrich the stocking of the poorly-stocked logged-over forest stand, both in terms of quantity as well as quality of the timber trees produced. Although substantial funds are required for the implementation of such rehabilitation activities, past records clearly indicate that enrichment planting is economically viable. It will inevitably be incorporated into the SMS practices, particularly for the management of the hill forests in Peninsular Malaysia.

Finally, no 'silver bullet' or 'golden rule' can be applied universally to ensure sustainable timber harvesting in the hill forests. This remains the most important issue and poses a great challenge to forest managers. Coordinated and aggressive R&D amongst the forest related agencies is necessary. Successful R&D findings would ensure strengthening the effective implementation of SFM in the hill forests.

REFERENCES

Abdul Rashid, M.A. & Mokhtar M.I. 1997. Issues and problems in implementation of Selective Management Systems in the States. *Proc. Workshop on Selective Management System and Enrichment Planting "Towards Sustainable Forest Management*", pp. 29–38. 24–26 June 1997, Perak.

Anonymous. 1967. *Land capability classification in West Malaysia—explanatory handbook*. Kuala Lumpur, Malaysia, Economic Planning Unit, Prime Minister's Department.

Anonymous. 1974. *The regeneration sampling (RS) list of 1974*. Forestry Department of Peninsular Malaysia. (unpublished)

Appanah, S., Shamsuddin, I., Chong, P.F., Ismail, H. & Wan Shukri, W.A. 1997. Future directions and improvement in Selective Management System based on research findings. *Proc. Workshop on Selective Management System and Enrichment Planting "Towards Sustainable Forest Management",* pp. 39–52. 24–26 June 1997, Perak.

Appanah, S. & Weinland, G. 1993. *Planting quality timber trees in Peninsular Malaysia—a review*. Malayan Forest Records No. 38. Kuala Lumpur, FRIM. 221 pp.

Awang Noor, A.G., Mohd Basri, H. & Shamsuddin, S. 1997. Economics of enrichment planting in Peninsular Malaysia. *Proc. Workshop on Selective Management System and Enrichment Planting, "Towards Sustainable Forest Management"*, pp. 133–143. 24–26 June 1997, Perak.

Azahar, M. 1997. Implementation and problems of enrichment planting based on experiences in the States. *Proc. Workshop on Selective Management System and Enrichment Planting, "Towards Sustainable Forest Management"*, pp. 107–116. 24–26 June 1997, Perak.

Azman, H., Wan Razali, W.M., Shahrulzaman, I. & Abdul Rahman, K. 1991. Growth performance of indigenous species under enrichment planting in logged-over forests. *In* S. Appanah, F.S.P. Ng & I. Roslan, eds. *Proc. Conference on Forestry and Forest Products Research*, pp. 30–40. Forest Research Institute Malaysia.

FDPM/PSFD/JICA. 1999. *Integrated report on the Multi-Storied Forest Management Project in Malaysia (1991–1999)*. 5 pp.

Haron, A., H. & Abdul Rahman, A.R. 1991. Forest and land use policy in Malaysia. *Malaysian Forester* 54: 150–158.

Manokaran, N. & Swaine, M.D. 1994. *Population dynamics of trees in dipterocarp forests of Peninsular Malaysia*. Malaysian Forest Records No. 40. Kuala Lumpur, Forest Research Institute Malaysia. 173 pp.

Nussbaum, R., Anderson, J. & Spancer, T. 1996. Planting dipterocarps for the rehabilitation of log landings and skid trails in Sabah, Malaysia. *In* S. Appanah & K.C. Khoo, eds. *Proc. Fifth Round Table Conference on Dipterocarps*, pp. 299–309. Chiang Mai, Thailand, 7–10 November 1994. Kuala Lumpur, Forest Research Institute Malaysia.

Raja Barizan, R.S. & Shamsuddin, I. 1997. Future direction and improvements to enrichment planting based on research findings. *Proc. Workshop on Selective Management System and Enrichment Planting "Towards Sustainable Forest Management"*, pp. 117–131. 24–26 June 1997, Perak.

Saw, L.G & Sam, Y.Y. 1999. Conservation of Dipterocarpaceae in Peninsular Malaysia. *Journal of Tropical Forest Science* 12: 593–615.

Shaharuddin, M.I. 1997. Technical requirements for the successful implementation of Selective Management System in Peninsular Malaysia. *Proc. Workshop on Selective Management System and Enrichment Planting, "Towards Sustainable Forest Management"*, pp. 15–27. 24–26 June 1997, Perak.

Singh, L.S. 1970. Enrichment planting—Its future in hill forest silviculture. *Malayan Forester* 33: 135–143.

Tang, H.T. & Chew, T.K. 1980. Preliminary results of two six-year-old under-planting trials at Tapah Hills Forest Reserve, Perak. *Malaysian Forester* 43(2): 193–211.

Thang, H.C. 1987. Forest management systems of tropical high forest, with special reference to Peninsular Malaysia. *Forest Ecology and Management* 21: 3–20.

Thang H.C. 1997. Concepts and basis of Selective Management Systems in Peninsular Malaysia. *In Proc. Workshop on Selective Management System and Enrichment Planting, "Towards Sustainable Forest Management"*, pp. 1–13. 24–26 June 1997, Perak.

Wan Yusoff, W.A. & Abdul Rahman, A.R. 1997. Status of enrichment planting in Peninsular Malaysia. *Proc. Workshop on Selective Management System and Enrichment Planting "Towards Sustainable Forest Management"*, pp. 87–105. 24–26 June 1997, Perak.

Zuhaidi, A. & Weinland, G. 1993. *Species choice for reforestation with quality timber species in Peninsular Malaysia: approach and concept*. FRIM. (unpublished)

23 Financing community-based watershed reforestation in the Philippines

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ABSTRACT

In 1992, the National Power Corporation (NPC), a government operated and controlled corporation, secured funds for the development of about 1 000 ha of tree farms within the Lake Lanao-Agus River watershed reservation in Lanao del Sur, Philippines. About US$1.1 million was used to finance development activities in reforestation and environmental rehabilitation in determined areas within the watershed reservation. Community participation was ensured after six to nine months of social preparation prior to the initiation of the project. More than 150 individual cooperators representing their households participated by way of a contract for the development of their areas into tree farms. Technical support and assistance were provided by the Paper Industries Corporation of the Philippines (PICOP). More than 1 500 ha of private land were developed into tree farms and planted with Acacia mangium, Durio zibethinus and other indigenous tree species. Post-project monitoring and evaluation of the established tree farms indicated a very high tree survival rate of 98 percent and favorable growth rates. In 1996, the project was turned over by the PICOP to the NPC which then continued the rehabilitation effort through internal funds. This innovative experience in community-based reforestation and environmental stewardship may set a good example of how to rehabilitate degraded lands.

INTRODUCTION

Geographically, the Philippines is situated within the tropical belt at the range of 4–21°N and 117–127°E. It is an archipelago with over 7 000 islands, the largest being Luzon to the north and Mindanao in the south. Most islands have mountainous interiors rising

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from 1 000 to 2 500 m above sea level. This topography supports a diverse forest ecosystem, and causes violent hydrological patterns that can promote severe erosion if the forest cover is removed.

Over the years, excessive deforestation has degraded the upland watersheds to a critical level. Recognizing this, the government has adopted community-based forest management as the national strategy to ensure the sustainable development of the country's forest land resources (Ramos 1995).

In the early 1990s, the Philippines experienced an energy crisis. The problem was compounded when the El-Ñino phenomenon hit the country thereby adversely affecting hydroelectric power generation particularly in the central part of Mindanao. The indicative losses due to frequent power outages in Mindanao were at that time estimated to be about \$100 million per month. It is in this vein that this paper is being written.

THE COMMUNITY-BASED REFORESTATION PROJECT IN LAKE LANAO-AGUS RIVER WATERSHED

Significance of the project

The Lake Lanao-Agus River (LLAR for brevity) watershed is the main source of water used by the series of six hydroelectric power (HEP) plants for power generation. The combined generating capacity of these HEP plants is about 720 megawatts. The power generation potential of these HEP plants represents more than 60 percent of the electricity power demand of Mindanao in the 1990s.

The project concept

There is a need to reforest and rehabilitate the LLAR watershed. The forest cover of the area has been reduced to a critical level due to uncontrolled logging which started as early as in the 1960s and continued to the 1990s. The mesoclimate regime in the area has been unpredictable if not erratic. The free flow discharge of the Agus River declined from an average of 113 $m^3 s^{-1}$ in 1950–1977 to a regulated discharge of 87 $m^3 s^{-1}$ in 1978–1989.

Project objectives

The general aim of the reforestation project was to ensure stable hydroelectric power generation of the Agus plants through improved water yield of the LLAR watershed on a sustainable basis. The specific objectives of the project were: (1) to develop about 1 000 ha of tree farms within the LLAR watershed reservation within three years from 1993 to 1996, (2) to raise the level of stakeholder's awareness on the value of the watershed and the need for its protection and conservation, and (3) to gain the community's full support for the project.

Project financing and management

In 1992, the National Power Corporation (NPC), a government operated and controlled corporation, secured funds for the development of about 1 000 ha of tree farms within the Lake Lanao-Agus River watershed reservation in Lanao del Sur, Philippines. About US\$1.1 million was used to finance development activities in reforestation and environmental rehabilitation in determined areas within the watershed reservation. The amount was contributed by the Mindanao Association of Electric Cooperative. This amount represents corporate investment of industries and utilities for the improvement of hydro-power generation. The Paper Industries Corporation of the Philippines (PICOP) was designated as the project implementor and takes charge of the management of the project. The NPC was the fund manager.

Brief background of the project area and the people

Lake Lanao, the second largest freshwater resource of the country, is located at the heartland of Mindanao. The lake has a normal water elevation of 702 m above sea level with a surface area of 36 000 ha. The lake is recharged by five major tributary rivers. The limnological study of Frey (1968) revealed that the deepest part of the lake is 118 m and the mean depth is 60 m. Its only outlet is the Agus River (the word "agus" in the local dialect means flowing) which cascades about 700 m down to Iligan Bay at a distance of only 36 km. The total area of the watershed is 186 000 hectares.

The Maranao

The Maranao or the people of the lake have an estimated 1980 population of about 750000 of which over 95 percent embrace the Islamic faith. The extent of their attachment to the lake was aptly illustrated by Washburn (1977) in her article, "Our lake for others", which describes the Maranao this way: "*As long as the Maranao have been a people, Ranao—the lake—has existed. To the lake they bound their identity; in their own eyes and in the eyes of the outsiders they are Maranao, the people of the lake. On their shores they established their villages and towns and built their mosques, with its water they purify themselves for prayer, in its wetlands they cultivate their rice, from its depth they gather fish, across its expanse they transport their goods and people, from it they take water for drinking and cleaning. Each boulder and island in the lake, each hill and valley in the land surrounding it, seems woven into the legends and epics of the people. And each Maranao can willingly trace his ancestry to the original "pat a pengampong" – four encampments on the lake, and their mythical founders. Thus it is with some justification and no little pride that the Maranao consider Lake Lanao "Our lake.*"

THE PROJECT COMPONENTS

Social preparation

The project's operation manager initiated a series of consultation meetings with various stakeholders, from the Barangay level up to the Municipal level. These included very frequent congregational meetings at the mosques during Friday, the day of worship among Muslims. The main context of these meetings focused on the need and importance of cooperation among the local folks in the preservation of the lake. The people were enjoined to take heed of the divine injunction to protect and preserve the natural resource, which is a gift from God. Coupled with these were scientific as well as helpful indigenous justifications for conserving the environment and restoring back the degraded areas. The project manager solicited the people's willingness to participate in the programme by enlisting as farmer cooperators.

Establishment of tree farms and reforestation

People who enlisted to participate were asked to comply with some project requirements, such as letter of intent, proof copy of land ownership and tax payment, sketch of land property, and referral from the village chief. The management then acted upon the application by scheduling the following activities for each of the project cooperators: (i) land-use survey mapping and planning (LUSMP), (ii) site preparation, (iii) tree planting, and (iv) maintenance and protection.

RESULTS

Community acceptance of the project was ensured after more than six months of social preparation. Social activity prepares the community for the project implementation. Local community and religious leaders were instrumental in convincing the people to give full support to the project. They took it upon themselves and pride to endorse the project as it would be for their own benefit. More than these, the focus was not much of what they could get out of the project fund but what they could give and volunteer as their project counterpart. They were willing to offer their idle lands and even agricultural lands for a worthwhile endeavour.

More than 150 cooperators representing their households and clans participated by way of a formal contract for the development of their own areas into tree farms as well as agroforestry farms. Technical support and assistance were provided by the Paper Industries Corporation of the Philippines (PICOP), the project implementor. More than 1 500 ha were reforested or planted with trees and fruit trees by the project cooperators. About 3 million seedlings were planted by the cooperators and the supporters in the communities.

Cost effective analysis (CEA) indicated that social preparation costs were more than recovered in terms of the excess area reforested or planted with trees. Performance analysis indicated that project acceptability was the most important factor for the success of the reforestation project. Project acceptability leads to optimization of people's participation. Small landholding farmers, who comprise the major segment of the population, are the most sincere and effective implementors of reforestation projects.

When the project was subjected to post-project auditing by the external corporate auditor for the NPC, it was found out that the established tree farms had very high survival rates of more than 95 percent. Because of this, they recommended to the higher management that continued rehabilitation of the lake could be funded out of corporate funds. This recommendation was approved. An annual budget for the purpose was provided and managed by the Watershed Management Division of the NPC Mindanao Regional Office (MRO), based in Iligan City.

When the initial project ended in 1996, the tree farmers organized themselves into cooperatives by municipality and later on formed a federation for the province of Lanao del Sur. One of the purposes of the cooperatives was to update its members on the development of their own farms.

By this year 2002, most of the *Acacia mangium* and *Gmelina arborea* trees were of harvestable size. The lanzone (*Lanzium edule*) and durian (*Durio zibethinus*) fruit trees are now producing on season in commercial quantities. These species were interplanted or line planted on corn (*Zea mays*) as well as coffee (*Coffea robusta*) farms. The NPC was also involved in assisting tree farmers who wanted to utilize their timberland for value-added activities, such as lumbering and furniture-making, as alternatives to stumpage sale.

DISCUSSION

Reforestation is one of the most direct ways of restoring a degraded land. Yet reforestation will not be successful unless it is combined with other sound practices. This project proved that community acceptability of the project is very important to project performance or success. Social preparation is an assurance of project success, and without it the project is doomed. The project can only be implemented if community acceptability is indicated from the social preparation.

A comparative analysis of the project with other similar local and national projects illustrates this point as shown in Table 1.

Table 1. Comparative data on reforestation targets and accomplishments

Implementor	Source of funding	Budget (US$)	Area targeted for reforestation (hectares)	Percentage accomplishment	Reforestation species
Local reforestation by contractors in the province of Lanao del Sur	Reforestation fund of DENR	2 M	2 000	<5	Fast growing (e.g.) *Paraserianthes falcataria* and *Sweitenia macrophylla*
DENR contract reforestation	ADB Phase I	300 M	300 000	10–15	Fast growing (e.g.) *Paraserianthes falcataria* and *Sweitenia macrophylla*
DENR contract reforestation	ADB Phase II	300 M	300 000	20–25	Fast growing (e.g.) *Paraserianthes falcataria* and *Sweitenia macrophylla*
This project	Industry contribution	1.1 M	1 000	>200	*Acacia mangium* and indigenous species

The table above shows very wide gaps in the performances of reforestation activities.

CONCLUSION

Forest rehabilitation is an amplification of man's role in the development of his environment for his own survival. How he plays the role spells the difference between success and failure.

BIBLIOGRAPHY

Acosta, R.T. 1999. *Community-based forest management: issues and initiatives in pursuing upland development*. Paper presented at the 12th Philippine Environmental Congress, 8–10 April, 1999. Laguna, Philippines.

Cali, C.A. 1991. *Assessment of Growth and Nodulation of Acacia mangium Willd. and Sesbania grandiflora (L.) Pers. in two Philippine soil types*. University of the Philippines at Los Baños, College, Laguna, Philippines. (Ph.D. dissertation)

DENR. 1996. *Basic community organizing handbook for community-based forest management programs*. Quezon City, Philippines, DENR.

DENR. 1996. *Administrative Order 96–29 dated October 10, 1996, Rules and Regulations for the Implementation of Executive Order 263, Otherwise known as the Community-Based Forest Management Strategy (CBFMS).*

DENR. 1997. *Guidelines for the formulation of community-based resource management framework and annual work plan for community-based forest management areas.* DENR Memo Circular No. 97–12.

DENR. 2002. *Forestry sector project: policies and guidelines*. A compilation of FSP policies and other related guidelines 1996–2001. Dilliman, Quezon City, Philippines, Department of Environment and Natural Resources, National Forestation Development Office (NFDO).

ETFRN. 2002. *Innovative financing mechanisms for conservation and sustainable forest management*. ETFRN News No. 35 Winter 2001/2002. ETFRN Coordination Unit, Tropenbos International, PO Box 232, 6700 AE Wageningen, the Netherlands.

Frey. 1968. *Limnological reconnaisance of Lake Lanao*. Marawi City, Philippines, Mindanao State University.

Gallardo, O.C. 1991. *Reservoir sizing by transition probabilities as applied to Lake Lanao controversy*. International Post-Graduate Course in Hydrology. Water Resources Research Centre, Budapest, Hungary.

Magno, F.A. 1994. The contract reforestation program. *Philippine Journal of Public Administration*. XXXVIII (3): 260–274.

Mero, D.C. & Miranda, P.T. 1998. Habitat rehabilitation technologies for Lake Lanao watershed. *Proc. International Conference on Applied Tropical Ecology. Aspects on Ecosystem Management in Tropical Asia.* 8–10 September, 1998. Baybay, Leyte, Philippines, Visayas State College of Agriculture (ViSCA).

NPC. 1990. *Statistical data on Lake Lanao*. Iligan City, Philippines, National Power Corporation (NPC), Mindanao Regional Office.

Poffenberger, M. (Ed.). 1990. *Keepers of the forest: land management alternatives in Southeast Asia*. Quezon City, Philippines, Ateneo de Manila University Press.

Ramos, F.V. 1995. *Executive Order No. 263*. Adopting Community-Based Forest Management as the National Strategy to Ensure the Sustainable Development of the Country's Forest Land Resources and Providing Mechanisms for its Implementation.

Sajise, P.E. *et al*. 1990. *State of the Philippine environment*. University of the Philippines National Assessment Project, Dilliman, Quezon City, Philippines, U.P. Press.

Serna, C.B. 1993. Community-based resource management perspectives, experiences and policy issues related to forestry and upland development. *In* F.P. Jr. Fellizar, ed. *Community-based resource management perspectives, experiences and policy issues*, pp. 64–81. College, Laguna, Philippines.

UNCED. 1992. *United Nations Conference on Environment and Development*. Final advanced version of Agenda 21, Chapter 11, Combating Deforestation.

Washburn, L. 1977. *Our lake for others*. Dansalan Research Center (DRC) Bulletin. Marawi City, Nov.–Dec. 1977.

24 Initiatives for improving reforestation strategies: an enabling framework of criteria and indicators for forest land evaluation

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ABSTRACT

Viet Nam, a country in transition and passing through a process of economic renovation from 1986, is striving to balance development with environmental protection. In order to revamp the forestry sector and to counter the devastating deterioration of forests, it has launched since 1998 an ambitious National Five Million Hectares Reforestation Programme (FMHRP) aiming to restore forest cover to 43 percent by 2010. With a view to assist the Ministry of Agriculture and Rural Development to effectively implement the National FMHRP, the Food and Agriculture Organization of the United Nations is supporting a technical cooperation programme, TCP/VIE/0066, from March 2001 to March 2003. The project seeks to evolve an enabling implementation framework by focusing on three interrelated outputs: (1) generate a set of criteria and indicators (C & I) for forest land evaluation, (2) develop guidelines for participatory forest land use planning, (3) elaborate guidelines for monitoring and evaluating plantation establishment and natural forest regeneration. The process of completing work on output (1) from August 2001 to May 2002, essentially an institutional collaboration between two national level institutions had three stages: (1) conceptualization and developing of a set of preliminary C & I, (2) testing of preliminary C & I by applying at two sites to assess their relevance, (3) finalization by integrating results of testing and documenting the final version of C & I for forest land evaluation. Consequently a framework of C & I as tools for microlevel field assessments of non-forested bare lands has been evolved having two parts: the first part comprising 6 biophysical criteria with matching 23 indicators, and the second part comprising socio-economic criteria with matching indicators. To consolidate and integrate

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field assessments, a method has been suggested to assess the suitability of sites by three potential productivity classes, namely High, Medium and Low. By matching this classification with the socio-economic criteria, the next step of narrowing down priorities of forestry/agroforestry interventions according to location and specific requirements is suggested.

The paper describes how this evolving methodology, which has potential and relevance for other countries as a model for replication, can be usefully scaled up for efficient planning and for improving the eventual implementation of reforestation.

INTRODUCTION

The Food and Agriculture Organization of the United Nations has been a partner of Viet Nam since 1978 in supporting agricultural development. From the beginning of 1999, the multilateral and bilateral organizations that are most active in forestry have joined together with the government in support of the National Five Million Hectares Reforestation Programme (FMHRP). This ambitious initiative launched to counter the devastating deterioration of forests aims to restore the forest cover of the country to 43% by 2010. The FAO is an active partner in the Government–Donor Partnership, and is committed to its future success. More specifically, a technical cooperation programme, TCP/VIE/0066*, has been designed to assist the Ministry of Agriculture and Rural Development to effectively implement the National FMHRP. The project, lasting 24 months from March 2001 to March 2003, has a budget support of US$333 230. The Forest Inventory and Planning Institute (FIPI) is responsible for its execution. The project seeks to evolve an enabling implementation framework by focusing on the following three interrelated outputs**:**

I. Generate a set of criteria and indicators (C&I) for forest land evaluation (FLE).
II. Develop guidelines for participatory forest land use planning (PFLUP).
III. Elaborate guidelines for monitoring and evaluating plantation establishment and natural forest regeneration.

This paper reports on work carried out in Viet Nam by highlighting conceptual issues and the methodological development of an enabling framework of criteria and indicators for forest land evaluation designed for the eventual implementation of reforestation. The process of developing this methodology and testing was completed at all stages as a collaborative work based on consultancy inputs by the first author and the support of two national level institutions, namely the FIPI and Forest Science Institute of Viet Nam (FSIV).

OBJECTIVES

The key objective of evolving an enabling framework of C & I for FLE is to improve the methodology for evaluating a forest land in terms of its productive potential and suitability for natural regeneration and tree planting. It aims to provide simple guidelines to planners and implementing agencies to assess the potential productivity and suitability of a certain piece of land for any intended silvicultural treatment/choice of given species for planting.

* Project Implementation Plan 2001–2003, May 2001 Version.

PROCESS AND METHODOLOGY

The process of conceptualization, testing and finalization of the basic framework of C & I to its present stage was conducted from August 2001 to April 2002. It underwent refinements, broadly in three interlinked phases as follows:

Conceptualization phase

Conceptualization commenced with the first mission undertaken between August and October 2001 (60 days). The mission accomplished the following activities:

- institutional contacts with national agencies and key international projects;
- evaluation and analysis of available documents;
- frequent internal discussions with the FIPI, FSIV and other key related institutions to develope a shared vision;
- field visits to two sites, namely Son Dong district and Bac Giang province in the northeast region, and An Khe district, Gia Lai province in the central highland region; 13 consultative meetings at province, district, commune and village levels to assess existing practices and constraints;
- synthesis of all inputs for conceptualizing a basic framework to elaborate key issues;
- sharing in a workshop in October 2001, the rationale and conceptual parameters necessary for developing a set of preliminary C & I;
- finalization of a preliminary set of C & I for FLE of bare lands, to be tested by the FSIV and developing a working draft report on the first mission for comments and suggestions.

Testing phase

The FSIV having been contracted for field testing and related activities carried out the preparatory field surveys and actual testing of the preliminary set of C & I from October 2001 to April 2002. Testing results at two sites have established the relevance of the preliminary C & I as a workable framework to assess the suitability of bare lands for forestry/agroforestry interventions. In addition, many useful practical findings have emerged.

Finalization phase

In the finalization and validation phase, a second mission lasting 30 days was undertaken in March–April 2002.The finalization of C & I integrates in a holistic manner the results of testing and the necessary adjustments suggested, i.e.

- synthesis of results of testing by the FSIV;
- adjustments of preliminary C & I;
- validation and consolidation for documentation of the final C & I including drafting of guidelines for application of C & I in the field;
- consultations with the FSIV/FIPI to incorporate minor adjustments.

SITUATION ANALYSIS

An analysis of the current status of land use and key aspects of the forestry sector formed the basis of developing this methodology in order to relate it more closely to ground realities.

Country context

Since 1986, Viet Nam has embarked on an ambitious programme of reforms ("doi moi") as a process of transformation and an important part of a wider national process of change. The "doi moi" philosophy encompasses a combination of policy and institutional adaptations associated with liberalization, opening up and reform. Its adoption has resulted in rapid economic advances in all sectors, particularly agriculture, forestry and fisheries. Recognizing the urgent need to promote development that balances environmental protection with economic progress for the benefit of the people, suitable strategies are being evolved.

Agriculture, forestry and fisheries, grouped in one of the three economic sectors, account for 24.30% of the total GDP at current prices as per preliminary figures for 2000. The gross output of forestry at constant 1994 prices is 5 652.5 billion dongs in 2000 (Statistical Year Book 2000).

Key issues of significance are as follows:

- There has been a phenomenal boost in the agricultural sector and food production from 1989–1990 onwards. As a consequence, the country has become a major rice exporting country in the world. Clearly this achievement has significantly contributed to a reduction in the pressure on forest resources.
- Decentralization has led to the strengthening of local governance structures (provincial, district and commune levels).

Status of land use

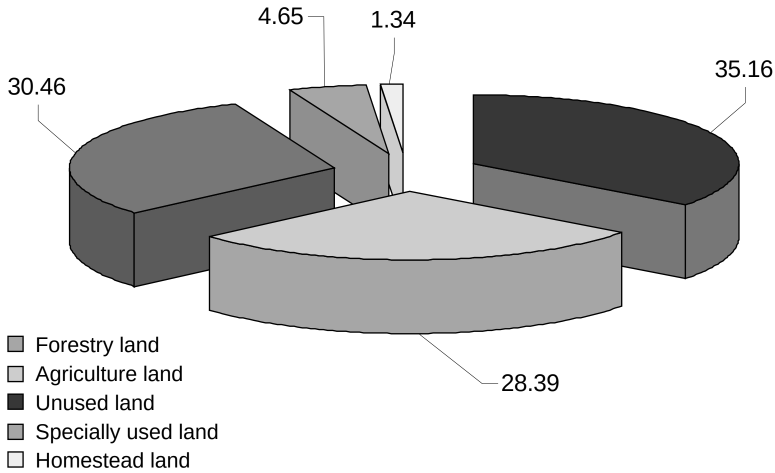
According to the overall inventory of land use in 2000 in the Prime Ministerial Order No. 24/2001/QD-TTg dated 1 March 2001, Viet Nam has a total area of 32 924,061 ha (32.92 million ha)*. Three-fourths of the terrain are hilly and mountainous, with a complex topography carved with many mountains, rivers, high plateaus and plains of different sizes. Hilly areas are relatively sparsely populated, and most of the 76 million* people are concentrated in intensively cultivated alluvial plains. The status of current land use is as follows:

Table 1. Existing land use statistics

Category	Total geog. area		Land granted and for rent	
	Area	%	Area	%
Total area	32.92	100.00	23.84	100.00
1. Forestry land covered by trees	11.58	35.16	9.81	41.13
2. Agriculture land	9.35	28.39	9.35	39.20
3. Unused land, springs, mountains	10.02	30.46	2.71	11.38
4. Specially used land	1.53	4.65	1.53	6.43
5. Homestead land	0.44	1.34	0.44	1.86

Unit: million hectares

* Statistical Year Book 2000.



Source: Statistical Year Book 2000.

Figure 1. Pie chart of existing land use

Key issues highlighted from Table 1 are as follows:

- The total area of unused land, rivers, streams and rocky mountains is 30.46%, of which only 27% is categorized as land granted and for rent implying that the remaining lands in this category could be allocated for reforestation under the National FMHRP to raise forest cover to 43% by 2010.
- The forestry land covered with trees comprises 35.16% of the total land area, of which 82% is under land granted and for rent category.

Forestry sector

Viet Nam is experiencing a fundamental transition period whereby great demands are being put on forests and other natural resources by rapid economic growth. Sustainability in the management of forests and forest lands is a key environmental and social issue. The ongoing policy reform, in particular the allocation of forest lands to farmers, is providing a new basis for future development strategies that have to be converted into action. The Government of Viet Nam is in the process of renovating its strategies for forestry development in order to bring these in line with new, broader socio-economic policies and orientation to a market economy.

Forest cover

An analysis* of the trend of changes of forest cover in Viet Nam indicates that in 1943 the forest cover was 43% of the country's total land, 31.8% in 1976, and 27.2% in 1990 and marginally went up to 28.1% in 1995.

Decision No. 661/QD-TTg dated 29 July 1998 takes into account the national forest cover of 28.1% as per the 1995 inventory which was to be raised to 43% (increase equivalent to 15% of the geographical area) by 2010 by raising additional 5 million ha of forests by natural and artificial regeneration.

* MARD-Department for Forestry Development, National FMHRP-HANOI 2001.

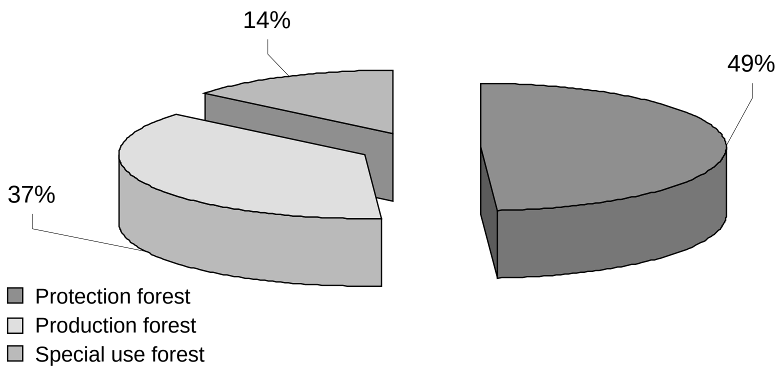
The latest statistics* on forests according to the overall inventory of forest in 1999 by Prime Ministerial Order No. 03/2001/QD TTg dated 5 January 2001 are given in Table 2.

Table 2. Statistics from the forest inventory

Million hectares

Category	Planned forest cover by 2010	Forested area			Non-forested land	FMHRP targets
		Total	Natural	Planted		
1. Protection forest	6.0–6.5	5.35 49%	4.81 90%	0.54 10%	0.7–1.2	1.0
2. Production forest	8 .0	4.04 37%	3.17 78%	0.87 22%	4.0	3.0
3. Special-use forest	2.0–2.5	1.52 14%	1.44 96%	0.06 4%	0.5–1.0	1.0
Total	16.0–17	10.91	9.44 87%	1.47 13%	5.2–6.2	5.0
Percentage of geographical area	50	33.14	28.67	4.46	15	15.0

Source: Draft Forestry Development Strategy 2001–2010.



Source: Draft Forestry Development Strategy 2001–2010.

Figure 2. Pie chart for three categories

The total forest area countrywide is 10.9 million ha accounting for 33% of the total geographical area. Natural forests comprise 87% and plantations 13% of the forest area. Forests are categorized into three functional categories:

- protection forest comprising 49%;
- production forest comprising 37%;
- special-use forest comprising 14%.

* Draft Forestry Development Strategy 2001–2010.

SIGNIFICANCE OF THE NATIONAL FIVE MILLION HECTARES REFORESTATION PROGRAMME

In Viet Nam, the entire thrust of reforestation activities is centered on the National FMHRP and consequently in relation to its objectives and key tasks, an effort has been made to develop the methodology of forest land evaluation and its intended application for improving planning and eventual implementation of reforestation activities.

Objectives

In December 1997, the second session of the Tenth National Assembly of the Socialist Republic of Viet Nam passed a Resolution on the creation of five million hectares of new forest during the period from 1998 to 2010.The National Five Million Hectares Reforestation Programme (FMHRP) has been launched in accordance with a Prime Ministerial Decision No. 661 of July 1998. Subsequently a Joint Circular No. 28/1999 of February 1999 elaborates the targets, guiding principles and tasks of this programme. Another related Circular No. 28/199 of March 1999 embodies detailed guidelines on the management of state funds for the FMHRP. The programme has three major objectives:

1. Establish five million hectares of new forest together with the protection of existing forests in order to increase the forest cover to 43% of the national territory, protect the environment, decrease the severity of natural disasters, increase water availability, preserve gene resources and protect biodiversity.
2. Use open land and bare hills efficiently, create employment opportunities, contribute to hunger eradication and poverty reduction, support fixed cultivation and sedentarization, increase income for rural mountain people, create stable social conditions and strengthen national defence and security, especially in border areas.
3. Provide material for construction as well as raw material for the production of paper, wood-based panels, non-wood products and also fuelwood for local consumption as well as for export; develop the forest product processing industry, make forestry an economic sector, and contribute to improvement in the socio-economic situation in mountain areas.

Tasks

1. Protection of existing forests
   Highest priority will be given to the protection of natural forest classified as special-use forest, and essential and very essential protection forest, including protection forests in Programme 327, as well as production forests with rich and medium stocks. Allocation of forest land to organizations, households and individuals combined with supporting fixed cultivation, sedentarization, hunger elimination and poverty reduction should be made from the very beginning in order to protect, regenerate and plant the forest.
2. Planting of new forests
   (a)Two million hectares of protection and special-use forests are to be created, of which one million are planted through assisted natural regeneration forest and one million through planting in combination with fixed cultivation and sedentarization.
   (b) Three million hectares of production forest are to be created, out of which about two million hectares are for the supply of raw material for paper production, wood-

based panels, non-wood products, and logs of valuable species; and about one million hectares are for plantations of long-term industrial species and fruit trees. In addition, organizations and people are encouraged to plant scattered trees on open land.

Time frame

The planned duration of the programme is for a period of 13 years divided into three phases as follows:

1998–2000: plantation of 700 000 ha (of which 260 000 ha are protection and special-use forests), assisted natural regeneration of 350 000 ha;
2001–2005: plantation of 1 300 000 ha (of which 350 000 are protection and special-use forests), assisted natural regeneration of 650 000 ha;
2006–2010: new plantation of 2 000 000 ha (of which 390 000 ha are protection and special-use forests).

FINDINGS AND RESULTS

Approach and process for developing criteria and indicators for forest land evaluation

Conceptually the underlying approach followed in identifying most relevant biophysical site characteristics and socio-economic parametres (criteria) was mainly based on the existing site classification methods being followed in some projects. To strengthen this analysis, it was made consistent with concepts and principles from the publications listed below.

FAO. 1983: *Guidelines: land evaluation for rain-fed agriculture*. FAO Soils Bulletin 52. Rome.
FAO. 1984: *Land evaluation for forestry*. FAO Forestry Paper 48. Rome.
FSIV 2001: *Assessment of potential productivity of forest land in Viet Nam.*

However, standardized classification systems have to be adapted to match with country specific requirements.

Definitions

- Forest land
  The definition of forest land as given in Decree 163/1999 of November 16, 1999 covering two types of land is as follows:
  – land which has natural or planted forest
  – land which does not have forest but should be afforested through planting, assisted natural regeneration, or protection of vegetation for forestry purposes.
- Non-forested land (bare land)
  According to Regulation No. 84 on Forest Management and Planning issued by the former Ministry of Forestry, non-forested land (bare land) means that the vegetation on the land is not classified as forest.

Non-forested land consists of grass, shrubs or scattered woody trees with crown cover of less than 0.3 density. This is being considered by the FIPI for preparing vegetation status maps and has three categories as follows:

- vegetation cover typically with grass or banana plants;
- vegetation cover of mainly bushes and some scattered timber trees or bamboo;
- vegetation cover comprising regenerated woody trees. The number of regenerated woody trees is over 1 000 trees ha^{-1} which are more than 1 m high.

Scope of use

It should be clearly understood that the proposed criteria and indicators for forest land evaluation have been developed basically for assessment of non-forested lands (bare lands) planned to be assessed for their suitability and potential for forestry/agroforestry interventions in:

- three categories of forests, namely production, protection and special-use forests;
- home gardens, forest gardens, village forests, community forests, commune forests and mass organization forests.

Framework of biophysical criteria and indicators for assessing natural potential productivity

The proposed framework of C & I for FLE has two parts, the first part comprising 6 biophysical criteria and matching 23 indicators (verifiable quantitatively) and the second part comprising socio-economic criteria and indicators (qualitative information). It is necessary to explain that after completing field assessments for each land unit, the next step of consolidating and integrating results from all C & I has to be followed. Therefore, it is proposed to adopt a positive point marking method for consolidation of results by integrating assessments of indicators of 6 biophysical criteria. By this method each indicator is assigned a numerical point 4, 3, 2 or 1 as an index of its potential rating and suitability for FLE. For example point 4 assigned for *Soil type* means that the individual rating of the indicator is the highest and in a descending order point 1 means that the rating is the lowest (Table 3).

Weight age for limiting factors

Based on practical considerations, two criteria, namely *Slope type* and *Soil depth*, which strongly affect potential productivity, are given an overriding weight age as limiting factors while assessing overall grading of a site and adjusting it in three productivity classes as follows:

- Class 1: multiply with 1.5 if slope class is < 15° or soil depth is > 100 cm;
- Class 4: multiply with 0.5 if slope > 35° or soil depth belonging is < 50 cm.

Combination of criteria and grading of indicators

For any intended combination of C & I, the suggested system for assigning points for grading of indicators is as follows:

Table 3. Suggested system for assigning points for grading indicators

No.	Criterion	Indicator	Base point	Adjusted point
1	Soil type	1.1. Loamy soil: medium texture	4	4
		1.2. Clayey soil: heavy texture	3	3
		1.3. Sandy soil: light texture	2	2
		1.4. Eroded and stony soil	1	1
2	Slope	2.1. Slightly sloping: < 15°	4	6
		2.2. Moderately sloping: 16–25°	3	3
		2.3. Steep: 26–35°	2	2
		2.4. Very steep: > 35°	1	0.5
3	Soil depth	3.1. Deep: > 100 cm	4	6
		3.2. Moderately deep: 50–100 cm	2	2
		3.3. Shallow: < 50 cm	1	0.5
4	Vegetation status	4.1. Regrowth trees > 1000 trees/ha, H > 1 m	4	4
		4.2. Regrowth trees 300–1000 trees/ha	3	3
		4.3. Regrowth trees < 300 trees/ha	2	2
		4.4. Mainly grass	1	1
5	Altitude	5.1. Low: < 300 m	4	4
		5.2. Moderate: 300–700 m	3	3
		5.3. High: 700–1700 m	2	2
		5.4. Very high: > 1700 m	1	1
6	Rainfall	6.1. High: > 2000 mm	4	4
		6.2. Moderate: 1500–2000 mm	3	3
		6.3. Low: 100–1500 mm	2	2
		6.4. Very low: < 1000 mm	1	1

Proposed natural potential productivity classes

Based on the above methodology, the potential productivity may be assessed and grouped into three classes as follows:

Table 4. Proposed natural potential productivity classes

Class of potential productivity	Total adjusted points of 6 indicators as per Table 3
1. High – land with few limiting factors for use	> 21
2. Medium – land with some limiting factors for use	12–21
3. Low – land with a number of limiting factors for use	<12

Socio-economic criteria

In Viet Nam a country-wide classification of all regions, down to commune level has been carried out into three categories reflecting the overall status of prevailing socio-economic factors by the Committee of Ethnic and Mountain Areas (CEMA). The three regions are as follows:

I primary development region
II relatively stable region
III difficult region

The above classification is based on the following five criteria:
- residential location—accessibility;
- infrastructure—means of transport;
- social factors—living standards and literacy;
- production condition—agricultural production;
- living conditions—level of poverty and living standards.

Initially four socio-economic criteria, namely accessibility, market, local needs and population density, were identified in consultation with the FIPI and FSIV. However, during the finalization stage, it was considered appropriate to take advantage of the existing classification system to access the present potential productivity of the land.

Assessment of present potential productivity

Based on the assessment of natural potential productivity, and matching it with the classification of socio-economic conditions based on the criteria and indicators of CEMA (region I, region II, region III), the present potential productivity can be assessed as follows:
- If the natural potential productivity of an area of forest land in commune A is assessed high, but commune A is classified as region III, then the present potential productivity of this area is considered medium.
- If the natural potential productivity of an area of forest land in commune A is assessed low, but commune A is classified as region I, then the present potential productivity of this area is considered medium.

Assessment of suitability of species

Finally for site and species matching, suitability of tree species is determined by comparing the actual results of field assessments based on biophysical C & I with standard criteria of suitability for each species. Suitability is classified into four categories:
(i) highly suitable (S1)
(ii) moderately suitable (S2)
(iii) marginally suitable (S3)
(iv) not suitable or very limited (N)

Clearly each species requires a certain environment for growth, such as soil type, slope, climate conditions and altitude. Therefore based on research results of the physio-ecological requirements of specific tree species, the optimum conditions for planting can be inferred. After establishing the standard criteria for suitability assessment of species, it will be followed by matching as described below:

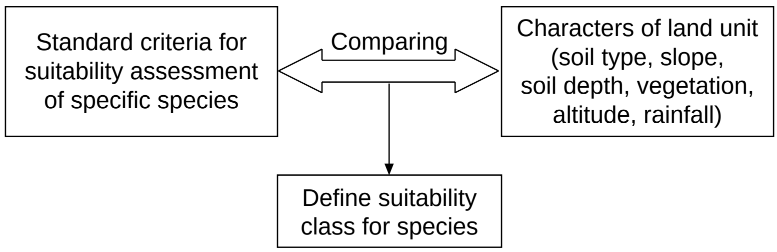


Figure 3. Suggested methodology for matching results

CONCLUSION

- *Innovative initiative:* Conceptually the key objective of developing an enabling framework of criteria and indicators for forest land evaluation is to improve the methodology to evaluate the potential and suitability of forest land for tree planting and natural regeneration.
- *Planning tool for implementation:* For the rehabilitation of degraded forest lands through reforestation, the application of C & I for FLE would be important for implementing agencies. This is done through an analysis of existing data and available maps, supplemented by on-ground verification. The agencies would then be able to realistically assess the potential productivity/suitability of the site and match suitable species for reforestation.

  Thus from a practical perspective, the suggested methodology could provide a strong technical basis for sustainability and economic efficiency of any major reforestation programme.
- *Scope for replication:* The reforestation programmes in many developing countries are generally constrained by scarce financial resources coupled with poor site/species matching. Viewed in this context, the proposed methodology would facilitate efficient implementation through cost-effective field activities of planting suitable species matching with the potential productivity of the site and socio-economic factors.

  Clearly the results, backed by field testing, suggest the scope and practicality of the above methodology as a model for replication in other countries. With the necessary adaptation the eventual implementation of reforestation can be efficiently planned and improved.

BIBLIOGRAPHY

Agriconsulting S.P.A. 2000: *Draft final report. Study on the policy and institutional framework for forest resources management (ADB 3255-VIE).*

CIFOR. 1999: *The CIFOR criteria and indicators*. Criteria and Indicators Toolbox Series.

FAO. 1983. *Guidelines: land evaluation for rain-fed agriculture.* FAO Soils Bulletin 52. Rome.

FAO. 1984. *Land evaluation for forestry*. FAO Forestry Paper 48. Rome.

FAO. 1992. *Land evaluation for forest resource development planning at national level.* Rome.

FAO. 1998. *Asia and the Pacific: National forest programmes: Update 33*. Bangkok.

FAO. 1999. *Terminology for integrated resource planning and management.* Rome.

FAO. 1999. *State of the world's forests.* Rome.

FAO. 1999. *Terminology for integrated resources planning and management.* Rome.

FAO. 2001. *Country profile for the forum on "The role of forestry in poverty alleviation"*. Viet Nam.

FAO. 2001. *A compendium on criteria and indicators for sustainable forest management*. Working Paper FM/5.

FSIV. 2001. *Assessment of potential productivity of forestland in Viet Nam.*

Ministry of Agriculture and Rural Development. 2001. *National Five Million Hectare Reforestation Programme*. Hanoi.

International Cooperation Department. *Forest sector support programme and partnership, Part I. Draft memorandum of agreement.* Hanoi.

Statistical Yearbook 2000. Viet Nam, Statistical Publishing House.

TCP/VIE/0066. *Technical support for the Five Million Hectares Reforestation Project, Project Implementation Plan 2001–2003.*

To Dinh Mai. 2001. *Analysis of policies of the FMHRP.*

25 Operational use of remote sensing and GIS for forest rehabilitation planning

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ABSTRACT

The focus of forest resource management in Malaysia is currently geared towards managing the second growth or second rotation forest in the Permanent Reserve Forest (PRF). To effectively manage the resource much information needs to be collected in particular on the extent and distribution of these forested areas. Even though information on the PRF is systematically collected and recorded, much more need to be gathered as regards the second growth forest. Some of this information can be collected with the help of remote sensing and GIS technologies. This paper highlights the operational use of remote sensing and GIS for forest rehabilitation activities in the second growth forest. Remote sensing technique is used to identify degraded second growth forest, which needs to be rehabilitated. The information was integrated with other spatial information in GIS database which enables analysis to be carried out and decision be made based on various assumptions and scenarios to suit the current suitable forest management (SFM) practices.

INTRODUCTION

Today, among the world's biggest concerns is conserving the existing forest resources to ensure the forest's sustainability for generations to come. Most of the resources are found in tropical countries many of which are developing. A developing country will exploit its natural reserves as much as possible to develop economic and social activities. However, after a series of international conferences and declarations, these developing countries began to realize the importance of sustainability of the forest. Hence steps and measures are being taken to manage the forest sustainably and at the same time derive its benefits. In relation to this, Malaysia, together with other tropical countries rich in

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flora and fauna diversity is committed in taking action to ensure that the remaining forests are managed and ultimately be certified as sustainable managed forests.

At present, most of the natural forests left for harvesting are located in the hill areas, which, due to their poor accessibility has resulted in the need for forest planning. This is where decision-making requires information that is timely, fast, reliable, accurate and easy to manipulate (Ismail *et al.* 1993). Since Malaysia is approaching its second harvesting cycle, information on the status of the forest is very important. Immediately after logging, the status of a forest, whether poor or rich, will determine any rehabilitation treatments that should be carried out. The decrease in the productivity of natural forests following initial logging (Chin 1989) has created interest in planting timber trees in logged forest (Pinso & Moura Costa 1993).

Generally in forestry, conventional remote sensing methodology is based on qualitative analysis of information derived from 'training areas' (i.e. ground-thruthing). This has certain disadvantages in terms of the time and cost required for training area establishment, and the accuracy of results obtained (Rikimaru 2002). To overcome this problem, a new technique was developed by the ITTO where forest status is assessed on the basis of canopy density. The methodology is presently identified as the forest canopy density mapping model or FCD Model.

STUDY AREA

The study was carried out in Tekam Forest Reserve, which is situated northeast of Kuala Lumpur in the district of Jerantut, Pahang, Malaysia. Tekam Forest Reserve is also part of the main range called Banjaran Titiwangsa that stretches in the middle of Peninsular Malaysia. The study area, which covers an area of 10 x 10 km, lies between 102° 32' 24"–102° 37' 48" E and 03° 57' 36"–04° 03' 00" N as shown in Figure 1. It is accessible from the logging road and adjacent oil palm roads. The forest type of the area is Hill Dipterocarp. Topography of the area is undulating steep and rugged hill slopes with most of the slope gradients exceeding 45°. The elevation of the terrain ranges from 60 to 800 m. The forest, which was first logged in 1976 and recently in 1986, consists of trees of various ages. There are 27 compartments within the study area covering 7 690 ha.

MATERIALS AND METHODS

Acquisition of spatial data

Spatial data collection started with compilation of satellite image, maps and some ancillary data. The topographic maps and forest maps are required to obtain information such as land use, contours, river network, roads, compartment boundaries and years of logging. However, to detect changes and to obtain a recent picture of the study area, a satellite image was purchased from the Malaysian Centre of Remote Sensing (MACRES). In this study, the satellite image available was Landsat TM, which was captured in 1998 and is shown as Band 543 in Figure 2. Information about the forest of the study area was obtained from Forestry Department.

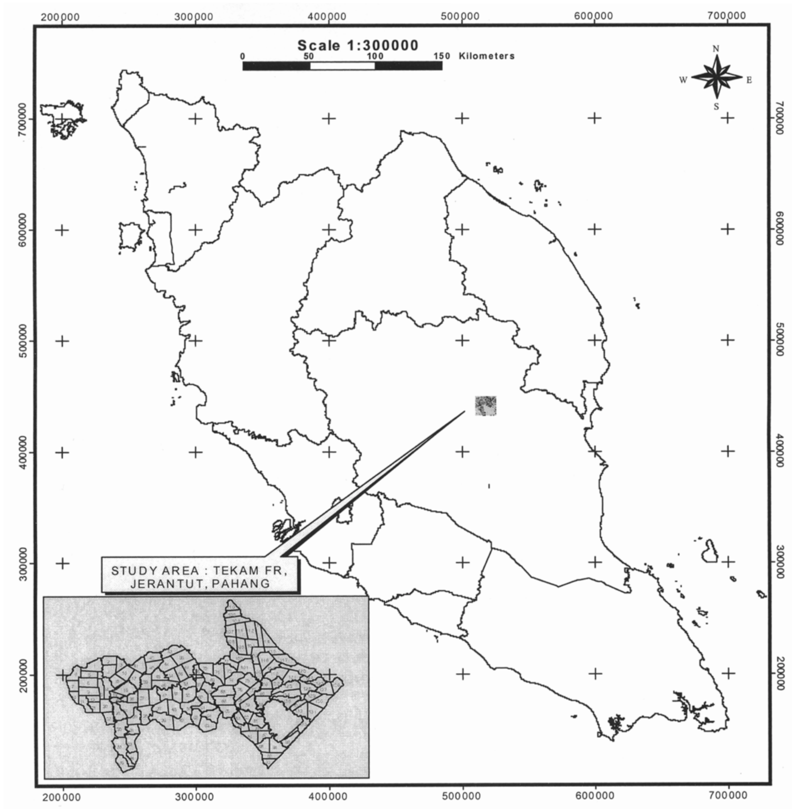

Figure 1. Location of study area

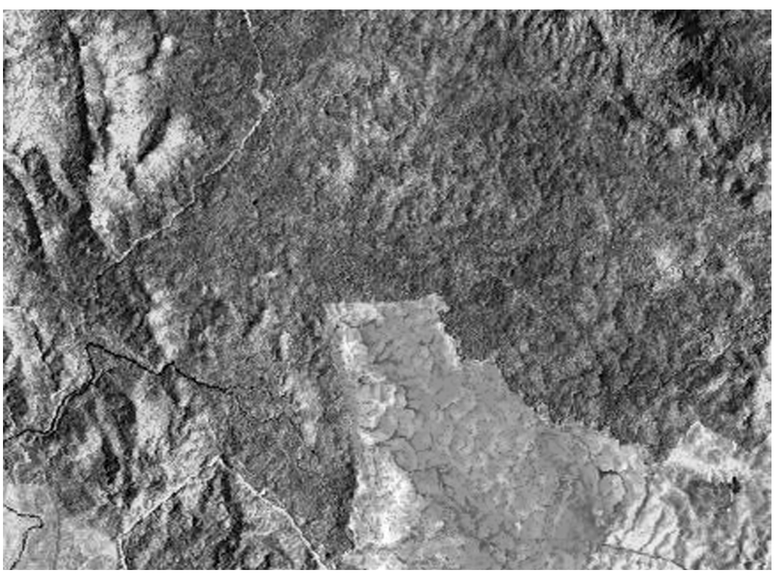

Figure 2. Raw image of Landsat TM Band 543 for Tekam Forest Reserve

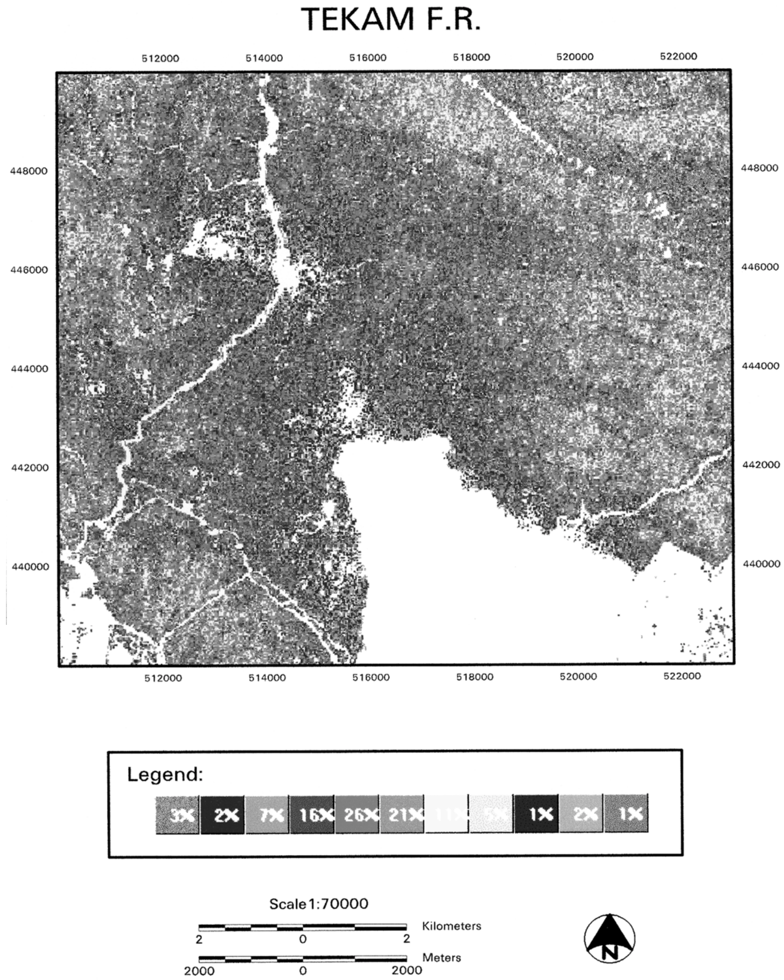

Figure 3. Unsupervised classification of the study area

Image processing

Raw satellite images need to undergo all related pre-processing operations. These pre-processing operations of the remote sensing images are particularly important. Indeed, the quality of this pre-processing will contribute substantially to the accuracy of the final thematic products. In this study, image processing has been adopted using a newly developed model called FCD (forest canopy density). Forest canopy density model (FCD) is based on the growth phenomenon of the forest, which is a quantitative analysis. FCD utilizes forest canopy density as an essential parameter for characterization of forest conditions. The degree of forest density is expressed in percentages. It also indicates the degree of degradation and, hence, the intensity of rehabilitation treatment that may be required. The source of remote sensing data for FCD-mapper is Landsat TM. FCD-mapper is a semi-expert system computer software package compatible with windows-type personal computers. In this study, the image was first processed for noise reduction

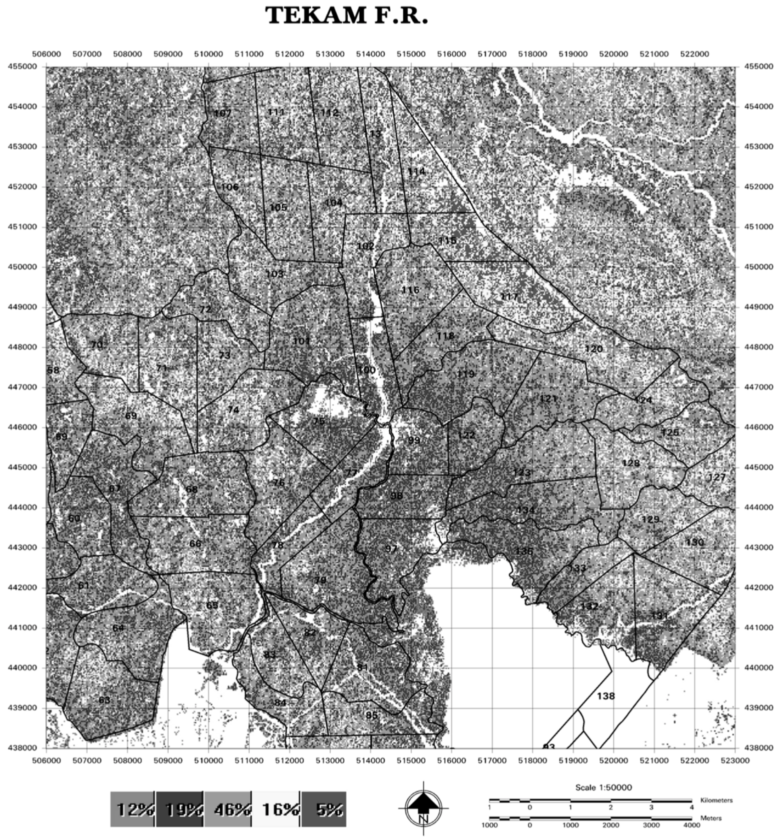

Figure 4. Supervised classification of the study area

because clouds or cloud shadow or water area could adversely influence the statistical treatment and analysis of imagery data. Then, range normalization of the Landsat TM data for each band was carried out. The FCD model comprises biophysical phenomenon modeling and analysis that utilizes data derived from four indices:

1. advanced vegetation index (AVI)
2. bare doil index (BI)
3. shadow index or scaled shadow index (SI, SSI)
4. thermal index (TI)

The four index values were calculated in percentage for each pixel. Using the above four indices and modeling operation, the FCD of the study area was determined. Then, unsupervised classification using the FCD model was carried out. Altogether, ten classes were assigned and the result of the classification is shown in Figure 3. However, when ground thruthing was carried out, it was found that only five different classes could be identified. This information was then keyed in to perform supervised classification and the result is shown in Figure 4. The flowchart of the procedures for the FCD mapping model is illustrated in Figure 5.

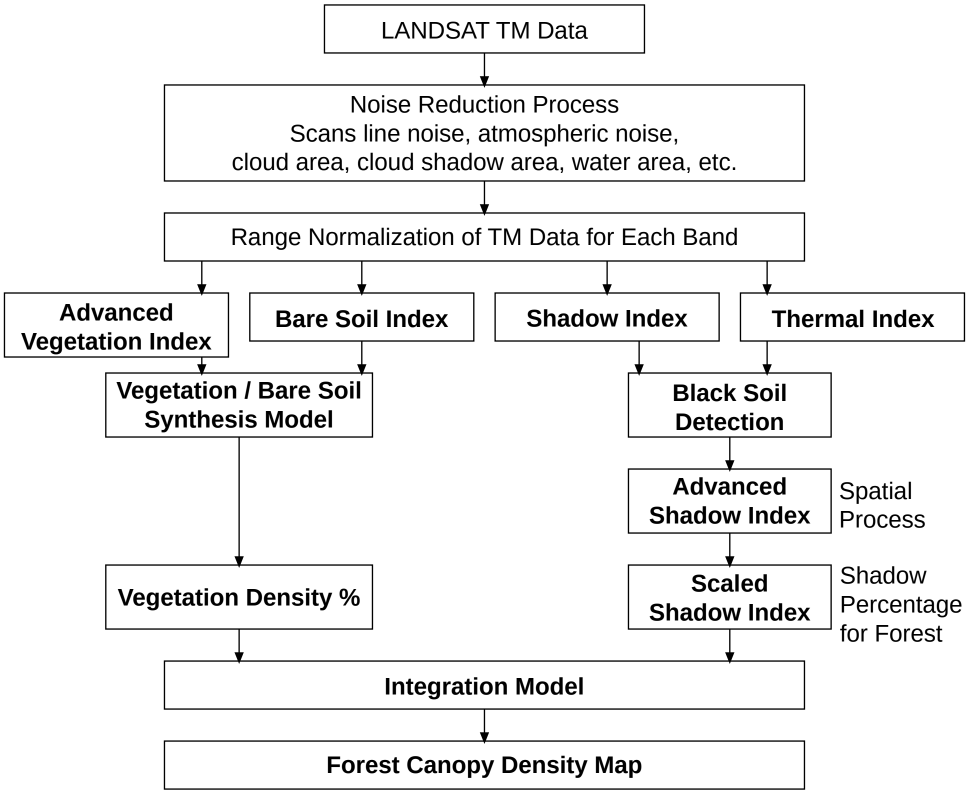

Figure 5. Flow chart of FCD mapping model (Rikimaru 2002)

Ground thruthing

Ground truthing was carried out to verify the compartment boundaries, forest class and also to observe any special features that could not be detected by the image. For each forest class, several ground thruthing plots were established and various data were collected from each plot. Basically, ground thruthing gives a description of the forest features, such as layers of trees, dominant tree spp., elevation, location, understorey vegetation and tree diameter at breast height (dbh). Once these data were collected, they would be keyed into the computer to define the classified image and related maps were produced.

RESULTS AND DISCUSSION

Results from the FCD supervised image in Figure 4 are summarized in Table 1. When supervised classification was carried out based on ground thruthing data, it was found that all ten classes assigned in the unsupervised classification could be reduced and categorized into five classes. From these five classes, forest density class of 30–50 percent has the highest density percentage, i.e. 46 percent whilst class >70 percent has the lowest, i.e. 5 percent. Forest density class 15–30% has 19% density whereas class <15 percent has 12 percent. If these two classes are combined, the total density percentage is 31 percent of the whole study area. For rehabilitation purposes, only these two classes are considered.

From the ground thruthing, it was found that class <15 percent has no big trees (dbh >60 cm) and consists of skid trail, roads and decking site but class 15–30 percent has a few big trees. However, both classes have many saplings and seedlings, showing that the volumes of seedlings and saplings in the study area are high and these might provide a sufficient volume for the next harvesting cycle. The result also indicates that the area might have had rehabilitation treatment before and therefore the forest growth is ensured. Nevertheless, rehabilitation treatments are still needed, especially in the areas of the class <15 percent which are near open spaces like skid trail, roads and decking sites.

Table 1. FCD results based on supervised image

FCD classes (%)	Colour	Density (%)
>70	Green	5
50–70	Yellow	16
30–50	Brown	46
15–30	Blue	19
<15	Light blue	12

From the results, it can also be concluded that the number of big trees in the study area is low. This is because the percentage of the forest canopy density, which is more than 70% is only 5 percent of the total study area. This is further emphasized by the FCD percentage class 50–70, where only 16% of the study area falls under this category. Again, if these two categories are added up, only 21 percent of the whole study area consists of bigger trees.

CONCLUSION

The study clearly shows that the forest canopy density technique could be used to classify logged-over forest into different forest canopy density classes. This information will enable forest managers in identifying degraded areas that need to be rehabilitated and in planning treatments or rehabilitation techniques that should be carried out in these areas.

BIBLIOGRAPHY

Alias, M.S., Zulkifli, M., Mohd Puat, D. & Ibrahim S. 2001. *Canopy density mapping —a new tool for forest management.* Paper presented at the 13th Malaysian Forestry Conference. 20–25 August 2001. Johor Bahru, Malaysia. 12 pp.

Chin, S.C. 1989. Managing Malaysia's forests for sustained production. *Wallaceana* 55:1-11.

Ismail, H., Khali Aziz, H. & Azman, H. 1993. *The use of remote sensing and geographic information system in tropical forest in Peninsular Malaysia*. Paper presented at the 21st International Forestry Student Symposium, 22–24 November 1993. Universiti Pertanian Malaysia, Serdang, Selangor, Malaysia. 8 pp.

Khali Aziz, H. 2002. *Classification technique of second growth forest. Preliminary results for Sungai Tekam Forest Reserve study area.* Paper presented at the RM8 Second Growth Forest Project Committee Meeting. 17 April 2002, FRIM, Kepong, Malaysia.

Nezry, E., Yakam-Simen, F., Romeijn, P., Supit, I. & Demargne, L. 2000. *Advanced remote sensing technique for forestry applications: a case study in Sarawak, Malaysia*. Invited paper at Multi-Conference on Systemics, Cybernetics and Informatics, 23–26 July 2000. Orlando, USA. 6 pp.

Pinso, C. & Moura-Costa, P.H. 1993. Greenhouse gas offset funding for enrichment planting—a case study from Sabah, Malaysia. *Commonwealth Forestry Review* 72: 343-349.

Rikimaru, A. 2002. *Concept of FCD mapping model and semi-expert system*. Paper presented at the International Workshop onTropical Forest Cover Assessment and Conservation Issues in Southeast Asia. 12–14 February 2002, IIRS, Dehradun, India. 10 pp.

Safiah Yusmah, M.Y., Khali Aziz, H., Rodziah, H. & Abd. Azhan Shah, I. 2001. *Forest type classification using AIRSAR image data*. Poster presented at the International Conference on Forestry and Forest Products Research, 1–3 October 2001, Kuala Lumpur, Malaysia.

Van Oorschot, G., Van Winkel, I. & Moura-Costa, P. 1996. The use of GIS to study the influence of site factors in enrichment planting with dipterocarps. *In* S. Appanah & K.C. Khoo, eds. *Proc. Fifth Round-Table Conference on Dipterocarps*, pp. 267–278. Kepong, Malaysia, FRIM.

26 Policies and practices for the rehabilitation of degraded lands and forests in leasehold forestry, Nepal

Shree Prasad Baral*

ABSTRACT

This paper aims primarily to share experiences gained in Nepal in the rehabilitation of degraded forest lands and forests and its impacts on the local communities. The government policy is to lease out patches of degraded forest lands to small groups of poor families ensuring long-term land tenure for a maximum of 40 years, with extension for another term. From 1993 to 2001, a total of 7 000 ha degraded forest lands has been leased out to 1 655 groups covering 11 255 poor families. Moreover, leasees are given minimum inputs, forage seeds and planting materials, with training and simple technology. The processes of rehabilitation of degraded lands, with total participation of poor families are: protection from grazing and fire, invigoration of natural regeneration of desired species and their proper management, promotion of hedgerows along contours, and planting of perennials and preferably leguminous forage species, fruit trees and multipurpose tree species. The government policy is that all the benefits from the leasehold forests can go directly to the leasehold families by a group decision or sale of surplus products without sharing with government agencies. An assessment showed that vegetation that covered only 32% of degraded land in a newly handed-over area steadily increased to 50% in the 2-year-old group, 68% in the 4–5-year-old group and 78% in the 6–7-year-old group. Likewise, the most significant measurable difference in the vegetation between 1994/95 and 2000 is the tremendous increase in species diversity. Leasees directly benefited from huge amounts of fodder, fuelwood and other non-timber forest products from these forests in reduced collection times, especially by women who are the main workers in the hills. With the increased production of forage, poor families have now increased the number of goats and milking buffaloes that give them a good source of income. Despite many challenges, this leasehold policy is successful and the government has converted it from project to programme, implemented in 30 districts.

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INTRODUCTION

Context of degradation of natural resources in Nepal

Of 23 million population, 52.7% people of Nepal reside in hills and mountains (CBS 2002). And, over 60% of the households in these regions are living below the poverty line. Fragmentation of lands, declining productivity and deteriorating farm incomes have forced families to become increasingly reliant on common access resources, i.e. forest resources. The forest provides various goods and services to the rural people, which consist of forest products like timber, fuelwood, fodder, leaf-litter, agricultural implements and several other types of non-timber forest products (NTFPs). These days, collection and sale of NTFPs have become a good source of income and employment to a large number of the rural poor in hills and mountain regions. Intangible goods and services include the forest's role in soil conservation and enrichment and environmental and biodiversity conservation. In Nepal, fuelwood is a major source of energy for the rural population. About 94% of fuelwood comes from the forest. Moreover, there are no other visible sources for substitutes of fuelwood in the near future (HMG 1989).

In hills and mountain regions, there is strong linkage between agriculture and forestry. Farmers collect dry leaf litter from the forest and use it as animal bedding material. Mixed with animal dung, it is converted into compost and applied to farmland. To sustain the subsistence farming system of one hectare of agricultural land, it requires 1.33–2.8 ha of unmanaged productive forest (Wyatt-Smith 1982, Mahat *et al*. 1987).

Livestock raising is an important agricultural enterprise and also the source of off-farm income. Free grazing of animals in the forest is a very common practice and it is widespread all over the country. Trampling by animals in the forest compacts the soil and negatively affects the sprouting and natural regeneration of valuable species. Further, heavy pressure on the forest for firewood, fodder and grazing is the main cause of forest degradation.

Of 14.72 million hectare land area, forest covers about 4.27 million ha (29%) and shrubs 1.56 million ha (10.6%). From 1978 to 1994, the forest area declined at an annual rate of 1.7 percent. Both forest and shrubs together have decreased at an annual rate of 0.5 percent (DFRS 1999). It is estimated that about 240 million cubic meters of topsoil are lost every year. Similarly, Nepal's forest area, which was 45% in 1964, declined to 37% in 1986 and further to 29% in 1998.

The incidence of poverty is higher in the rural setting than in urban areas. It is severe in remote parts of the hilly and mountainous regions, which are most exposed to environmental risks. The resulting situation is that high levels of poverty are manifested in and reinforced by further depletion of the natural resource base.

The degraded forest lands, which are handed over to the poor families, are poor sites, exposed rocky, stony places, dry land with severely eroded topsoil, shrubland, barren land and riverbeds (Figure 1). Soil analysis shows that the majority of leasehold sites are acidic, deficient in nitrogen and phosphate and low in organic matter with poor to very poor soil fertility and minimum depth of topsoil. A large number of native plant species available in degraded sites have low nutritional status and productivity, which is estimated at 0.5-1 tonnes of green matter ha^{-1}. However, some of the indigenous species that are present in sample plots, such as *Heteropogon contortus, Pogonatherum* species, *Desmodium* species and *Flemingia* species, have been said to increase milk and butter production, indicating therefore that they have substantial nutritional value (Pariyar 1996).

The grassland area has little plant cover and low productivity. Shrubland, on the other hand, consists of relatively better sites, with moderate soil fertility, thicker topsoil and better moisture retention capacity (Pariyar 1996, Singh 2000).

Figure 1. Degraded lease land

Government policies

Poverty alleviation is the prime objective of the government programmes (NPC 2001). The Agricultural Prospective Plan (1995) has a long-term vision for economic growth and poverty reduction. The overall strategies supported by the plan include integrated development of the agriculture and forestry sectors, reduction in economic and social disparities among communities and regions, empowering local bodies and cooperatives for sustainable development of different economic sector, and expanding social and economic services to the backward communities and regions

The Master Plan for the Forestry Sector (MPFS) in 1989 aims to fulfill the needs of the people for fuelwood, timber, fodder and other forest products on a sustainable basis and to protect the land against degradation. In order to meet the objectives the MPFS has adopted six primary development programmes. The National and Leasehold Forestry Programme is one of them. The main strategy of the Master Plan is to enlist the active participation of the people and hand over the forest to them to the extent that they are interested and capable of managing the forest resources (HMG 1989).

The concept of leasing degraded forest to any persons and institutions was introduced in 1978. However, a trivial attempt was made to bring it into field reality. The MPFS 1989 focuses on leasing forest land for industrial plantation. The amendment of Forest Rules 1978 in 1989 opened the arena of leasehold forestry to hand over forest lands to families living below the poverty line stating that '*Majesty's Government (HMG) may prepare project related to the leasehold forest for the communities living below the poverty line and hand over the leasehold forest to the beneficiaries of such project*'. This policy was given further continuity in the Forest Act 1993 and the Forest Regulation 1995 which has replaced the previous forestry laws.

The community-based leasehold forestry has been actually implemented since 1993 which allowed for the leasing of forest land to poor communities.

The Ninth and Tenth Five-Year Plans (1997–2007) recognizes the role of leasehold forestry in poverty alleviation and stated that '*support to poverty alleviation will be* *provided by promoting leasehold forestry through the identification of policy related and legal problems seen in the sectors'*. As per the spirit of government policy, leasehold forestry policy has been made simplified and conducive.

His Majesty's Government has recently approved the Leasehold Forest Policy 2002. This policy has explicitly defined the land to be leased and simplified the handing-over process to the leasee.

Potential lease land
- shrublands
- areas recovered from encroachers
- rehabilitated forest area
- forest areas having less than 20% crown cover
- sensitive areas for soil conservation

The policy is to amend the forestry laws to decentralize authority to the District Forest Officer (DFO) for approval of lease application, hand over lease land, redefine the poor families in consultation with the National Planning Commission (NPC) and other concerned organizations, and develop mechanisms of benefit sharing from the existing old trees in the lease land, and exemption to submit financial feasibility reports for the groups of poor families.

Translation of policies into practices

The concept of leasehold forestry for the poor has come into practice through the Hills Leasehold Forestry and Forage Development Project (HLFFDP) since 1993. The main objectives were to improve environmental conditions by rehabilitating degraded lands, and to raise the incomes of the poor families. The mechanism is to lease out small patches of 5 to 10 ha degraded forest lands to the small groups of 5–10 households for a period of 40 years. The target groups are the families living below the poverty line (and also called small and marginal farmers), i.e. families with less than 0.5 ha of private land and/or per capita income of less than $50 per annum.

This is an integrated programme involving the Department of Forest (DoF), the Department of Livestock Services (DLS), the Nepal Agricultural Research Council (NARC) and the Agricultural Development Bank, Nepal (ADB/N). The DoF is the lead agency and responsible for coordination in the central level. The District Forest Officer (DFO) coordinates the project at district level and initiates the leasing process. The DLS is responsible for technical support to leasehold groups for fodder and pasture development, and the animal health services. The ADBN is responsible for the identification of the poorest households and credit to the leasehold farmers for the income generating activities. The NARC is responsible for carrying out the applied research on forage and providing inputs such as grass and legume seed, rootstock and improved breeding stock.

The government policy documents focus on rehabilitation of degraded lands, environmental conservation and poverty reduction through people's participation (APP 1995, MPFS 1988 & Tenth Five-Year Plan, 2002–2007). APP recognizes the need to expand livestock production in the hills with enough supply of fodder and forage from the forest. Similarly, the MPFS recognizes that the management of community forest would play the primary role in the restoration of public forest land in the hills. The leasehold forestry is an appropriate instrument to tackle the issues outlined by the policies in the development objectives.

To translate the leasehold forestry concept into practice the first step is the identification of the degraded blocks of forest land to be leased out, followed by the identification of families below the poverty line. Assisting them in the preparation of their management plan for the lease land improvement, and providing technical support and minimum inputs for the rehabilitation of degraded land are the joint responsibilities of the line agencies.

In order to develop suitable technology for the different eco-zones, an Integrated Research, Development and Extension Training Programme (IRDET) has been developed and applied in leasehold sites. These initiatives include a farmer-based field network that integrates research, development and extension work.

The IRDET focuses on:

- minimum tillage and line planting;
- use of leguminous fodder trees, shrubs and pasture species;
- strategic use of starter fertilizer;
- cut and carry management;
- protection of the lease land from grazing and fire;
- protection and management of multi-purpose species in natural regeneration as well as plantation.

For action research, detailed information on the local preference for common fodder species, land formation and soil composition, vegetation analysis, and socio-economic conditions was collected. The farmer's perceived constraints and preferences for developing fodder for livestock on their lease land were analysed.

For research purpose leasehold sites have been classified into three altitudinal zones, namely (a) low altitude 400–1 200 m altitude, (b) transitional zone 1 201–1 800 m, and (c) high altitude 1 801–2 500 m altitude.

The NARC was the leading organization for research. Other line agencies (forestry, livestock services and microcredit) were involved in the selection of sites and development of strategies. Leasehold members were consulted, motivated and brought into the consensus through the process of orientation. All necessary technical as well as material supports were provided by the NARC. Local beneficiaries were involved in site preparation, sowing, planting and weeding and protection of sites from grazing and fire. Moreover, the concerned leasehold groups now own all the products of action research. Singh (2000) stated that the involvement of beneficiaries in action research gave them exposure on:

- preparation of contour line with the help of A-frame;
- land preparation method with minimum tillage;
- identification and selection of suitable forage and tree species for degraded land rehabilitation and improvement of soil fertility;
- proper sowing, plantation and curing as well as harvesting techniques;
- sharing of forage species for goats, cattle and buffaloes.

In order to develop processes, the following research trials were conducted in the leasehold sites.

Pasture legume establishment trials: In each eco-zone, twelve research plots were established. *Stylosantheses guianensis* (cv. Cook) was tested in low and transitional altitudes with and without fertilizer including minimum tillage (Figure 2). This trial included (i) primary turf skimming not deeper than 20 cm and covering 30 cm bands along hill contours at 70 cm intervals; (ii) lime sowing (5 kg ha^{-1}), inoculation; (iii) lime pelleting of the seed (10 kg ha^{-1}); and (iv) a basal dose of (starter) fertilizer applied, $N:P_2O_5$, and S at the rate of 45:115 and 30 kg ha^{-1}. Local grasses were occasionally cut from between five and ten inches on both sides of the turf in order to increase green fodder production and control competition. This procedure was repeated three to four times each year. The productivity data were collected each year. Parameters collected including sward height, plant tillering, and green matter (GM) yield.

Figure 2. Minimum tillage and contour planting

Similarly, in the moist sites of high altitude white clover (*Trifolium repens* cv. Khumaltar) was tested under minimum tillage lime coating, inoculation, proper sowing depth and use of starter fertilizer (NPK+S) 34:75:0 + 30 kg ha^{-1} with and without fertilizer (Figure 3).

Figure 3. Forage production in the lease land

Action research showed that the condition of open degraded grassland and shrubland improved through the technology generated under minimum tillage and lime sowing, use of starter fertilizer (45:115:0 + 30 kg ha^{-1}), inoculation and lime pelleting up to 1 700 m altitude. Using this simple technology, *Stylosantheses guianensis* (cv. Cook) produced an average of 34 tonnes GM ha^{-1} vs the original vegetation production of 1 tonne ha^{-1} in low altitude and 9–15 tonnes ha^{-1} in transition belt. In addition, soil fertility was increased due to the inclusion of legume species. It was observed that soil erosion was reduced by covering more than 70 percent of the land with beneficial plants. Above 1 700 m altitude, white clover (*Trifolium repens* cv. Khumaltar) showed the potential to produce 3–5 GM tonnes ha^{-1} under occasional grazing in the moist sites with minimum tillage, lime coating, inoculation, proper sowing depth and use of starter fertilizer 34:75:0 + sulphur 30 kg ha^{-1}.

Introduction of minimum tillage (20 x 30 cm at 70-cm intervals) along contours in hills and mountains reduces the inputs requirement and the soil erosion risk. Biologically a forest killer, the annoying and invading weed, *Eupatorium* species, has been easily replaced by the introduction of stylo and molasses in the degraded and bushy areas.

Nitrogen fixing trees/shrub establishment trials: At four sites in low and transitional altitudes seedlings of *Bauhinia purpurea*, *Leucaena divertifolia*, *L. pallida* and *L. leucocephala* were planted along the contours at five-meter distances (plant to plant and row to row). Planting technology included three treatments: T1, the recommended method (50 x 50 x 50 cm pit size + DPA 250 g and sulphur 150 g); T2, the current improved practice (30 x 30 x 30 cm pit size); and T3, the indigenous method (20 x 20 x 20 cm).

Farmers also planted other local multipurpose tree species. The parameters were plant height, number of branches per plant and survival rate. *Bauhinia purpurea* and *L. leucocephala* in three years attained the height over 2–3 m and over 68% survival up to 1 700 m altitude under proper pit size and management of 50 x 50 x 50 cm + starter fertilizer (250 g DPA+ 150 g sulphur per pit).

Fodder hedgerow establishment trials: Seven leguminous shrub species were introduced in a low altitude belt in the degraded lease land using the simple method, along the contours and working the soil with a pickaxe. Results show that four species, *Crotalaria* species, *Flemingia congesta, Cajanus cajan* and *Tephrosia candida,* are promising. Some of these species also produce green fodder in the dry season. Farmers preferred *F. congesta,* which provides a large amount of green fodder throughout the year.

The poor farmers, involved in action research, are knowledgeable and skillful in the rehabilitation of degraded lands. They are now working as extension agents. However, poor farmers lack money to purchase and apply fertilizer not only for lease land but basically for cereal crops. In such a situation, application of fertilizer in degraded land is questionable for forage development. Action research was also targeted to identify local species for degraded sites, proper time of sowing, establishment of multipurpose trees, suitable hedgerow species and effectiveness of different fodder and hedgerow species on degraded lands.

Still, suitable species above 1 700 m altitude have not been explored for rehabilitation of degraded lands. Due to the harsh climatic condition, the growth and regeneration of vegetation is much slower. Large areas of grass and bushy rangeland are distributed in this region; thus, livestock rearing is the prime enterprise for them. But stall feeding of livestock is not an attractive option.

The leasehold forestry project has developed very simple techniques to restore the degraded lands; these techniques are easily adopted by the poor families. This mechanism usually includes the protection of degraded lands from fire and grazing, and includes plantations of multipurpose tree species, leguminous and perennial forage species. However, very small patches of land are planted with such species. Tree plantation is not very successful. In the low altitude moist sites, regeneration of grasses, shrubs and woody species is flourishing. Studies of species diversity in two sites between 1995 and 2000 show a tremendous increase in species diversity, i.e. in a 9-ha leasehold forest, an increase of 57% and in a 76-ha lease land, an increase of 86% (NFRI 2000, Ohler 2000).

From 1993 to 2001, a total of 7 000 ha degraded forest land has been leased out to 1 655 groups covering 11 255 poor families of about 78 000 population. Many case studies confirm the positive impacts of rehabilitation of degraded land on the livelihoods of the targeted beneficiaries by increases in the species diversity over time. Forest lands have become more structured, and multi-layered resulting in easy availability of fodder and fuelwood, reduction of fodder shortage period and increased stall feeding practices. Moreover, there is increased income and diversification of income sources from livestock (goats to buffaloes), and off-season vegetable farming which has increased the food security periods of the leasee.

The assessment showed that the structure of vegetation has changed, the number of tree saplings increased, but the average height and size decreased, because the new saplings are below the average height. Much change has occurred in the ground vegetation with decrease of local weeds. An assessment on the vegetation cover showed that in a newly formed group only 32% of the ground was covered with vegetation which steadily increased to 50 percent in a one- to two-year-old group, to 68 percent in a four- to five-year-old group and 78 percent in a six- to seven-year-old group (Figure 4) (Ohler 2000, Singh & Shrestha 2000).

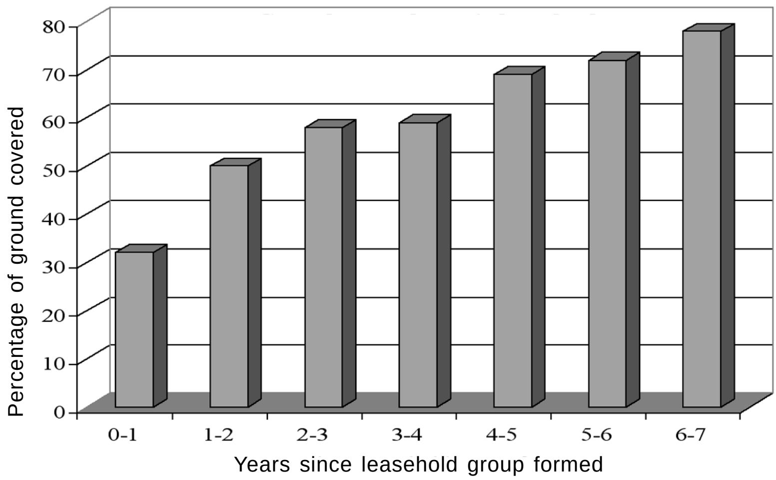

Figure 4. Ground cover change in lease land

Due to the increased vegetation on the leasehold forest, farmers have progressively been able to harvest forest products (fodder, animal bedding materials and fuelwood). It is noted that most of the lease lands were idle before handing over. This is a good indicator of the progressive improvement in the degraded forest lands.

Yadav and Dhakal (2000) concluded that many leasehold sites, which were barren at the time of handing over, have now been developed into green lush areas covered with trees, grasses and natural regeneration. This has improved the ecological balance in the area through revegetation and soil stabilisation. It has achieved poverty reduction in an environmentally sustainable manner.

The project data indicate that at least 60 000 ha of degraded lands are still available for leasehold forestry in project areas, which would be sufficient for at least 80 000 families. At the national level, enough degraded forest could be available to hand over a half to one hectare of the land to each of the approximately 0.9 million poor households (households with less than 0.5 ha of land) in the hills and mountains (Yadav & Dhakal 2000).

PROBLEMS AND CONSTRAINTS

- Leasehold forestry for the poor is limited to the handing-over of degraded forest.
- Simple technology and suitable species for degraded sites above 1 700 m altitude have not been devised. Thus, the present technology may not be applicable in such sites.
- Chemical fertilizer is an expensive imported input, which is not readily available in all the locations and sites, particularly in remote hills and mountains. Further, poor farmers are not in a position to afford the use of fertilizer even in the degraded sites as starter as recommended by the research.

RECOMMENDATIONS

- The Forest Act and Regulation should be amended to bring leasehold policies into practice in spirit.
- The protection of natural regeneration seems to be more effective for tree establishment in degraded sites than new plantations. Indigenous local species are most likely to succeed under high degraded and harsh climatic conditions. Whenever possible, tree establishment should be carried out through natural regeneration, direct seeding, transplanting, protection and ground cover management. Focus should be given on the nitrogen-fixing species of grasses and trees, which are important for soil improvement.
- A more integrated approach is required to improve degraded lands by the execution of different activities, assuring better coordination and unification of the inputs of the agencies concerned; such a holistic approach will result in more impact than isolated interventions.
- Protection from grazing and fire invigorates natural regeneration, which is the cheapest option for the rehabilitation of degraded lands both in hills and mountains.
- Technology developed for the rehabilitation of degraded lands should be simple and affordable. The approaches could be replicated and tested on different eco-zones. The methodology developed under the IRDET can be replicated and tested over a wide range, provided appropriate technological support is given.

CONCLUSION

Community-based leasehold forestry intervention has contributed greatly to the rehabilitation of degraded forest lands and improved the economic conditions of the village poor. There is steady increase in vegetation coverage both from protection and supplementary planting of forage and multipurpose tree species using simple technology. This technology can be easily and widely adopted for the rehabilitation of degraded lands in the hills and mountains. Assessing the good impacts of the leasehold forestry, the government has extended this modality in 30 remote and challenging districts to address both poverty and environmental issues. The project approach has been changed into programme approach as a regular programme of the government rather than of donors. The Tenth Five-Year Plan (2002–2007) has also taken it as a national priority sector programme.

There is a need to reconsider the integration of leasehold forestry and community forestry for long-term viability. This will minimize conflicts in future. It will also help address the current burning issue of social equity in community forestry. Leasehold forestry is a relatively new approach of degraded forest management; it is likely that new issues will keep coming up, for which amendments to the policies, acts and rules may be needed from time to time. If the legal environment is made conducive, this programme can safely flourish on a national scale, addressing the issues of poverty and environment.

REFERENCES

CBS. 2002. *Statistical pocket book*. Kathmandu, Nepal, National Planning Commission Secretariat Central Bureau of Statistics.

DFRS. 1999. *Forest resource of Nepal (1987–1998).* Kathmandu, Nepal, Department of Forest Research and Survey, Ministry of Forest and Soil Conservation.

HMG. 1989. *Master plan for the forestry sector.* Kathmandu, His Majesty's Government of Nepal.

Mahat, T.B.S., Griffin, D.M. & Shepherd, K.R. 1987. *Human impact of some forests of the middle hills of Nepal: forest in the subsistence economy of Sindhupalchok and Kabhreplanchok*. Mountain Research Development.

NARC. 2000. *Annual report.* Khumaltar Lalitpur, Hills Leasehold Forestry and Forage Development Project, Nepal, Nepal Agricultural Research Council, Pasture and Fodder Research Division.

NFRI. 2000. *Impact assessment of the Hills Leasehold Forestry and Forage Development Project on vegetation and social development in Bhagawatisthan site*. Project Internal Document 14/2000. Kathmandu, Nepal.

Ohler, F.M.J. 2000. *The impact of leasehold forestry on livelihoods and environment*. Kathmandu, Nepal, Hills Leasehold Forestry and Forage Development Project.

Ohler, F.M.J. 2001. *The impact of leasehold forestry on marginal mountain farms of Nepal*. Paper prepared for the International Symposium on Marginal Mountain Farms, Kathmandu, Nepal.

Pariyar, D. 1996. Forage resource development on degraded land in Nepal: a new approach. *In* D.J. Miller & S.R. Craig, eds. *Rangelands and pastoral development in the Hindu-Kush Himalayas*. Proceedings of a Regional Experts Meeting, November 1996. Kathmandu, Nepal, International Centre for Mountain Development.

Singh, B.K. 2000. *Rehabilitation of degraded forestlands by the poor families in the hills of Nepal: the community-based action research.* Paper presented in the XXI IUFRO World Congress, Kuala Lumpur, Malaysia.

Singh, B.K., & Shrestha, B.B. 2000. *Status of leasehold groups and leasehold sites.* Kathmandu, Nepal, FAO.

Wyatt-Smith, J. 1982. *The agricultural system in the hills of Nepal: the ratio of agricultural to forest land and the problem of animal fodder*. APROSC Occasional Paper 1. Kathmandu, Agricultural Projects Service Centre.

Yadav, R.P., & Dhakal, A. 2000. *Policy outlook: leasehold forestry for the poor, an innovative pro-poor programme in the hills.* Kathmandu, Nepal, HMG Ministry of Agriculture/Winrock International.

27 The effects of forest restoration activities on the species diversity of naturally establishing trees and ground flora

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ABSTRACT

The framework species method of forest restoration aims to rapidly re-establish forest ecosystem structure and function. At the same time, it aims to encourage wildlife, attracted to the planted trees, and accelerate recovery of biodiversity through facilitating seed dispersal into planted sites. The objectives of this study were to determine whether forest restoration encourages recruitment of non-planted tree species into planted areas and increases the species diversity or changes the species composition of the ground flora. The study was carried out on degraded, evergreen forest land in Suthep-Pui National Park, northern Thailand. The land had been planted with 30 framework tree species in 1997 and 1988 to compare the relative performance of different framework tree species and develop suitable silvicultural treatments to maximize tree performance. Treatments included fire protection, application of fertilizer, and weeding. Two non-planted control plots were also demarcated, in which only fire protection was implemented. Vegetation surveys were carried out in replicated 10-m diameter plots, recording the presence of ground flora species and naturally established trees (> 1 m tall). They were carried out three times in 1999: in the dry season, in the middle of the rainy season and at the end of rainy season. In the first year after planting, the species richness and evenness of the ground flora in the plot planted in 1998 increased, compared with the plot planted in 1997. This was probably due to the effects of weeding, which removed dominant perennial herbs, allowing invasion, in the 1998 planted plots, by annual herbs, especially those of the Compositae family. However, two years after tree planting, the diversity of the ground flora decreased in the 1997 planted plot. This was probably due to shade caused by closing of the forest canopy, which reduced opportunities for establishment

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of new ground flora species. Evenness was also lesser here as compared to the 1997 control plot, since fire removed most of the dominant weed species. Weeding and fertilizer accelerated establishment of natural seedlings and further increased the tree density of naturally established trees (wildings) in the planted plots. Most of planted tree species were in good health and fast growing. All of the planted tree species, except Nyssa javanica and Garcinia meckeaniana, were found suitable for forest restoration.

INTRODUCTION

Many countries have recognized the value of rehabilitating degraded tropical area, to utilize natural resource for sustainable development and maintain biodiversity. Techniques have been established to achieve objectives such as assisted natural regeneration (ANR) (Dalmacio 1986, RECOFTC 1994) and the Miyawaki method (Fujiwara 1993, Miyawaki 1993).

Assisted or accelerated natural regeneration (ANR) was suggested by Dalmacio and is already practised for accelerated reforestation of degraded uplands and *Imperata* grassland in the Philippines (Dalmacio 1986, Durst 1990). The basic concept of ANR emphasizes protection and nurturing of tree seedlings and saplings already existing on degraded sites, rather than establishment of entirely new forest plantations. ANR requires tree seedlings and saplings on degraded sites to be marked and assisted in their survival and growth by one or more of the following activities: 1) pressing or cutting of competing grasses; 2) weeding around existing seedlings and saplings; 3) fire protection; and 4) enrichment planting. The advantages of ANR are not only accelerated secondary succession of forest, but also maintenance of species diversity, provision of useful products and many ecological values. In ANR implementation can often be accomplished for as little as one-third the cost of conventional reforestation.

In Thailand, ANR has not been successful because knowledge of how to assist the natural regeneration of each species is lacking. Literature on fruit production, seed germination, seed banks, and tree seed dispersal is much needed. Different species require different ANR methods. Suitable methods may include planting *Beilschmiedia* sp. (Lauraceae) under the shade of existing herbaceous vegetation, direct sowing of *Prunus cerasoides* (Rosaceae), and for *Eugelhardia spicata* (Juglandaceae), cutting weeds (particularly grasses and ferns) or shading them out with nurse trees (Hardwick *et al*. 1997).

The Miyawaki method has been used successfully to restore forest in many places in Japan and in other places in Southeast Asia (Miyawaki 1993). The technique includes:

1) species selection using as many native canopy species as possible, based on the potential natural vegetation at each site by the phytosociological method;
2) mixed plantations;
3) use of potted seedlings with well-developed root systems (with heights of up to 80 cm);
4) soil preparation, including provision of good drainage and use of organic fertilizers such as compost, weeds, dropped, broken blocks, etc.;
5) dense planting (3–9 individuals per square meter);
6) mulching with rice straw, leaves, etc., for protection against soil dryness, soil erosion and loss of nutrients;
7) no management after two or three years from planting (Fukiwara 1984, 1993, Miyawaki 1984).

Miyawaki (1993) and Said (1993) reported the first assessment of planting native seedlings (such as *Shorea* spp., *Dipterocarpus* spp., *Hopea* spp., etc.) and using some techniques of the Miyawaki method at Bintulu, Sarawak State, Malaysia. The percentage survival of such seedlings on areas of soil erosion and compaction after planting for a year was very high (approximately 71%). Moreover, percentage survival was 89.2% where 1-m-wide strips of vegetation had been removed with half-meter-wide strips of existing vegetation retained to provide shade to the planted seedling. In addition, the planted seedlings grew well, and had well-developed crowns after weeding and using rice straw as a mulch (Miyawaki 1993). Native seedlings, 50 cm tall, planted using oil palm leaves as a mulch at a shopping center, Jaya Jusco in Malacca, Malaysia, grew to 150–270 cm six months later (Fujiwara 1993, Miyawaki 1993).

Such techniques for rehabilitating selected degraded areas will ultimately depend on the priorities of the stakeholders, the costs and benefits associated with available rehabilitation techniques, and the economic, social, and environmental values of these land resources in their current and desired future states (Lamb 1994, Parrotta *et al*. 1997).

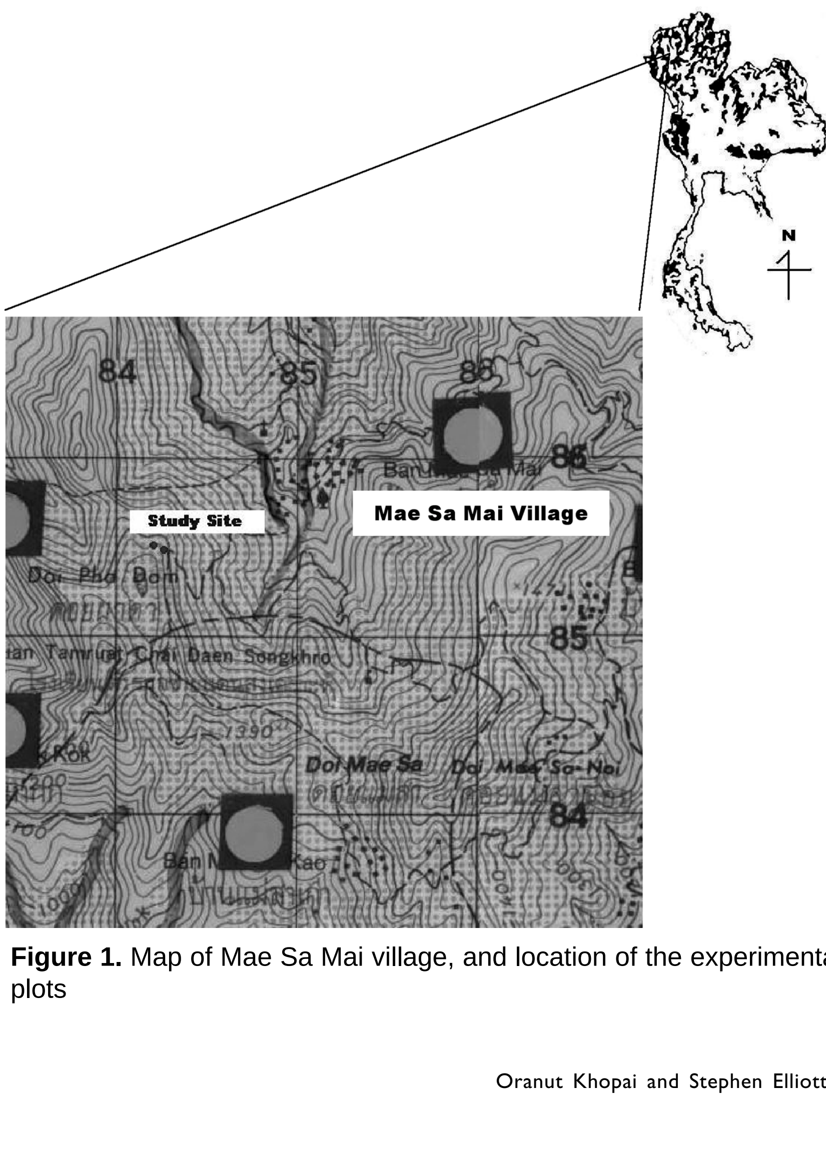


Figure 1. Map of Mae Sa Mai village, and location of the experimental plots

STUDY SITE DESCRIPTION

There are many suggested techniques to achieve forest restoration, but only the *framework species method* combined with various silvicultural treatments was applied in this field research project on degraded evergreen forest in the Doi Suthep-Pui National Park, Chiang Mai, Thailand (Figure 1). The framework species method uses native trees for planting in degraded areas, and matches these criteria: fast growing with dense spreading crowns, attractive to seed-dispersing wildlife (especially birds and bats), and easily propagated in the nursery. This method has been used successfully in ecological rehabilitation of forest and biodiversity conservation in north Queensland (Tucker & Murphy 1997). The aims of the framework species method are to rapidly re-establish forest ecosystem structure and function and accelerate recovery of biodiversity through facilitating seed dispersal into planted sites. The framework species in the planted sites were divided into three important groups: 20% of figs (*Ficus* spp., Moraceae), 10–15% of species of families Fagaceae and Leguminosae, and the rest of other species matching the framework criteria (FORRU 1998). The framework species are listed in Table 1.

Table 1. The framework species

No.	Botanical name	Family
1	*Bischofia javanica* Bl.	Euphorbiaceae
2	*Melia toosendan* Sieb. & Zucc.	Meliaceae
3	*Manglietia garrettii* Craib	Magnoliaceae
4	*Diospyros glandulosa* Lace	Ebenaceae
5	*Sapindus rarak* DC.	Sapindaceae
6	*Hovenia dulcis* Thunb.	Phamnaceae
7	*Aphanamixis polystachya* (Wall.) R. Parker	Meliaceae
8	*Quercus semiserrata* Roxb.	Fagaceae
9	*Spondias axillaris* Roxb.	Anacardiaceae
10	*Prunus cerasoides* D. Don	Rosaceae
11	*Ficus altissima* Bl.	Moraceae
12	*Gmelina arborea* Roxb.	Verbenaceae
13	*Eurya acumminata* DC. var. *wallichiana* Dyer	Theaceae
14	*Phoebe lanceolata* (Nees) Nees	Lauraceae
15	*Helicia nilagirica* Bedd.	Proteaceae
16	*Sarcosperma arboreum* Bth.	Sapotaceae
17	*Horsfieldia amygdalina* Warb. var. *amygdalina*	Myristicaceae
18	*Aglaia lawii* (Wight) Sald. & Rama.	Meliaceae
19	*Garcinia mckeaniana* Craib	Guttiferae
20	*Nyssa javanica* (Bl.) Wang.	Nyssaceae
21	*Heynea trijuga* Roxb. *ex* Sims	Meliaceae
22	*Markhamia stipulata* (Wall.) Seem. *ex* K. Sch. var. *kerrii* Sprague	Bignoniaceae
23	*Cinnamomum iners* Reinw. *ex* Bl.	Lauraceae
24	*Horsfieldia thorelii* Lec.	Myristicaceae
25	*Phoebe lanceolata* (Nees) Nees	Lauraceae
26	*Quercus kerrii* Craib var. *kerrii*	Fagaceae
27	*Erythrina subumbrans* (Hassk.) Merr.	Leguminosae, Papilionoideae
28	*Eugenia albiflora* Duth.*ex* Kurz	Myrtaceae
29	*Castanopsis calathiformis* (Skan) Rehd. & Wils.	Fagaceae

Such framework species were planted in deforested area in 1997 and 1998 (plots F97 and F98) combined with silvicultural treatments, i.e. fire protection, application of fertilizer, and weeding. Plots C97 and C98 were established as the control plots of each year, with no tree planting and activities except fire protection. The treatments in each plot are summarized in Table 2.

Table 2. Summary of treatments in each experimental plot

Plot	Activity
F98 (40 × 40 m)	*Before and when planting* 1. No cutting of naturally established tree seedlings, saplings, and trees. 2. A non-residual herbicide was used to clear the plot before planting. 3. Planting with native trees (29 species, 500 trees/rai or 3 125 trees/ha) in June 1998 with 100 g of fertilizer applied, when planted. 4. Fire-break. *After planting* 1. Weeding with hand tools once per month, in the rainy season and application of fertilizer (about 100 tree^{-1}) immediately after weeding, and weeds used as mulch. 2. Fire-break before dry season.
C98 (40 × 40 m)	No planting, weeding, and fertilizing except fire-break
F97 (20 × 20 m)	The same with plot F98, but native trees were planted in June 1997 and there was a partial burn in the dry season of 1998.
C97 (20 × 20 m)	The same as plot C98, but partial burn in the dry season of 1998.

To maintain the planted areas, new seedlings are planted to replace dead ones one year and, if necessary, two years after planting.

METHODOLOGY

Data collection

To determine whether forest restoration increases the species diversity or changes the species composition of the ground flora and encourages recruitment of non-framework tree species into planted areas, vegetation surveys were carried out in replicated 5-m diameter subplots, and covered about 24% of each plot, recording the presence of ground flora species (< 1 m tall) and naturally established trees (> 1 m tall). The Braun Blanquet scale was used to quantify abundance of the herbaceous ground flora (Shimwell 1971, Goldsmith *et al*. 1986). The naturally established trees were surveyed and labeled by both circular subplots and walking survey. Their height and health were measured with a measuring tape and scored respectively.

For the framework trees, their health, survival and growth were monitored only in the subplots, to know how they were effective in reforestoration for this area.

The surveys were done three times in 1999: in the dry season, in the middle of the rainy season and at the end of the rainy season. Some specimens of vegetation were collected and identified at the Herbarium, Department of Biology, Chiang Mai University.

Table 3. The Braun Blanquet scale for ground flora abundance and health scale for naturally established and framework trees

The Braun Blanquet scale
+ = less than 1%, sparsely or very sparsely present, cover very small
1 = 1–5%, plentiful, but of small cover value
2 = 6–25%, very numerous or covering at least 5% of the area
3 = 26–50%, any number of individuals covering $^1/_4$ to $^1/_2$ of the area
4 = 51–75%, any number of individuals covering $^1/_2$ to $^1/_4$ of the area
5 = 76–100%, covering more than $^1/_4$ of the area
The health scale was divided into 4 levels:
0 = dead
1 = not healthy, no leaves but still alive
2 = normal, but may have some yellow leaves, brown spots, insect damage, etc.
3 = very good

Data analysis

Ground flora

Different aspects of ground flora communities, i.e. species richness, evenness, diversity, and distance coefficient between sampling sites, were analysed from the formulas (Table 3 and 4) using the basic computer programs SPDIVERS.BAS and SUDIST.BAS (Ludwig & Reynolds 1988).

To compare the similarities and differences of ground flora in each experimental plot, the two indices were used (Table 4).

Table 4. The calculation formulas of species richness, species diversity, evenness and distance coefficient using the basic computer programs SPDIVERS.BAS and SUDIST.BAS

Species richness

Species richness was determined by direct count or

N0 = total number of ground flora species.

Species diversity (Hill's number)

1. $N1 = e^{H'}$
2. $N2 = 1/\lambda$

where: N1 = number of abundant species in the sample
N2 = number of very abundant species in the sample
H' = Shannon's Index
λ = Simpson's Index

Shannon's Index (H') is computed as:

$$H' = \sum_{i=1}^{s} (p_i \ln pi)$$

Simpson's Index (λ) is computed as:

$$\lambda = \sum p_i^2$$

where: p_i = proportion of individuals belonging to i^{th} species and is computed as:

$$p_i = n_i / N$$

where: n_i = number of individuals of the i^{th} species
N = total number of individuals
S = number of species

Evenness (Modified Hill's Index)

$$E5 = \frac{(1/\lambda) - 1}{e^{H'} - 1}$$

Table 5. The distance coefficient formula

Sorensen's Index (SI) for similarity coefficient

$$SI = 2C / (A + B)$$

where: C = number of species common to both community
A = total number of species in community A
B = total number of species in community B

Chord distance (CRD) for difference coefficient

(Calculation using the basic computer programs SPDIVERS.BAS and SUDIST.BAS)

$$CRDjk = 2\ (1\text{-}ccosjk)$$

where: CRDjk = chord distance between sample unit j(SUj) and sample unit k (Suk) which range from 0 to 2
ccos = chord cosine is computed from

$$ccos = \frac{\sum_{i=1}\{(Xij) \times (Xjk)\}}{\left[\sum_{i=1} Xij^2\right] \times \left[\sum_{i=1} Xjk^2\right]}$$

where: X_{ij} = number of individuals of the ith species in sample unit j
Y_{ik} = number of individuals of the ith species in sample unit k
S = number of species

Naturally established and framework trees

Species richness of naturally established trees was determined by direct count. The health, survival and the growth of naturally established trees and framework trees were calculated as health average, % survival and relative growth rate (RGR) (Table 6).

Table 6. The calculation of relative growth rate, health average and % survival

Relative growth rate (RGR)

Height relative growth rate

$$\text{RGR (\% increase in height per year)} = \frac{(1nh1 - 1nh2)}{(T2-T1)} \times 100 \times 365$$

where: RGG = relative growth rate

H1 = height of species A in the first survey

H2 = height of species A in the last survey

T2 –T1 = number of days between T1 and T2

ln = natural log

Health average

Ha = (H1 + H2 + H3)/3

where: Ha = health average

H1 = health score of plant species A in first survey

H2 = health score of plant species A in second survey

H3 = health score of plant species A in third survey

% Survival rate

Percent survival rate = (SN / TN) x 100

where: SN = number survived

TN = total number of species

RESULTS AND DISCUSSION

One hundred and thirty-six plant species (except framework trees), including 103 ground flora and 48 naturally established trees, were recorded in this study (Table 7).

Table 7. Total numbers of ground flora species, natural established trees and planted trees found in all surveys

Plot	Number of ground flora species found	Number of natural tree species found*	Total number of species found**	Framework tree species found
F98	75	29	95	22
C98	51	27	71	–
F97	28	5	33	14
C97	37	4	41	–
All plots	103	48	136	29

Remarks

* = including naturally established seedlings, saplings and trees in both circle and walking surveys.

** = not including planted trees. Some of the ground flora and natural tree species were the same.

GROUND FLORA

Diversity indices

Ground flora species were abundant in all plots. The most abundant ground flora species recorded in all surveys were *Pteridium aquilinum, Ageratum conyzoides, Eupatorium adenophorum, Mucuna bracteata* and *Pennisetum polystachyon* (Table 8).

Table 8. Percent cover of ground flora species recorded in all plots

Species	F98	C98	F97	C97	Total	No. of plots recorded
Ground flora*						
Pteridium aquilinum	5	260	7	167	439	4
Ageratum conyzoides	208	5	67	13	293	4
Eupatorium adenophorum	110	25	33	103	271	4
Mucuna bracteata	2	25	23	220	270	4
Pennisetum polystachyon	10	0	193	33	236	3
Mitracapus villosus	150	22	47	0	219	3
Conyza sumatrensis	122	13	60	17	212	4
Bidens pilosa	55	15	87	43	200	4
Phragmitus vallatoria	107	90	0	0	197	2
Imperata cylindrica	33	150	0	7	190	3
Cyperus cyperoides	42	15	47	57	161	4
Thysanolaena latifoia	27	100	0	0	127	2
Crassocephalum crepidiodes	38	22	40	20	120	4
Eupatorium odoratum	52	47	3	17	119	4
Setaria parviflora	63	10	3	17	93	4
Rhynchelytrum repens	27	12	47	3	89	4
Microstegium vagans	8	73	0	0	81	2
Digitaria setigera	25	5	23	20	73	4
Artemisia indica	35	27	10	0	72	3
Polygonum chinense	7	0	13	40	60	3
Spilanthes paniculata	47	0	7	3	57	3
Clerodendrum glandulosum	5	28	3	20	56	4
Centella asiatica	43	10	0	0	53	2
Drymaria diandra	7	0	33	10	50	3
Mimosa diplotricha	0	0	0	50	50	1
Alectra avensis	48	0	0	0	48	1
Dioscorea glabra	7	32	0	0	39	2
Solanum nigrum	12	0	20	7	39	3
Blumea balsamifera	37	0	0	0	37	1
Galinsoga parviflora	17	0	10	10	37	3
Triumfetta pilosa	7	30	0	0	37	2
Triumfetta rhomboidea	0	0	3	33	36	2
Trichosanthes tricuspidata	0	0	0	33	33	1
Panicum notatum	7	17	0	7	31	3
Setaria palmifolia	17	10	0	0	27	2

Species	F98	C98	F97	C97	Total	No. of plots recorded
Buddleja asiatica	25	0	0	0	25	1
Oroxylum indicum	7	0	0	17	24	2
Paspalum conjugatum	8	3	13	0	24	3
Millettia pachycarpa	0	0	0	23	23	1
Oxalis corniculata	3	0	20	0	23	2
Anaphalis margaritacea	12	8	0	0	20	2
Desmodium heterocarpon	5	15	0	0	20	2
Dioscorea alata	0	10	0	10	20	2
Solanum torvum	3	7	0	10	20	3
Seteria verticillata	0	17	0	0	17	1
Alpinia malaccensis	13	3	0	0	16	2
Sporobolus diander	13	0	3	0	16	2
Boehmeria chiangmaiensis	0	3	0	10	13	2
Neyraudia reynaudiana	13	0	0	0	13	1
Sida rhombifolia	0	0	3	10	13	2
Sonchus oleraceus	13	0	0	0	13	1
Acacia megaladena	2	10	0	0	12	2
Carex baccans	2	0	0	10	12	2
Eugenia albiflora	7	5	0	0	12	2
Asparagus filicinus	10	0	0	0	10	1
Cissampelos hispida	0	0	0	10	10	1
Commelina benghalensis	0	0	0	10	10	1
Dioscorea prazeri	0	10	0	0	10	1
Merremia vitifolia	0	0	0	10	10	1
Urena lobata	2	5	3	0	10	3
Desmodium velutinum	0	5	0	3	8	2
Pterocarpus macrocarpus	8	0	0	0	8	1
Aneilema sinicum	7	0	0	0	7	1
Arthraxon castratus	7	0	0	0	7	1
Boehmeria diffusa	0	0	0	7	7	1
Borreria laevis	7	0	0	0	7	1
Murdannia scapiflora	7	0	0	0	7	1
Rauvolfia verticillata	0	0	0	7	7	1
Capillipedium parviflorum	3	0	3	0	6	2
Argyreia aggregata	0	5	0	0	5	1
Embelia sessiliflora	0	5	0	0	5	1
Entada rheedii	0	5	0	0	5	1
Gmelina arborea	0	5	0	0	5	1
Helicteres elongata	0	5	0	0	5	1
Ixora cibdela	5	0	0	0	5	1
Kuniwatsukia cuspidata	5	0	0	0	5	1
Maesa montana	0	5	0	0	5	1
Melastoma normale	2	3	0	0	5	2
Paris polyphylla	0	5	0	0	5	1
Saccolepis indica	5	0	0	0	5	1

Species	F98	C98	F97	C97	Total	No. of plots recorded
Smilax perfoliata	5	0	0	0	5	1
Sterculia villosa	0	5	0	0	5	1
Abrus pulchellus	0	3	0	0	3	1
Castanopsis argyrophylla	0	3	0	0	3	1
Codonopsis javanica	0	3	0	0	3	1
Dalbergia stipulacea	3	0	0	0	3	1
Firmiana colorata	0	3	0	0	3	1
Laggera pterodonta	3	0	0	0	3	1
Pteris biauria	3	0	0	0	3	1
Schima wallichii	0	3	0	0	3	1
Vernonia divergens	3	0	0	0	3	1
Aporusa villosa	2	0	0	0	2	1
Argyreia obtecta	2	0	0	0	2	1
Chamaecrista leschenaultiana	2	0	0	0	2	1
Crotalaria dubia	2	0	0	0	2	1
Cyrtococcum accrescens	2	0	0	0	2	1
Eleusine indica	2	0	0	0	2	1
Embelia subcoriacea	2	0	0	0	2	1
Erythrina suberosa	2	0	0	0	2	1
Mussaenda parva	2	0	0	0	2	1
Paederia wallichii	2	0	0	0	2	1
Phyllanthus urinaria	2	0	0	0	2	1
Wendlandia scabra	2	0	0	0	2	1
Total	1 615	1 202	824	1 087	4 728	
Total number of species	75	51	28	37	103	

* Percent cover average X 100

Considering diversity indices of the ground flora (Table 8) shows that plot F98 had higher species richness (75), more abundant (N1 = 32.16) and very abundant (N2 = 19.12) species, and a more even distribution of ground flora species (E5 = 0.61) than plot C98. It can be explained that coming up of ground flora species in F98 plot would be affected from weeding which produced gaps in the herbaceous ground flora, allowing the establishment of a wider range of species. Five species, *Ageratum conyzoides*, *Conyza sumatrensis*, *Bidens pilosa*, *Crassocephalum crepidiodes* and *Rhynchelytrum repens*, became especially abundant in the framework plots but less abundant in the control plots (Table 8). Most of them (except *Rhynchelytrum repens*, Gramineae) are fast-growing annual herbs in the family Compositae, with small seeds that readily germinate on exposed soil after weeding. Therefore, they can survive and flourish even in frequently weeded plots. Planting trees and associated activities, especially weeding, probably caused an increase in abundance of these ground flora species. Weeding removed dominant herbs and created patches of bare earth which favoured seed germination of these species.

The abundant ground flora species in the control plots were *Pteridium aquilinum* (Dennstaedtiaceae), *Mucuna bracteata* (Leguminosae, Papilionoideae) and *Clerodendrum glandulosum* (Verbenaceae). These ground flora species are perenial herbs which were not weeded in the control plots, so their percent cover was higher than in the planted plots.

Table 9. Species richness, diversity (Hill's number) and evenness (modified Hill's ratio) in the four plots

Plot	Species richness	Species diversity		Evenness (E5)
		N1	N2	
F98	75	32.16	19.12	0.61
C98	51	21.20	10.92	0.49
F97	28	15.70	10.62	0.66
C97	37	19.22	11.51	0.58

For 1997 plots, the richness and diversity of ground flora species in plot C97 were higher than in plot F97, and also had a greater number of abundant (N1 = 19.22) and very abundant species (N2 = 11.51). However, C97 had fewer very common species because the evenness index of ground flora (E5 = 0.58) was less than in plot F97 (E5 = 0.66). Moreover, three ground flora species, *Eupatorium adenophorum* (Compositae), *E. odoratum* (Compositae) and *Setaria parviflora* (Gramineae), were very abundant in plot C97 and less abundant in plot F97 (Table 8). This result was inverted in the 1998 plots since these species were less abundant in plot C98 and most abundant in plot F98. These results might indicate that these species are affected by fire, because there was partial fire in plots F97 and C97. It means that these three ground flora species were very abundant after tree planting and weeding, but their abundances decreased after fire occurred.

Considering the five most abundant ground flora species in the 1997 and 1998 plots (Table 10), the most dominant ground flora species in the 1998 plots (except *Phragmites vallatoria*, Gramineae) were quite different. So by eye, the plots appeared very different. Also there were completely different abundances in ground flora species in the 1997 plots. It means that the main ground flora compositions of plant communities changed after tree planting and weeding. Comparing the five most abundant ground flora species between the planted and control plots, there were three species, viz. *Ageratum conyzoides* (Compositae), *Conyza sumatraensis* (Compositae) and *Mitracarpus villosus* (Rubiaceae), found in the planted plots, but only one ground flora species (*Pteridium aquilinum*, Dennstaedtiaceae) was found in the control plots (Table 10). It means that even though there were no tree planting and any activities in the control plots, the main ground flora composition of plant communities changed after fire occurred.

Table 10. The five most abundant ground flora species found in each plot

Plot	Abundant species	Per cent cover average
F98	*Ageratum conzoides*	208
	Mitracapus villosus	150
	Conyza sumatraensis	122
	Eupatorium adenophorum	110
	Phragmites vallatoria	107
C98	*Pteridium aquilinum*	260
	Imperata cylindrica	150
	Thysanolaena latifolia	100
	Phragmites vallatoria	90
	Microstegium vagans	73
F97	*Pennisetum polystachyon*	193
	Bidens pilosa	87
	Ageratum conyzoides	67
	Conyza sumatraensis	60
	Mitracarpus villosus	47
C97	*Mucuna bracteata*	220
	Pteridium aquilinum	167
	Eupatorium adenophorum	103
	Cyperus cyperoides	57
	Mimosa diplotricha	50

Similarity and difference indices

Different methods of measuring similarity and difference coefficients yield different results. Between plots C98 and C97, the similarity coefficient was lowest (0.43, indicating less similarity, Table 11), but CRD was also lowest (1.00, indicating less difference, Table 12). The highest similarity coefficient was in plot pair F97 and C97, but they had CRD (1.16) higher than the plot pairs F98 and F97 (1.01), and C98 and C97 (1.00). Only the plot pair F98 and F97 had a high similarity coefficient (indicating high similarity) and also low CRD (indicating less difference). These contradictory differences in results are common when using Sorensen's index and CRD. Sorensen's index is a great advantage in terms of rapid assessment, but it does not take into account the abundance of each species. CRD does take into account relative abundance of different species. In this survey, the biggest differences occurred between the dominant or abundant species and these are given more weight when using CRD. However, Sorensen's index and CRD should be used together in vegetation analysis to find the similarities between communities and to get more accurate results.

Table 11. Similarity coefficients (Sorensen's Index) of ground flora in all four plots.

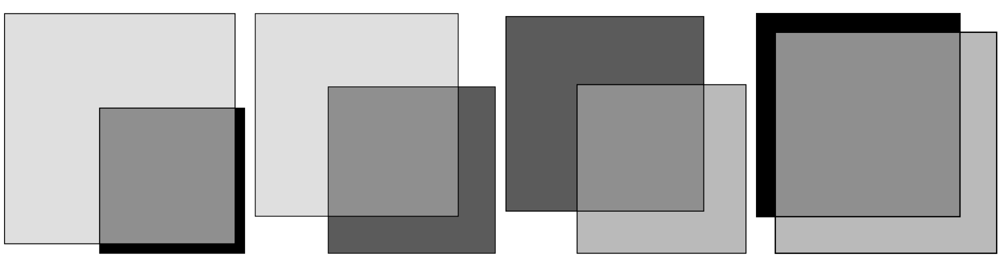
Experimental plot pairs	A	B	C	2C/(A+B)
F98-C98	75	51	31	0.49
F98-F97	75	28	26	0.50
C98-C97	51	37	19	0.43
F97-C97	28	37	21	0.65

Table 12. Chord distances (CRD) between four experimental plots in plot x plot matrix form (ground flora)

Plot	C98	F97	C97
F98	1.20	1.01	1.24*
C98		1.34*	1.00
F97			1.16
C97			

Remark: * this value is not discussed because there is no point to compare the control plot from one year with the planted plot from another.

In addition, ground flora species overlap diagrams were made to visualize changes during the succession process in each experimental plot pair (Figure 2). In plot pair F98 and C98, CRD was highest (1.20, indicating less similar, Table 12). Plot F98 accumulated more ground flora species than plot C98 which was also observed from the residual yellow in plot F98 compared with the remaining blue area in plot C98. This means that tree planting and weeding caused a gradually shifting of the ground flora to a different composition. Also the ground flora composition was fairly different in plot pair C98 and C97, with no tree planting and weeding. However, the difference was reduced after planting which could be noticed from plot pair F98 and F97. Plot F98 accumulated more ground flora species than plot F97. The number of ground flora species in plot F97 was a smaller subset of essentially the same ground flora species as in plot F98. It means that the number of ground flora species increased after tree planting and weeding. Although fire occurred in plot F97, the number of ground flora species did not change. Most of the ground flora species in plot F97 were also found in plot F98. In plot pair F97 and C97, the similarity coefficient of ground flora species was highest (0.65, Table 11). This result was probably caused by fire, because the succession process was the same in both plots, although the dominant ground flora species were different. Before fire occurred, the dominant herbaceous weeds in the 1997 plots were *Conyza sumatrensis* and *Cyperus cyperoides*, and also with very common species, e.g. *Bidens pilosa*, *Crassocephalum crepidioides*, *Solanum nigrum* and *Triumfetta pilosa*. After fire occurred, *B. pilosa* and *C. sumatrensis* were still found as the dominant herbaceous weeds in plot F97, but the dominant ground flora species changed in plot C97 (only *C. cyperoides* was found, Table 10). *Bidens pilosa* was still found in plot F97, because it is an annual herb and common in abandoned areas and silvicultural plots (Saelee 2000).



Plots F98-F97 Plots F98-C98 Plots C98-C97 Plots F97-C97

Figure 2. Ground flora species overlap diagrams from Sorensen's Index in the four plots

Naturally established trees

A total of 49 species of naturally established seedlings, saplings, and mature trees were found in both circle plots and walking surveys (Table 13). One hundred and forty-two individuals of naturally established trees were recorded. The most common naturally established tree species recorded was *Litsea cubeba.* The species richness of naturally established seedlings, saplings and mature trees was highest in plot F98, which also had the second highest total number of individuals.

Table 13. Numbers of naturally established tree species recorded at each plot

Species	F98	C98	P7	C97	Total	No. of sites recorded
Naturally established trees (h > 1 m)						
Litsea cubeba	7	20	0	0	27	2
Acacia megaladena	9	7	0	0	16	2
Albizia chinensis	9	5	0	0	14	2
Glochidion sphaerogynum	2	5	0	0	7	2
Gmelina arborea	0	5	0	1	6	2
Markhamia stipulata	0	5	0	0	5	1
Antidesma acidum	3	1	0	0	4	2
Prunus persica	0	0	2	2	4	2
Albizia odoratissima	0	1	1	1	3	3
Dillenia parviflora	0	3	0	0	3	1
Melia toosendan	2	1	0	0	3	2
Eugenia albiflora	1	2	0	0	3	2
Artocarpus gomezianus	2	0	0	0	2	1
Berrya mollis	2	0	0	0	2	1
Buddleja asiatica	1	0	1	0	2	2
Castanopsis armata	0	2	0	0	2	1
Erythrina suberosa	1	1	0	0	2	2
Phoebe lanceolata	2	0	0	0	2	1
Phylanthus emblica	1	1	0	0	2	2
Pterocarpus macrocarpus	2	0	0	0	2	1
Schima wallichii	1	1	0	0	2	2
Wendlandia tinctoria	1	1	0	0	2	2
Lagerstroemia speciosa	0	0	1	0	1	1
Aporusa dioica	1	0	0	0	1	1
Aporusa villosa	1	0	0	0	1	1
Boehmeria chiangmaiensis	0	1	0	0	1	1
Bridelia glauca	0	0	1	0	1	1
Callicarpa arborea	0	1	0	0	1	1
Clerodendrum glandulosum	1	0	0	0	1	1
Cratoxylum formosum	0	1	0	0	1	1
Dalbergia discolor	1	0	0	0	1	1
Dalbergia stipulacea	0	1	0	0	1	1
Dillenia pentagyna	1	0	0	0	1	1
Diospyros glandulosa	1	0	0	0	1	1
Fernandoa adenophylla	1	0	0	0	1	1

Species	F98	C98	P7	C97	Total	No. of sites recorded
Ficus hispida	0	1	0	0	1	1
Firmiana colorata	1	0	0	0	1	1
Garuga pinnata	1	0	0	0	1	1
Glochidion eriocarpum	1	0	0	0	1	1
Helicia nilagirica	1	0	0	0	1	1
Ixora cibdela	1	0	0	0	1	1
Maesa montana	0	1	0	0	1	1
Michelia baillonii	0	1	0	0	1	1
Mussaenda parva	0	1	0	0	1	1
Phoebe sp.	0	0	0	1	1	1
Securinega virosa	0	1	0	0	1	1
Sterculia villosa	0	1	0	0	1	1
Stereospermum colais	1	0	0	0	1	1
Turpinia pomifera	0	1	0	0	1	1
Total number of individuals	59	72	6	5	142	
Total number of species	29	27	5	4	49	

In order to find out if forest restoration activities increase naturally established seedlings, saplings, and mature trees, the rate of seedling establishment between the first and last surveys must be compared (Table 14). Only planted trees taller than one meter were considered in this analysis because they have high potential to develop into saplings and trees, and finally contribute to be the structure of the re-established forest. Naturally established trees were surveyed in both circle sample plots and walking surveys, but planted trees were recorded only in circle sample plots.

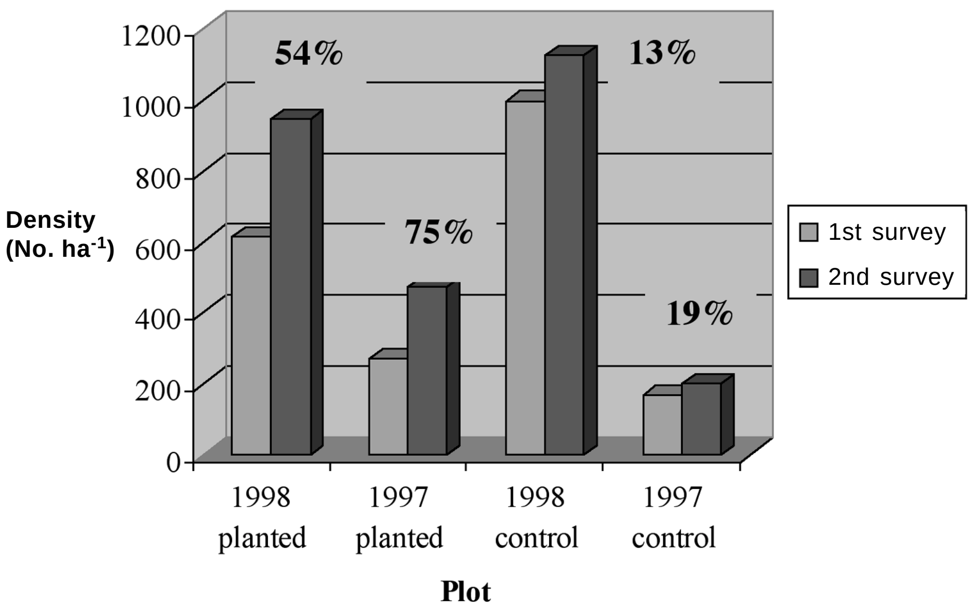


Figure 3. Density of naturally established trees in all surveys

The numbers of species of naturally established trees in the plots with planted framework trees (F) and control (C) in the first survey in summer were equal (Total C = 23, Total F = 23) but the F plots had accumulated more species than the C plots by the last survey in November (Total C = 29; increased 6 species, Total F = 33; increased 10 species). Considering density (Figure 3), the C plots had a higher density (728 No. ha^{-1}) than the F plots (528 No. ha^{-1}) in both the first and last surveys, but the F plots had a higher % rate of increase (830 No. ha^{-1}; increased 57.20%) than the C plots (867 No. ha^{-1}; increased 19.09%). Therefore, not only did tree planting and associated activities increase the species diversity of ground flora, but it also increased the % density of naturally established trees in the 1998 plots.

Similarly plots F98 and C98 showed that the numbers of species of naturally established trees in the first survey were equal (plot C98 = 22, plot F98 = 22), but by the last survey, plot F98 had more species than plot C98 (plot C98 = 27; increased 5 species, plot F98 = 29; increased 7 species). As for density, plot F98 had a higher % rate of increase (946 No. ha^{-1}; an increase of 54.32%) than plot C8 (1 126 No. ha^{-1}; an increase of 13.05%) although plot C98 retained a higher density throughout the study.

In plots F97 and C97, which were partially burnt, only 3 and 2 naturally established tree species respectively were recorded in the first survey, but by the last survey plot F97 had more species than plot C97, even though the increase in species was equal (plot C97 = 2; increased 2 species, plot F97 = 5; increased 2 species). Due to the disappearance of *Prunus persica* (2 individuals, an introduced fruit tree species planted by villagers) in the third walking survey in plot C97, density decreased (201 No. ha^{-1}) and to less than that in plot F97 (473 No. ha^{-1}). Furthermore, 2 other species were found in the last walking survey in plot C97, so the number of species found in this case was 3 (Table 13), but the total species found in all surveys was 4 (Table 7).

Framework tree species

Forty-nine individuals of 13 species of framework tree species taller than one meter were recorded in both plots F98 and F97 (Table 15). The most common planted tree species found was *Hovenia dulcis* (6 individuals). The total density of planted trees was 1 698 No. ha^{-1}. Plot F98 had less density (1 528 No. ha^{-1}) than plot F97 (1 935 No. ha^{-1}) (Table 14).

Table 14. Densities and numbers of species of planted (h >1 m) and naturally established trees found in circle sample plots and walking surveys

	First survey, April 1999						Last survey, November 1999					
	Total C	**Total F**	**C98**	**F98**	**C97**	**F97**	**Total C**	**Total F**	**C98**	**F98**	**C97**	**F97**
Circle plots survey												
Naturally established trees												
Density (No. ha^{-1})	441	340	661	407	102	204	509	543	713	611	102	407
No. species	8	7	7	5	1	2	9	13	8	9	1	4
Framework trees												
Density (No. ha^{-1})	0	0	0	0	0	0	0	1698	0	1528	0	1935
No. species	0	0	0	0	0	0	0	23**	0	13	0	13
Total												
Density (No. ha^{-1})	441	305	661	357	102	204	509	2241	713	2139	102	2342
No. species	8	7	7	5	1	2	9	35*	8	21	1	18
Walking surveys												
Naturally established trees												
Density (No. ha^{-1})	287	223	335	256	66	66	358	287	413	335	99	66
No. species	20	18	19	17	1	2	25	23	24	22	2 ***	2
Total of naturally established trees in circle plots and walking surveys												
Density (No. ha^{-1})	728	528	996	613	168	270	867 (+19.09 %)	830 (+57.20 %)	1126 (+13.05 %)	946 (+54.32 %)	201 (+19.64 %)	473 (+75.19 %)
No. species	23	23	22	22	2	3	29	33	27	29	3 ***	5

Remark * Planted tree and naturally established tree species were the same.
** Planted tree species in plots 1998 and 1997 were the same.

Table 15. Number of planted tree species recorded at each plot

Species	F98	C98	F97	C97	Total
Planted trees (h> 1m)					
Hovenia dulcis	4	0	2	0	6
Prunus cerasoides	3	0	2	0	5
Bischofia javanica	3	0	0	0	3
Gmelina arborea	2	0	1	0	3
Heynea trijuga	0	0	3	0	3
Manglietia garrettii	3	0	0	0	3
Melia toosendan	3	0	0	0	3
Sarcosperma arboreum	3	0	0	0	3
Erythrina suberosa	2	0	0	0	2
Phoebe lanceolata	0	0	2	0	2
Quercus semiserrata	2	0	0	0	2
Sapindus rarak	1	0	1	0	2
Spondias axillaris	2	0	0	0	2
Bridelia glauca	0	0	1	0	1
Castanopsis acumminatissima	0	0	1	0	1
Diospyros glandulosa	1	0	0	0	1
Ficus benjamina	0	0	1	0	1
Ficus subulata	0	0	1	0	1
Glochidion kerrii	0	0	1	0	1
Helicia nilagirica	1	0	0	0	1
Cinnamomum iners	0	0	1	0	1
Markhamia stipulata	0	0	2	0	2
Total number of individuals	30	0	19	0	49
Total number of species	13	0	13	0	0

Relative growth rate (RGR)

Most of the planted trees and naturally established seedlings species grew well. Weeding and fertilizing might have caused the differences in RGR between the planted and naturally established trees. The native tree species with the highest RGR was *Melia toosendan* (181.21 cm $cm^{-1}year^{-1}$) followed by *Manglietia garrettii* (175.24 cm $cm^{-1}year^{-1}$), *Diospyros glandulosa* (174.60 cm $cm^{-1}year^{-1}$) and *Sapindus rarak* (170.84 cm $cm^{-1}year^{-1}$). Surprisingly, *Erythrina subumbrans*, usually a fast-growing tree species, had low RGR in this survey, because most of individuals had their shoots broken by wind. Although most naturally established tree species grew well, their RGR were lower than those of planted tree species. Only two planted framework tree species, viz. *Gmelina arborea* and *Markhamia stipulata*, had higher RGR than those of naturally established trees of the same species. Therefore, weeding and applying fertilizer caused the increased RGR of these two tree species.

Health average and % survival rate

The health of natural and planted tree species was very good. The natural and planted tree species had high % survival rate except some planted tree species which were recorded as dead in the first survey, viz. *Garcinia mckeaniana*, *Nyssa javanica*, *Phoebe lanceolata* and *Aphanamixis polystachya*. However, *P. lanceolata* and *A. polystachya* were found in the other circle plots and in the other surveys, but *G. mckeaniana* and *N. javanica* were found just in the first survey. The % survival rate of *G. mckeaniana* and *N. javanica* could not be compared and should not be planted in this area. Furthermore, there was coppicing in many individuals of *Buddleja asiatica* (h < 1 m, treelet) only in plot P98 in all three walking surveys. Tree planting with weeding and fire protection probably caused this result.

CONCLUSION AND RECOMMENDATIONS

It could be concluded that:

1. In the first year after tree planting, the species richness and evenness of the ground flora in plot F98 increased when compared with plot C98, probably because weeding removed dominant perennial herbs, allowing invasion of plot F98 by annual herbs, especially of the family Compositae.
2. Two years after planting, the diversity of the ground flora species in plot F97 decreased because the planted tree canopy closed, which also shaded out and reduced opportunities for establishment of new species of ground flora. Ground flora diversity was higher in plot C97, but evenness was lower than in plot F97.
3. Weeding and fertilizing accelerated the establishment of natural seedlings and increased natural plant density in the planted plots, although the increase in species of naturally established seedlings was equal in the 97 plots and the numbers of natural tree species found did not differ significantly in both the 1998 and 1997 plots.
4. Most planted native tree species were in good health and growing fast. All of them, excluding *Nyssa javanica* and *Garcinia mckeaniana*, were suitable and proper species to plant for forest restoration in this area.

We should consider the value of biodiversity and ecology when we wish to restore the forest. The results showed that planting native trees with associated fire protection, weeding, and fertilizer application not only encouraged the establishment of natural seedlings, but also increased the diversity of ground flora species. Although this research was a preliminary study, the success of forest restoration will be recorded if the project is monitored continuously for at least three years. This research shows one way of accelerating forest succession. In other forest restoration projects, native tree species should be studied in other areas to find potential framework species in those areas before making decisions to restore the forest. Also after-care techniques, i.e. fire protection, weeding in the rainy season and applying fertilizer, should be considered and applied to support the growth and survival of planted and naturally established trees.

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BIBLIOGRAPHY

Dalmacio, V.M. 1986. *Assisted natural regeneration*: *a strategy for cheap, fast, and effective regeneration of denuded forestlands*. Region 8, Tacloban City. Philippines, DENR. 18 pp.

Durst, P.B. 1990. *Assisted natural regeneration*. Washington, DC, USA, Forest Service, Washington Office, Department of Agriculture. 24 pp.

FORRU (The Forest Restoration Research Unit). 1998. *Forest for the future*. Thailand, Department of Biology, Faculty of Science, Chiang Mai University. 3: 49–56.

Fujiwara, K. 1984. Investigation of the growth process of environmental forest in the industrial area in *Camellietea japonicae*. *In Abstracts*, *International Symposium on Urban Ecosystems and Environmental Science*, pp. 20–22. Japan, Yokohama National University.

Fujiwara, K. 1993. Rehabilitation of tropical forests from countryside to urban areas. *In* H. Lieth & M. Lohmann, eds. *Proc. Symposium on Restoration of Tropical Forest Ecosystems, 1991*, pp. 119–131. Osnabruck, Germany, University of Osnabruck.

Goldsmith, F.B., Harrison, C.M. & Morton, A.J. 1986. Description and analysis of vegetation. *In* P.D. Moore & S.B. Chapman, eds. *Methods in plant ecology*, p. 450. Oxford, England, Blackwell Scientific Publications.

Hardwick, K., Healey, J., Elliott, S., Garwood, N.C., & Anusarnsunthorn, V. 1997. Understanding and assisting natural regeneration processes in degraded seasonal evergreen forests in northern Thailand. *Forest Ecology and Management*. 99: 203–214.

Lamb, D. 1994. Reforestation of degraded tropical forest lands in the Asia-Pacific Region. *Journal of Tropical Forest Science*. 7: 1–7.

Ludwig, J.A. & Reynolds, J.F. 1988. *Statistical ecology: a primer on methods and computing*. New York, John Wiley & Sons. 85–103.

Miyawaki, A. 1993. Restoration of native tree forests from Japan to Malaysia. *In* H. Lieth & M. Lohmann, eds. *Proc. Symposium on Restoration of Tropical Forest Ecosystems, 1991*, pp. 5–24. Osnabruck, Germany, University of Osnabruck.

Parrotta, A.J., Turnbull, J.W., & Jones, N. 1997. Catalyzing native forest regeneration on degraded tropical lands. *Forest Ecology and Management*. 99: 1–7.

RECOFTC. 1994. *Forest restoration through natural regeneration*. Bangkok, Thailand, RECOFTC, Kasetsart University. 96 pp.

Saelee, P. 2000. *A handbook for tree lovers: grasses*. Bangkok, Ban and Suan Press, 34. (in Thai).

Said, B.A. 1993. The rehabilitation of tropical rainforests ecosystem. *In* H. Lieth & M. Lohmann, eds. *Proc. Symposium on Restoration of Tropical Forest Ecosystems, 1991*, pp. 109–117. Osnabruck, Germany, University of Osnabruck.

Saidee, P. 1994. Forest restoration using enrichment tree planting. *In Forest restoration through natural regeneration*, pp. 43–45. Bangkok, RECOFTC, Kasetsart University. (in Thai).

Stuetz, W. 2000. Assessment of organochlorine pesticide residues in human milk of hill tribes living in northern Thailand. Hohenheim-Kasetsart-Chiang Mai Universities, Interdisciplinary Research Project, Hohenheim University, Stuttgart. (M.Sci. thesis)

Tucker, N. & Murphy, T. 1997. The effects of ecological rehabilitation on vegetation recruitment: some observations from the wet tropics of North Queensland. *Forest Ecology and Management*. 99: 133–152.

28 Company–community partnership outgrower schemes in forestry plantations in Indonesia: an alternative to conventional rehabilitation programmes[1]

Ani Adiwinata Nawir* and Tini Gumartini**

ABSTRACT

Indonesia has a considerable area of degraded land requiring rehabilitation. However, most rehabilitation projects in the past have been government driven, depending on public funding (Indonesian Government and international donors), and have focused mainly on technical aspects. As a result people living in surrounding targeted areas are not adopting rehabilitation techniques. Innovative approaches are necessary if the objectives of a rehabilitation programme are to be met while providing benefits to private companies and local people. The findings of a study of outgrower schemes in Indonesian timber plantations suggested that company–community partnerships could be an alternative for implementing rehabilitation programmes. The partnership arrangement over a 10- to 45-year period is based on a contract. It states the rights and duties of each party in establishing a forestry plantation and the benefit-sharing agreement at the time of harvest. The schemes take place on logged-over forests and idle lands, mostly Imperata grasslands. The partnership provides opportunities for forestry plantation companies to play a social role and rehabilitate degraded resources. It also provides job opportunities to local people and incomes from harvested timber at the end of each rotation under a long-term contract.

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[1] The views expressed in this publication are those of the authors and not those of CIFOR. The outgrower schemes analysis in this paper was mainly abstracted from the paper of ‘Towards mutually beneficial partnership in outgrower schemes: lessons learnt from Indonesia” (Nawir *et al.* 2002).

INTRODUCTION

An estimated 43.6 million ha of forest lands, including Production Forests, and Conservation and Protected Forests (Ministry of Forestry 2002), are in need of rehabilitation in Indonesia due to improper forestry and non-forestry practices. Considering the different values provided by forest resources, it is essential that planted forests under rehabilitation programmes should be economically viable and socially acceptable alternative sources of wood in the country, thus protecting remaining forests while also improving poor peoples' livelihoods. The earliest rehabilitation initiative was probably the reforestation programme under the South Java Flood Control Sector Project (SJFCP) in 1976/77 financed with Inpres Funds (government funding based on a Presidential Instruction), covering the most degraded areas of the island of Java. This project provided *Paraserianthes falcataria* seedlings for people to plant. Since then, rehabilitation programmes that combat degraded forest areas have become an important focus of the Ministry of Forestry priorities. The latest initiative is the Rehabilitation Programme through Social Forestry, launched in 2002 to be implemented in eight provinces financed by the Reforestation Funds and coordinated by local governments.

Most rehabilitation projects in the past have been government driven, dependent on public funding from the Indonesian Government and international donors, and have focused mainly on the technical aspects of rehabilitation. Institutional arrangements to actually executing the rehabilitation programmes were not developed to establish effective implementation on the ground. As a result there has been little adoption of rehabilitation techniques by local people living in surrounding targeted areas. Innovative approaches are necessary if the objectives of a rehabilitation programme are to be achieved, at the same time giving associated socio-economic benefits to private companies and local people.

The findings of a study of outgrower schemes in Indonesian plantations show that company-community partnerships can be an alternative for implementing rehabilitation programmes. The outgrower scheme is defined as a partnership between two or more parties combining land, capital, management and market opportunities, formed with the intention of producing a commercial forest crop or timber in forestry plantations based on a contractual agreement (Mayers 2000). A study was conducted in Indonesia with the objective of establishing a mutually beneficial interaction between the local people and the plantation owners. This paper discusses alternative approaches in executing rehabilitation programmes in which private companies and local people partners are actively involved, at the same time meeting rehabilitation objectives. The discussion in this paper is outlined as follows:

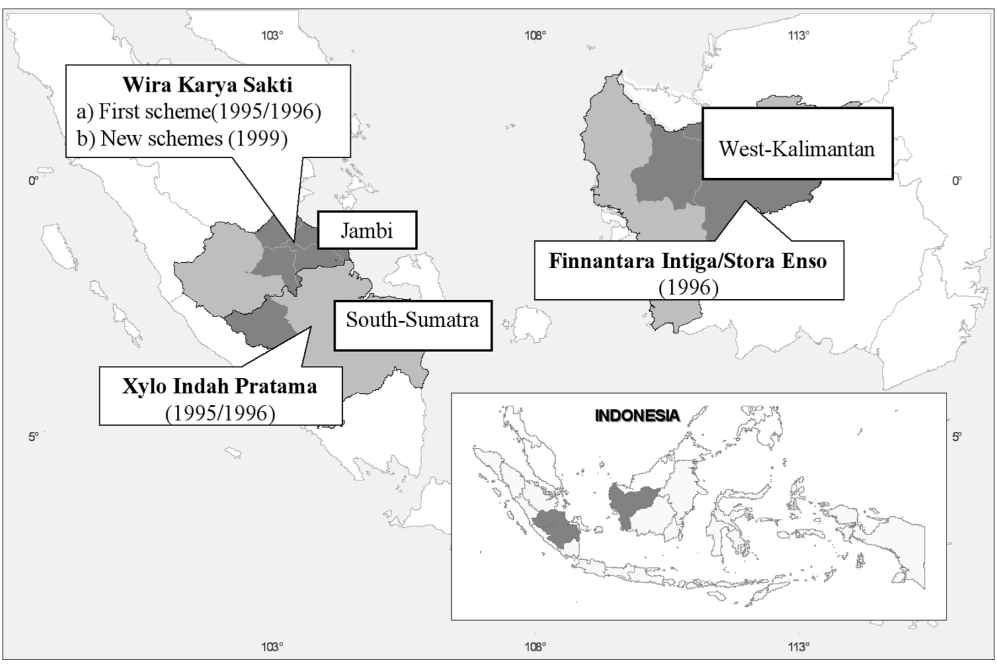
- characteristics of outgrower schemes;
- features of schemes that could allow for their potential positive contribution to rehabilitation success;
- pre-requisites for success of outgrower schemes;
- conclusions and policy recommendation.

CHARACTERISTICS OF OUTGROWER SCHEMES

With the primary objective of outgrower schemes to establish small-scale timber plantations, the partnership arrangement extends over a 10- to 45-year period based on a contractual document. It states the rights and duties of each party in establishing the forestry plantation, and the benefit-sharing agreement at the time of harvest. The schemes take place on logged-over forests and idle lands, mostly *Imperata* grasslands. The partnership provides opportunities for forestry plantation companies to play a social role and restore a degraded resource. It also provides job opportunities to local people and incomes from harvested timber at the end of each rotation under a long-term contract.

This study was conducted in collaboration with three private companies: Wira Karya Sakti (WKS) and Finnantara Intiga, both of which are timber plantation concessions planted to *Acacia*, and Xylo Indah Pratama, a non-concession timber plantation planted to *Alstonia* (Figure 1). Accordingly, schemes identified in the case studies were partnerships between:

1) *Timber plantation concession holder and land claimers/owners residing in the concession areas.* This partnership was initiated in 1999/2000 under a 43-year term. The first harvesting is expected in 2008. Included in this category were schemes initiated by WKS and Finnantara.
2) *Timber plantation concession holder and land owners on the surrounding plantation areas outside the concessions.* This partnership was initiated in 1999/2000 with a 43-year contract (initiated in 1995 under the Farm Forestry Scheme with eight years contract). The first harvest is expected in 2003. WKS also initiated this scheme.
3) *Non-concession timber plantation and private land owners.* This partnership was initiated in 1995 and the first harvest is expected in 2005. Included was the scheme initiated by Xylo.



Source: Nawir *et al.* (2002)

Figure 1. Locations of outgrower schemes in the case studies in Sumatra and Kalimantan

Company motivations varied from seeking a substitute for naturally grown timber or ways to plant claimed areas inside the concessions to improving its reputation. The landholders were mainly driven by the objective to utilize idle lands (both marginal and good quality lands), and to have extra income in the future. In the long term, companies were motivated to establish secure plantation operations by minimizing the economic risks through building good social relations with the communities. Consequently this would meet the public relation objectives of gaining better credibility at the national and international levels to be eligible for the wood certification. Xylo Indah Pratama was successfully certified by Smart Wood in 1999 following assessment of the ecological and socio-economic aspects of its management, and has maintained the classification every year since.

FEATURES OF OUTGROWER SCHEMES WITH POTENTIAL TO MAKE A POSITIVE CONTRIBUTION TO REHABILITATION SUCCESS ON DEGRADED LANDS

Different alternatives for rehabilitation projects involving communities have been the centre of discussions by various scholars, included Pasicolan *et al*. (1997) and Drilling (1989 in Kartawinata 1994). There are various management approaches to carrying out rehabilitation programmes and outgrower schemes complement these alternatives. However, the approach chosen should be influenced by the local socio-economic context and level of degradation (Lamb & Tomlinson 1994). Identified approaches in implementing rehabilitation project include:

a. farm forestry executed by spontaneous tree growers;
b. taungya system;
c. integrated Social Forestry/Joint Forest Management/Community Based Forest Management;
d. contract Reforestation Projects.

Although not specifically a rehabilitation project, PICOP (Paper Industries Corporation of the Philippines) initiated an outgrower scheme in 1968 with local communities to grow *Paraserianthes falcataria* for the company's pulpwood requirements. The number of participating farmers increased significantly from the 1980s until the early 1990s (Matela 1984 and Kato 1996, as cited by Arnold 1998), which was an indication of the farmers' interest in what was perceived to be a mutually beneficial undertaking. PICOP's scheme did not survive due to changes in the company management who were not interested in continuing the scheme, the fall of *P. falcataria* prices and technical problems of using *P. falcataria* to produce pulp. However, the PICOP's scheme provided valuable lessons for other companies to initiate outgrower schemes, and possibly to implement effective rehabilitation programmes. The lessons learnt from the outgrower schemes are useful in providing alternatives to managing rehabilitation projects in Indonesia.

Alternative modes of financing and enhancing potential economic viability of rehabilitation projects

Rehabilitation projects have always been associated with high costs (Lamb & Tomlinson 1994, Pasicolan *et al*. 1997). This applies also in Indonesia, as indicated by the Ministry of Forestry, which estimated the cost of forest rehabilitation at Rp2.5–5 million per hectare or approximately US$271–541 per hectare (Jakarta Post 2000, p. 2). Accordingly, using the current estimate of forestry-degraded areas, the budget required would be US$3 billion or Rp22 trillion. As a comparison, the average cost per hectare to develop outgrower schemes to produce timber as well as financing farming activities was US$518 for a scheme with *Acacia* and US$1 859 for a scheme with *Alstonia*[2], not including the revenues generated at the end of timber harvesting and from farming activities.

For the rehabilitation projects, the government has to seek loans from international donor agencies, and/or use the reforestation funds paid by private concerns. In outgrower schemes, private companies provide initial funding for the first rotation (with or without funding from commercial loans), and for the following rotation the fund is expected to come from the scheme's activities. The private funds would contribute to reducing the government's financial burden, securing the timber market in advance, accessing the company's technology and supporting local infrastructure development.

Addressing the underlying socio-economic causes of land degradation

Various socio-economic aspects have often been highlighted as the root of forest degradation; most previous rehabilitation projects failed to recognize these as they focussed mostly on technical aspects. The underlying socio-economic causes of degradation can be addressed by outgrower schemes.

Avoiding land tenure conflicts

One of companies' motivations in initiating the schemes was to find a way to productively plant the areas that were occupied by local people inside the concessions (categorized as state forests). During the initiation process, to prevent potential conflicts over lands (with financial implications), companies ensured the lands were free from conflict by clarifying land status. From the tree growers' perspective, this process has indirectly led to greater recognition of their long-term land-user rights or land status. Long-term contract agreements (11 to 45 years) could be a solution to disputes over access to forestry lands, since various types of tree-grower rights are acknowledged in the schemes (Table 1).

[2] Calculated based on the present values of costs for running the project for one rotation.

Table 1. Categories of land status included in outgrower schemes

1. Communal land belongs to the village (included *adat* lands):
• Community members respect the land status as required by adat or customary rules.
• May not be administered in the land status categories according to state law.
2. Individual land based on a judgement from the head of the village on land status or SKT- Surat Keterangan Tanah:
• Approved by the head of the village and respected by communities at the neighbouring villages.
• Can be used to obtain a land certificate from the National Land Agency at the provincial level.
3. Individual land based on a judgement from the head of *dusun* (sub-village) or *SPH-Surat Pengakuan Hak*:
• Approved by the head of dusun (sub-village) and may be respected among villages.
• Can be used to obtain a land certificate, but with longer administration procedures.
4. Individual land based on a land certificate:
• Legalised land status and approved by all levels of government authorities.
• Respected by all parties.
5. Paper on right over transmigration areas:
• Secured land status under government resettlement/transmigration programme.
• Respected by all parties.

Source: Nawir *et al*. (2002).

Creating a conducive environment for community participation through clear delineation of rights and responsibilities

a. Company's responsibilities and rights

Companies are responsible for all the costs in establishing plantations, as well as setting up institutional arrangements for local tree growers, conducting training and related extension programmes. In return, companies secure access to jointly managed lands and planted timber crops by placing supervision responsibilities in the hands of tree growers. Specific responsibilities and rights are as follows:

Company's responsibility:

1) to manage outgrower lands with the objective of developing timber plantations;
2) to make advanced payments in relation to the initial activities and expenses of schemes in establishing plantations;
3) to strengthen tree growers' capacities to become partners in the outgrower scheme by assisting the community to improve organisation skills and by providing training and extension in plantation management;
4) to guarantee commercial loans made by tree growers to use as basic capital (if loans are required);

5) to secure the rights of tree growers to have first priority to be employed in outgrower plantations and paid at the wage rate defined by the company;
6) to define procedures/terms of payments/wage rates.

Company's rights:

1) to have full rights and access over the land under the contract terms and to harvest planted trees;
2) to buy timber/cash crops at the current market price/to decide the royalty rates for calculating entitlements of tree growers under any benefit-sharing agreement.

b. Local tree growers' responsibilities and rights

In general, land owners/tree growers are mainly responsible for securing company access to the areas by not transferring the land ownership (unless the right to harvest remains with the company) to other people, and by maintaining and protecting the planted areas from theft and/or fires. If loans are involved, land owners as a group are responsible for paying back the credit. In return, besides receiving a certain proportion of the net revenue from harvested timber crops, tree growers have access to various incentives provided by companies, such as income options to bridge the period between planting and harvesting. Specific responsibilities and rights include:

Local tree growers' responsibilities:

1) to co-operate with the company and make no objection to hand over the land to the company during the period of contract;
2) to be responsible for planting, fertilizing and maintaining trees according to the company working plan;
3) to define land boundaries included in the schemes;
4) to protect plantations from trespassers and forest fires;
5) to face claims from a third party (if any), and reimburse all expenses paid by the company;
6) to grant secure company access to the plantation areas, since tree growers have no right to use, or lease their land to other parties without written permission from the company (and the right to harvest remains with the company);
7) to pay tax for land and property (*PBB- Pajak Bumi dan Bangunan*);
8) to form a Forest Farmer Co-operative, and to return the basic capital (if it was from loans).

Tree growers' rights:

1) to be employed to work on the plantations, and paid at the wage rate decided by the company;
2) to have their lands back if the contract is terminated;
3) to practise multi-cropping as long as the main timber crops are maintained;
4) to take over trees on their rights and other tree species growing on the lands (specifically for Xylo);
5) to transfer outgrowers' rights to their legal heirs (specifically for Xylo);
6) to be trained by the company;

7) to receive incentives on land, infrastructure, and revenues based on the royalty of 10% planted trees (Finnantara Scheme);
8) to enjoy the benefits from community development programmes: rubber, agroforestry, native species, credit facilities (Finnantara Scheme).

c. Providing benefit-sharing arrangements

Net revenue-sharing agreements between company and tree growers vary from equal sharing (50:50), 60 to 40, 80 to 20, and 90 to 10, depending on contributed inputs and the basis used to define the proportion, such as share holdings, royalties and company contributions to build the local infrastructures. Table 2 shows the Net Present Values (NPV) of the schemes for one rotation and the shared revenues according the agreement. NPV explain future net revenues of the scheme at the end of a rotation and are discounted to the present values by using the interest rate as the discount factor. In this study 12 percent (for savings) and 20 percent (for commercial loans) interest rates were used.

Table 2. Net Present Values (NPV) of outgrower schemes studied

Estimated values	Net Present Values (NPV)[a]	
	Rp (000)	USD
1. Low estimation[b]	2 134	231
2. High estimation[b]	5 689	616
Average	3 912	423
Shared benefits[c]:		
• Company	1 719	186
• Tree growers	898	97

Notes:

a. Estimated NPV of one rotation for three case studied schemes, and excluded one scheme with negative NPV.

b. Low and high estimation referred to estimated volumes of timber produced.

c. Estimated average values of all schemes. Individual scheme has specific benefit sharing arrangement for company and local tree growers.

Source: Analysed from Nawir *et al.* (2002).

Financially, the schemes have the potential to provide net revenues for local tree growers. However, since the revenues depend on the efforts to meet the timber targets, the main challenge is to meet the technical requirements so these target production are met. In the case of Finnantara in West Kalimantan, outgrower schemes could also be targeted at local shifting cultivators. Such an agreement would be beneficial because the shifting cultivators might be the main agent of forest degradation in the local area.

Financing rehabilitation through private investment with targeted long-term financial returns

Scope for companies to produce timber while maintaining ecological and social goodwill

Commercial feasibility in the long-term is very important for private companies to initiate outgrower schemes, likewise if they are willing to become involved in a rehabilitation project. The commercial feasibility of an outgrower scheme is determined by the quantity of timber produced from the plantations (Table 3).

Table 3. Estimated timber production from outgrower scheme areas (all schemes)

Comparison	Schemes planted to *Acacia*[a]	Scheme planted to *Alstonia*[b]
Potential harvested outgrower scheme areas per year[c]	Inside concessions: 5 993–10 296 ha On community lands: 1 644 ha	On community lands: 1 350 ha
Estimated standing volume per hectare[d]	75–150 m^3ha^{-1}	100–260 m^3ha^{-1}
Estimated total harvested volume	1 344 953–2 689 906 m^3	152 500–396 500 m^3
Contribution to annual company requirement[e]	33 – 67 percent	More than 100 percent[e]

Notes:

a. Schemes initiated by Wira Karya Sakti (WKS) and Finnantara Intiga inside timber plantation concession areas and on community lands.

b. Scheme initiated by Xylo Indah Pratama (XIP).

c. Based on estimated average planting areas per year, except for WKS scheme inside concession which was calculated based on potential areas planned to be managed under eight rotations.

d. The lower limit was estimated at 50 percent lower than the upper limit, which was the figure used by companies in the feasibility study.

e. Requirement of processing companies.

f. More than 100 percent because company owns small-scale processing capacity.

Source: Analysed from Nawir *et al.* (2002).

Overall the estimated timber produced suggests that the plantations developed under the outgrower schemes could become reliable wood sources. The estimated total wood produced could contribute up to 67 percent for pulp processing companies (in addition to companies' supplies from their own plantation areas). Excess supplies for Xylo processing plants would be used to produce pencil slats, since the company owns a small-scale plant. The excess supplies might also be absorbed by the local market to be used for construction purposes and mouldings.

Providing incentives and complementary income-generating programmes for tree growers

In line with the main outgrower scheme's objective to produce timber, the case studies focussed on 90–100 percent of the areas managed under partnership to develop timber plantations. In initiating the schemes, companies recognize that returns on the investment in timber plantations take many years before harvesting, which would be difficult for tree growers with limited income options to fulfil their basic needs during this waiting period. The companies are interested in filling these gaps to prevent the tree grower partners breaking the contract and to ensure the companies will get the timber at the end. Therefore, companies have provided different incentives and developed various complementary programmes to provide tree growers with options for generating incomes (Table 4).

Table 4. General designs of the case-studied outgrower schemes[a]

1. Main programme on outgrower scheme areas

a. 90–100 percent of the areas used for plantations (*Alstonia* and *Acacia*)[b]

b. On five to ten percent of the areas, company initiated:
- farming activities of food crops such as patin (local fish), and corn
- developing rubber plantations
- planting indigenous species

2. Other incentives as part of the partnership programme[c]

a. Farming/economic activities:
- agroforestry and cash crop programmes
- credit and savings programmes

b. Financial incentives:
- social funds
- land incentives and funds for infrastructure development
- incentives for conducting a traditional ceremony prior to land clearing

c. Capacity building:
- training in the field
- organising tree growers by forming cooperatives

Notes:

a. Summarizing from individual scheme designs in the case studies.

b. Government regulation ruled the composition of the main crops (90%) and other crops (10%).

c. Social funds provided in responce to local communities' requests for financing social occasions.

Source: Nawir *et al*. (2002)

The designs provided opportunities for tree growers to gain tangible and intangible benefits, such as access to field training. Companies could also act as agents to conduct forestry extension programmes as a complement to local forestry offices' responsibilities.

Promoting more ecologically based practices

In the case studies, outgrower schemes promote practices that are important from the ecological point of view. Timber plantation companies are mandated to manage logged-over areas, since these are areas granted by the Ministry of Forestry. The companies employ the tree growers for manual labour in operations such as land clearing. Because of the scattered locations of outgrower scheme plantations, sometimes it is not cost-efficient to apply mechanical operations.

By default, the rehabilitation project focusses on degraded areas that require adequate technical treatment, such as good planting stock and early weed control (Lamb & Tomlinson 1994). Involving private timber plantation companies (who usually have a department working on research and development) will be important to fulfil the technical requirements since the privates' sites are well equipped with the latest technical knowledge, and usually located closed to the areas for developing technical guidelines for local practices for their partners to improve their skills in outgrower schemes. Specific features included:

1) Environmental Impact Assessment (EIA):
   - conducted by an independent evaluation team (Finnantara Scheme);
   - conducted annually as part of company's working plans.
2) Focus on degraded lands (logged-over areas) and peat swamp areas

3) Community participation allows for low impact land preparation technique:
   a. manual land clearing, except for road development;
   b. forest fire prevention
      • minimum burning techniques in plantation areas;
      • demonstration of fire prevention techniques by company staff;
      • incentives provided for local tree growers to report burning activities to the company if they clear their gardens for planting food crops;
      • incentives provided for tree growers to supervise the plantation during the dry season.
5) Scope for having more mixed canopy change and higher species diversity:
   • at the landscape level through programmes on rubber plantations, local (indigenous) species and agroforestry;
   • area development based on the proportion of 90% (main timber crops) and 10% (cash crops);
   • multi-cropping allowed in *Alstonia* plantation areas.

ESSENTIAL PREREQUISITES FOR SUCCESS OF OUTGROWER SCHEMES

Sustaining the partnerships in outgrower schemes under a long-term contract is a challenge in itself. One way is to ensure the partnership is mutually beneficial for both parties, which will provide greater chances for outgrower schemes to be viable and can be effective in achieving defined objectives (could be land rehabilitation). This will be in line with the framework of prerequisites for mutually beneficial partnerships (Nawir *et al*. 2002), which are:

- commercially feasible under a long-term partnership contract;
- mutually beneficial arrangement, which is developed based on fair contractual agreement determined by fair valuation of shared inputs for mutual economic and social objectives, and a full understanding from both parties of the potential consequences and risks of joining the partnership;
- mutual economic and social objectives indicated by mutual acceptance of each partner's objectives as included in the arrangement;
- the process to achieve the objective to be in line with the co-management concept: participation as one of the key principles.

Further commercial viability to both company and tree grower partners depends on several conditions for success:

- link with processing industry/timber market, which is important to secure the market for timber produced by tree grower partners;
- taking into account the inputs of both parties to define the benefit-sharing agreement and timber-buying prices from tree growers;
- managing crucial cost components (such as transaction costs which include community organizing and social funds) based on cost-effectiveness of small-scale timber plantation management;
- designing a re-investment mechanism as part of the agreement.

Often, companies do not want to invest in outgrower schemes as they are sceptical that the tree growers' commitments can be secured in the long term. The case studies suggested that tree growers' long-term commitment could be secured by:

1) ensuring fair and profitable revenues from the first harvest which is important for tree growers to continue joining the partnership;
2) providing income opportunities during the grace period on the condition that there are high land opportunity costs and limited income opportunities;
3) accommodating local socio-cultural conditions and needs based on a proper community needs assessment for cost-effective investments on different programmes of alternative incomes;
4) securing the land status (although not necessarily land title, such as the user rights);
5) effective association/cooperative/institution to represent tree growers in negotiating with the company.

Maintaining outgrower schemes under a long-term contract is more difficult than the initiation process. The arrangement should be flexible enough to adapt to the changing socio-economic conditions within the framework of initial mutual objectives. Maintaining outgrower schemes under long-term contract is a continuing and dynamic process and trade-offs are inevitable. Taking into account the elements of the dynamic processes in maintaining outgrower schemes will be one way to ensure a mutually beneficial partnership.

CONCLUSION AND POLICY RECOMMENDATIONS

Case studies suggested that different arrangements of outgrower schemes could potentially have significant roles in managing rehabilitation projects. Outgrower schemes include potential features that are in line with farm forestry and can be regarded as cost-effective and sustainable schemes to reforest marginal remote areas (Pasicolan *et al*. 1997). They are cost-effective, since the process will mostly involve the most relevant key stakeholders, such as timber plantation companies and the surrounding communities, and socio-economic benefits are gained by both parties. However, challenges still remain to ensure the schemes are mutually beneficial for both parties. Policies should be directed to provide an environment for companies to become involved in rehabilitation programmes, while maintaining commercial objectives, such as:

- exempting private companies from paying Reforestation Funds, if they are committed to developing rehabilitation programmes in their operational areas under government supervision;
- clarifying the role of third parties (government at different levels and NGOs) for effective implementation of outgrower schemes on the grounds that they are essential areas to be further explored.

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BIBLIOGRAPHY

Arnold, M. 1998. *Trees as out-grower crops for forest industries: experience from the Philippines and South Africa*. Network Paper 22a, page 16. Oxford, Rural Development Forestry Network, ODI.

Jakarta Post. 2000. Minister appeals for foreign aid for reforestation. *The Jakarta Post*, page 2.

Jakarta Post. 2001. Community forest development called for: experts called on Monday for the development of a community forestry structure within the regional autonomy framework, comprising local communities, the government and the forestry authorities, for the purpose of managing the country's some 142 millions hectares forest. *The Jakarta Post*, 20 March 2001, page 2.

Kartawinata, K. 1994. The use of secondary forest species in rehabilitation of degraded forest lands. *Journal of Tropical Forest Science* 7: 76–86.

Lamb, D. 1994. Reforestation of degraded tropical forest lands in the Asia-Pacific Region. *Journal of Tropical Forest Science* 7: 1–7.

Lamb, D. & Tomlinson, M. 1994. Forest rehabilitation in the Asia-Pacific Region: past lessons and present uncertainties. *Journal of Tropical Forest Science* 7: 157–70.

Mayers, J. 2000. Company-community forestry partnerships: a growing phenomenon. *Unasylva* 200 51: 33–41.

Ministry of Forestry (Forestry Planology Agency). 2002. *Masterplan of forest and land rehabilitation policy and forest resource condition*. Presentation material by Dr. Ir. Dwi Sudharto, M.Si. (Dated 30 August 2002, in Indonesian languange), Jakarta.

Nawir, A.A., Santoso, L. & Mudfofar, I. 2002. *Towards mutually beneficial partnership in outgrower schemes: lessons learnt from Indonesia.* (Draft). PLT Program – Plantation Forestry on Degraded or Low-Potential Sites. Bogor, Center for International Forestry Research.

Pasicolan, P. & Tracey, J. 1996. Five case studies in Luzon, Philippines. Improving smallholder farming systems. *In* K. Menz, D. Magcale-Macandong & W.I. Rusastra, eds. *Improving smallholder farming systems in imperata areas of Southeast Asia: alternatives to shifting cultivation*, pp. 55–63. ACIAR Monograph No. 52.

Pasicolan, P.N., Udo de Haes, H.A. & Sajise, P.E. 1997. Farm forestry: an alternative to government-driven reforestation in the Philippines. *Forestry Ecology and Management* 99: 261–74.

World Bank. 2001. *Country profile table: Indonesia data profile*. Internet document. http://devdata.worldbank.org/external/CPProfile.asp.

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Land and forest degradation has become so devastating in the Asia-Pacific region that it is now bringing severe environmental and economic problems, and is beginning to threaten the livelihoods of millions of people. The need to rehabilitate these lands and forests is growing. Rehabilitation in the past was largely limited to monocultures and enrichment plantings. Most such efforts met with failure or were not cost-effective. But the science of rehabilitation has advanced significantly – now forest rehabilitation procedures seek to go far beyond commercial timber production. New rehabilitation techniques are being developed to increase biodiversity and ecological services, and initiatives are purposefully linked with social development programmes. This publication includes papers presented at an international conference held 7 – 10 October 2002 in Kuala Lumpur, Malaysia, giving a comprehensive overview of the various initiatives and experiences gained in *Bringing Back the Forests*.

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