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

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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"*

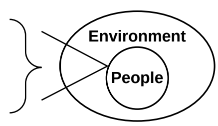
Multi-layered actions

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)

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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) Forest protection 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

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[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).

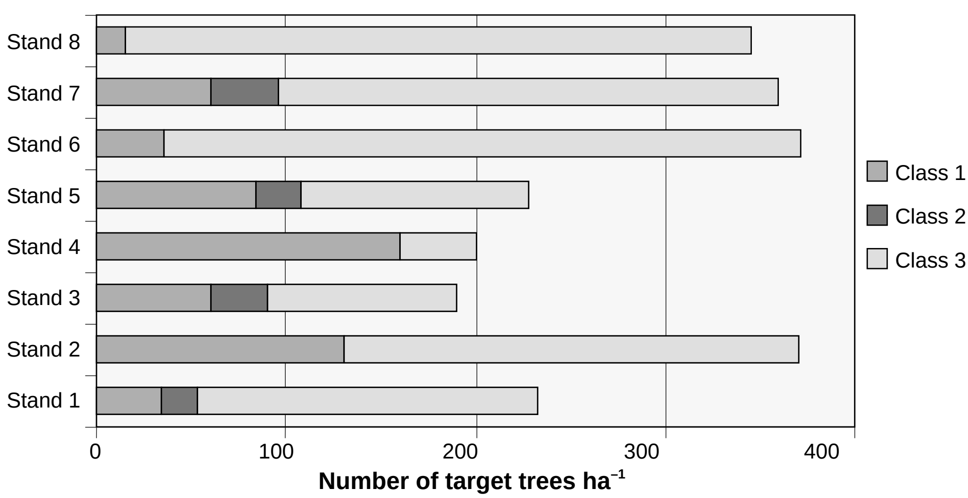

Figure 1. Number of target trees per hectare by class in eight randomly selected stands

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.

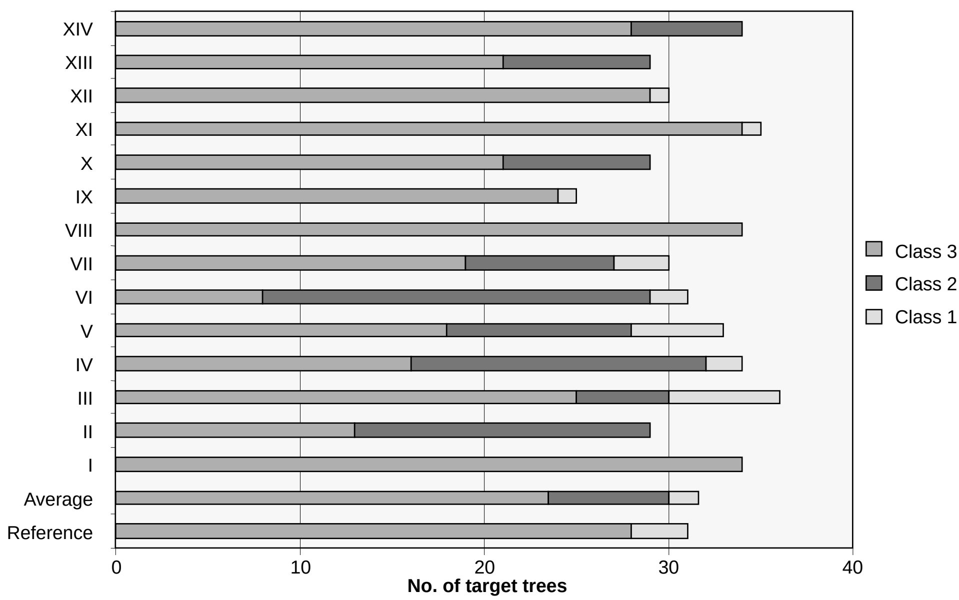

Figure 2. Determination of target trees by class. By 14 project participants (1–XIV)

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.

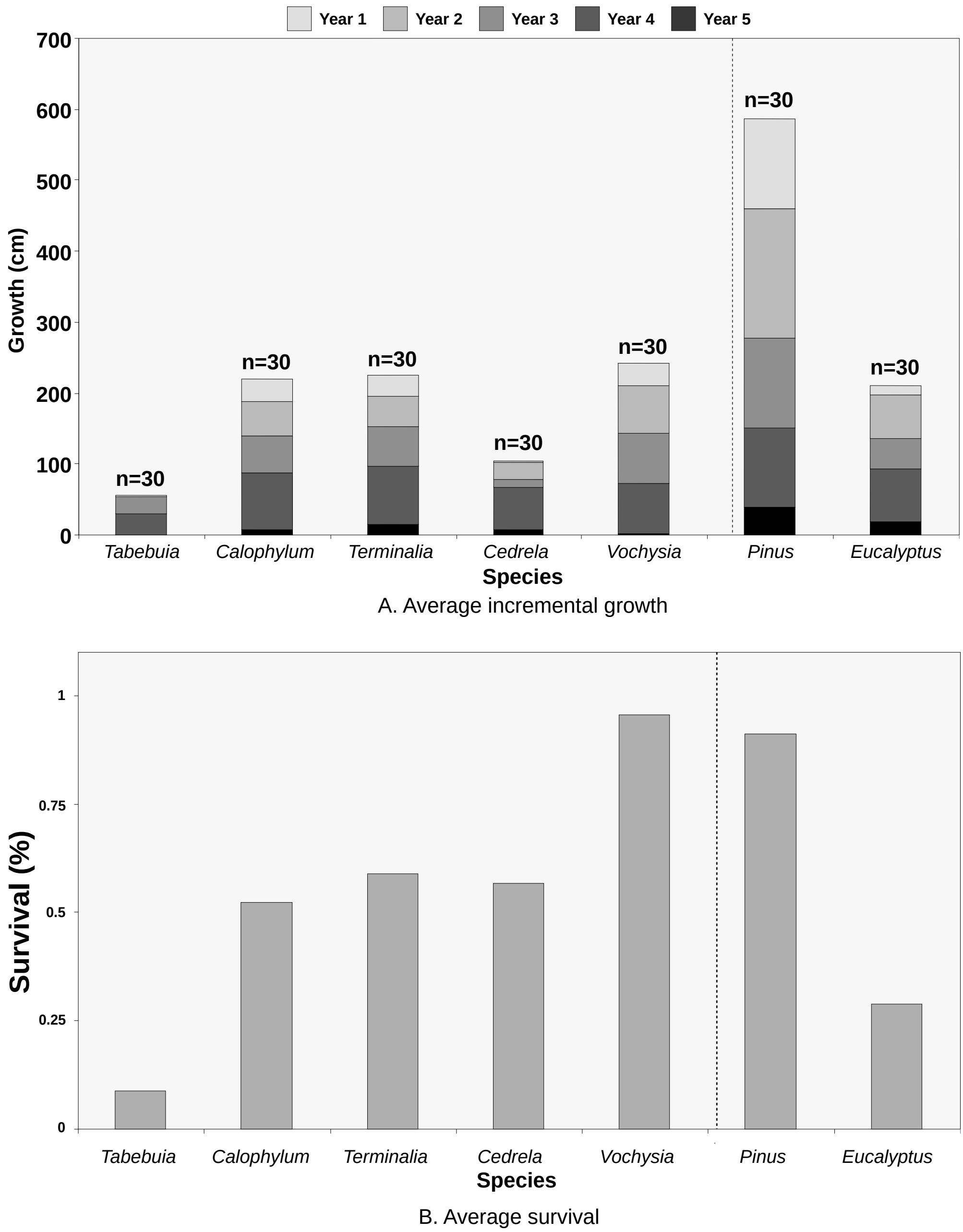


Figure 1. Growth from 1994 to 1999 and survival in 1999 of five native species of trees (left of vertical line) and two exotics (right of vertical line). A. Means of three trees per block averaged over 30 blocks for each species. B. Percent of the initial 90 trees of each species still alive in 1999. 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

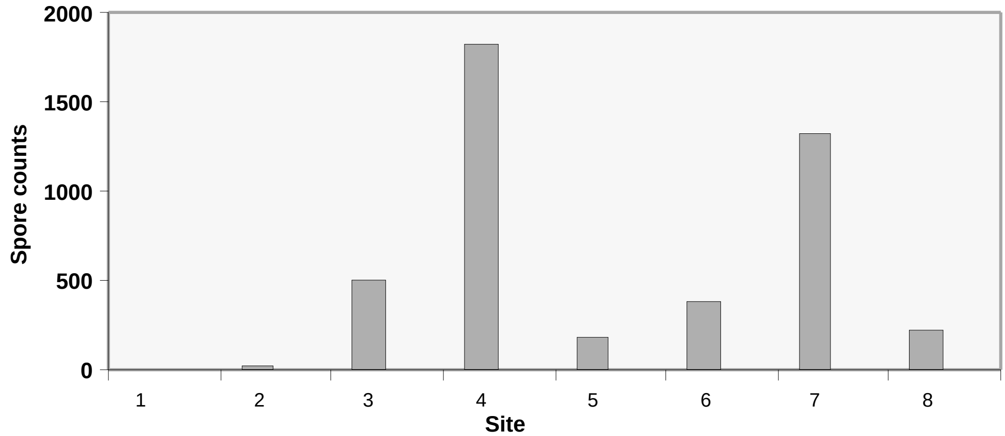
Fertilization of *Terminalia amazonia* (Experiment 3)

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.

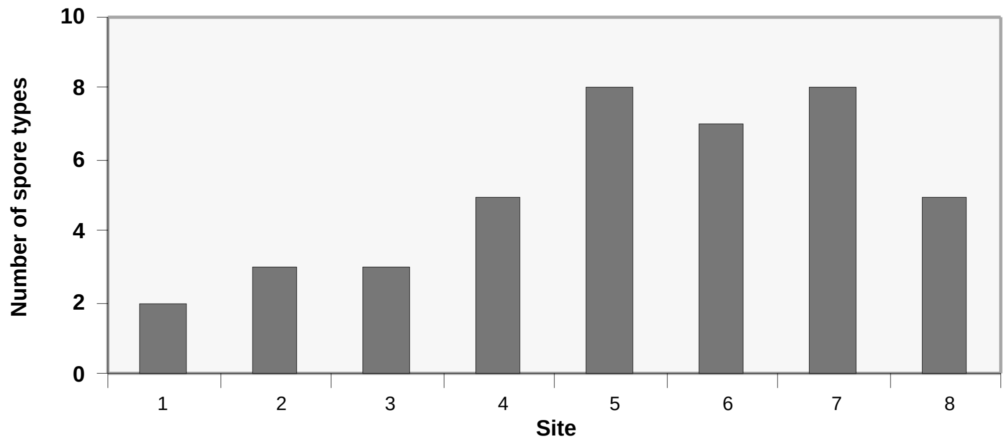
Mycorrhizal potential (Experiment 4)

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

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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	Canopy	Form
		Mean (m y^{-1})	St. Dev.	Worst site	Best site	DBHOB (cm y^{-1})	Dia (m y^{-1})	
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.

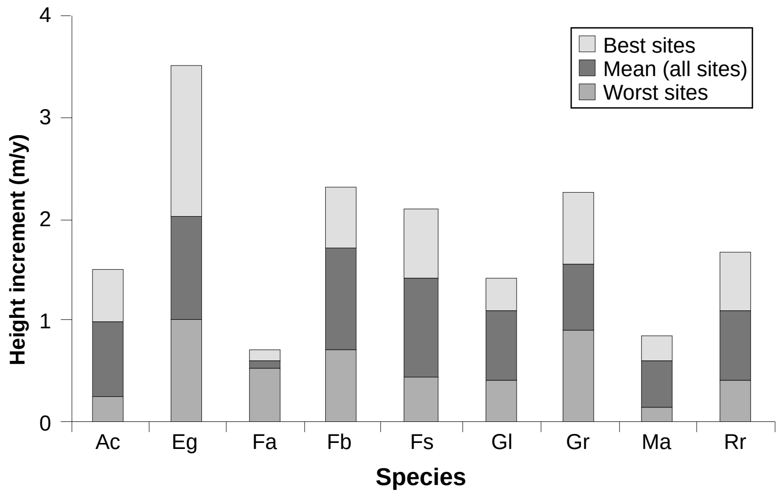

Figure 1. Mean annual height increments (my^{-1})

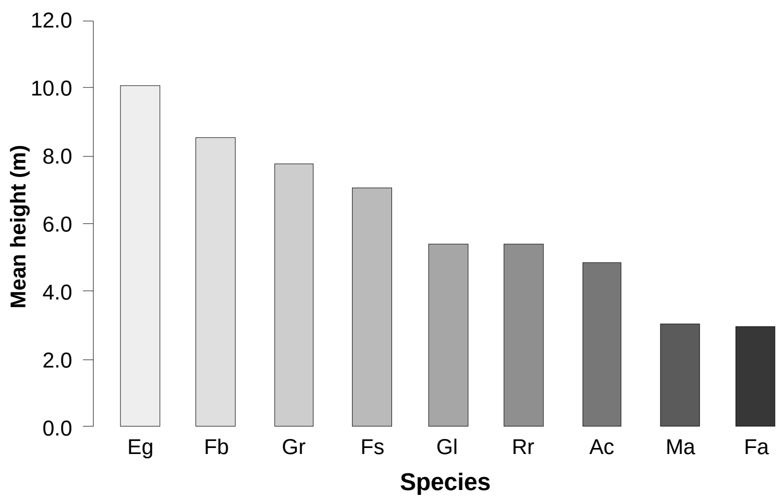

Figure 2. Mean heights at five years (m)

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.

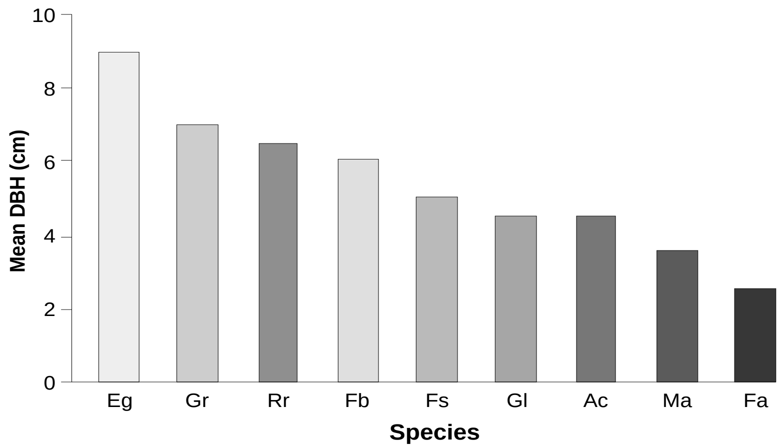

Figure 3. Mean stem diameters at breast height (cm) at five years

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).

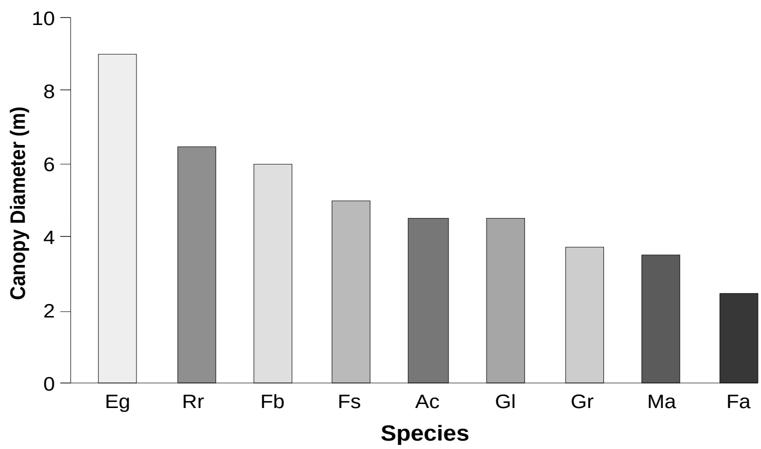

Figure 4. Mean canopy diameters (m) at five years

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).

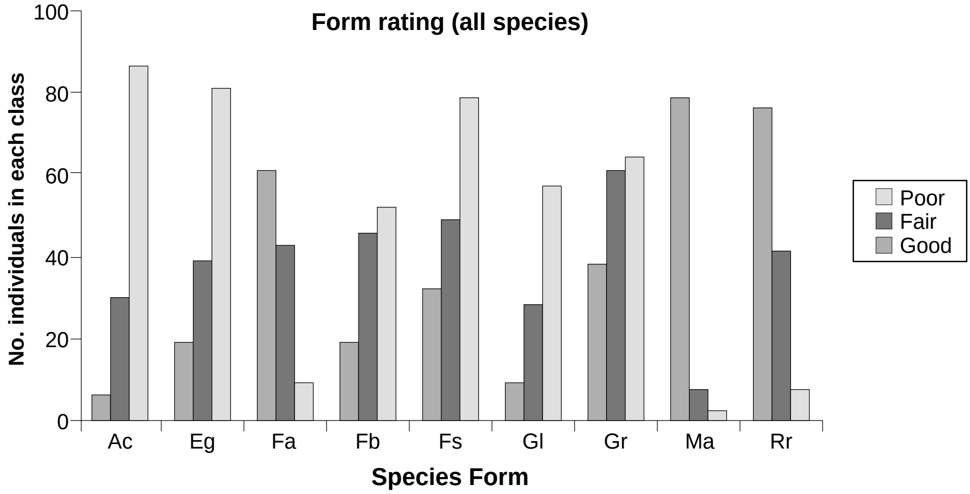

Figure 5. Form classification for each species

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

[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

Reinhard F. Hüttl* and Werner Gerwin*

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.

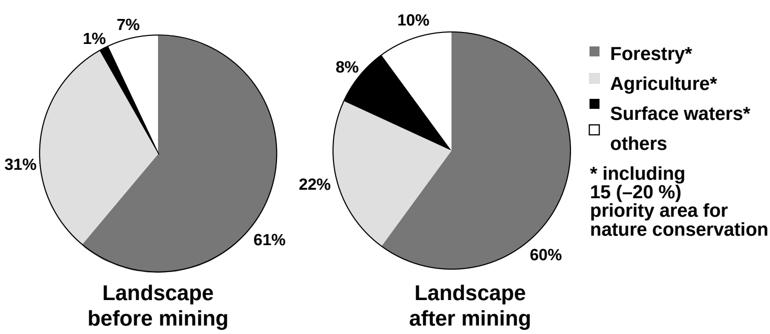

Figure 1. Distribution of land-use sectors before and after mining (Pflug 1998; modified)

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).

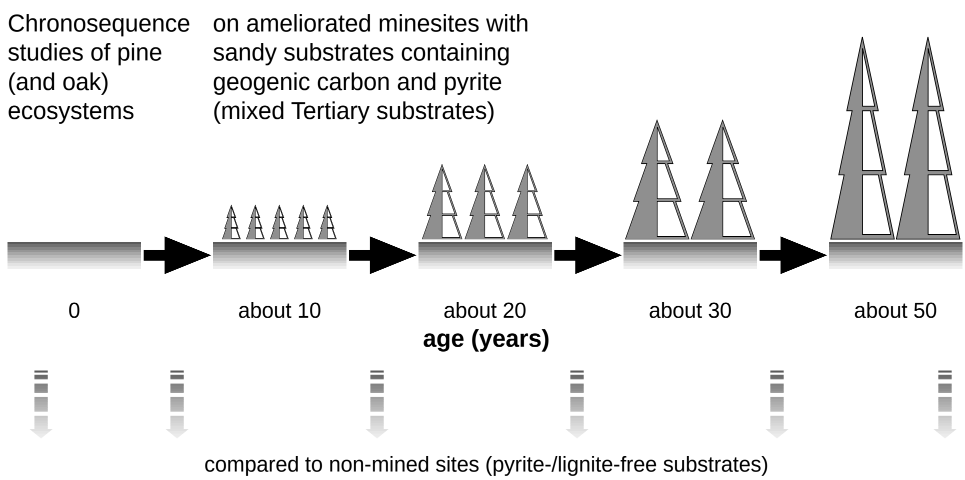

Figure 2. Chronosequence studies of pine ecosystems (schematically)

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

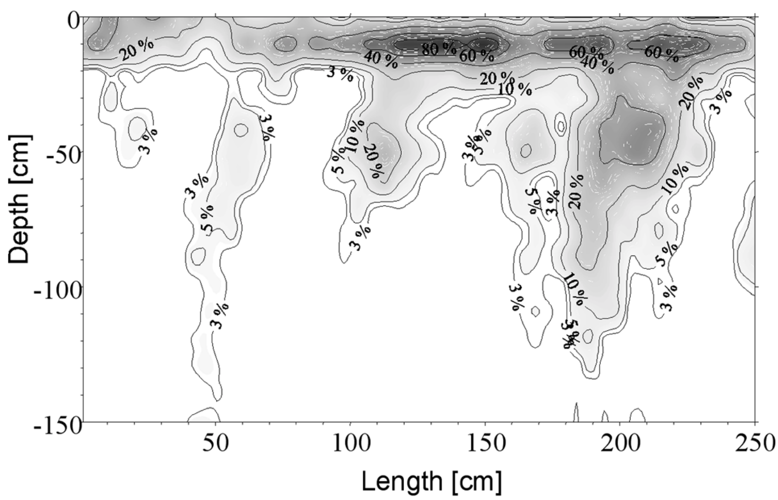

Figure 3. Spatial heterogeneity of dumps soils: results of a jodid-tracer study at Bärenbrück (distribution in %) (Gerke *et al*. 2000)

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.

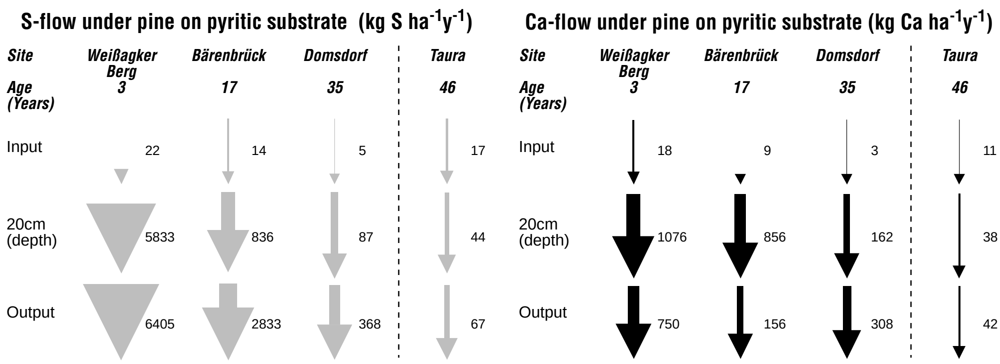

Figure 4. Sulphur- and calcium-flows under pine on pyritic, i.e. Tertiary substrate (Gast *et al.* 2000, modified)

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).

[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.

[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	
a. Wood industry		• market security • 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

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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)

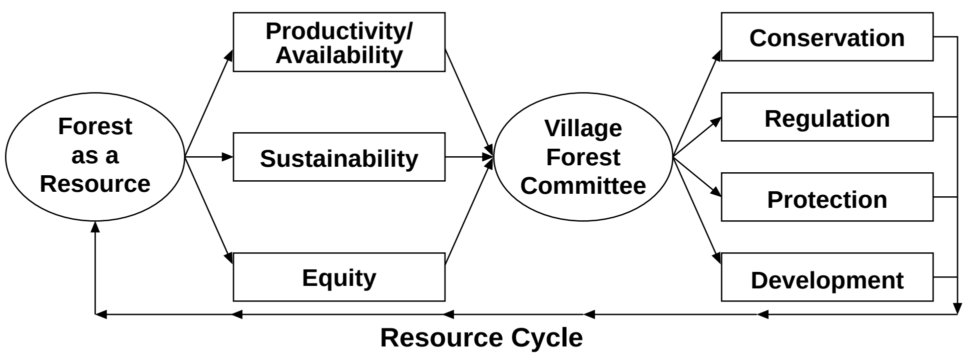

Diagram 1. Forest resource cycle
Source: Biswas (1993).

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.