Issues in Forest Conservation

Rehabilitation and Restoration of Degraded Forests

David Lamb and Don Gilmour

WWF

IUCN
The World Conservation Union

Issues in Forest Conservation

Rehabilitation and Restoration of Degraded Forests

This publication has been made possible in part by funding from Lafarge Aggregates, through its support to WWF's Forest Landscape Restoration Programme; the United States Department of State, Bureau of Oceans, International Environmental and Scientific Affairs; Yuhan-Kimberly and NEAFF (Northeast Asian Forest Forum).

Published by: IUCN, Gland, Switzerland and Cambridge, UK in collaboration with WWF, Gland, Switzerland

IUCN
The World Conservation Union

WWF

Citation: David Lamb and Don Gilmour. (2003). *Rehabilitation and Restoration of Degraded Forests.* IUCN, Gland, Switzerland and Cambridge, UK and WWF, Gland, Switzerland. x +110 pp.

ISBN: 2-8327-0668-8

Cover design: Patricia Halladay

Cover photo: Understorey regeneration, northern Queensland, Australia. Photo: R. Keenan

Layout by: Patricia Halladay

Printed by: SADAG Imprimerie, Bellegarde-sur-Valserine Cedex, France

Available from: IUCN Publications Services Unit
219c Huntingdon Road, Cambridge CB3 0DL, United Kingdom
Tel: +44 1223 277894, Fax: +44 1223 277175
E-mail: books@iucn.org
http://www.iucn.org

A catalogue of IUCN publications is also available

The text of this book is printed on 115 g/m^2 matte paper made from non-chlorinated pulp.

Issues in Forest Conservation

Rehabilitation and Restoration of Degraded Forests

David Lamb and Don Gilmour

September 2003

IUCN's Forest Conservation Programme

IUCN supports a people-centred approach to conservation that ensures that biological resources are positively employed to help secure sustainable and desirable livelihoods. The goal of the IUCN Forest Conservation Programme is the maintenance and, where necessary, restoration of forest ecosystems to promote conservation and sustainable management of forests, and equitable distribution of a wide range of forest goods and services. The Programme consists of a network of regional nodes located in Asia (http://www.iucn.org/themes/fcp/about/details.html), Africa, Latin America and Europe, coordinated by a small global secretariat located in the IUCN headquarters in Switzerland and an outposted global office in Canada. The network engages in partnerships undertaking a wide range of activities to further the mission of IUCN in relation to conserving and managing the world's forests, and fosters change by linking practice and policy at the landscape, national and global levels.

WWF's Forests For Life Programme

WWF's vision for the forests of the world, shared with its long-standing partner, IUCN, is that: "the world will have more extensive, more diverse and higher-quality forest landscapes which will meet human needs and aspirations fairly, while conserving biological diversity and fulfilling the ecosystem functions necessary for all life on Earth".

WWF's approach to forest conservation has evolved over time into a global programme of integrated field and policy activities aimed at the protection, management and restoration of forests, whilst at the same time working to address some of the key threats to forests which could potentially undermine these efforts. Those of particular concern to WWF are illegal logging and forest crime, conversion of forests to plantation crops of palm oil and soy, forest fires and climate change.

The Forests for Life Programme consists of a global network of more than 250 staff working on over 300 current projects/programmes in nearly 90 countries, with regional forest officers working to coordinate efforts in each of the five regions supported by a core team based at WWF International in Switzerland.

Contents

Boxes

Figures

Tables

Preface

Widespread deforestation and declining condition of the world's forests has resulted in environmentally, economically and aesthetically impoverished landscapes. To some extent the effects of deforestation and loss in forest quality have been offset through natural regeneration of forest and the establishment of plantations. However, much of the regenerated forest consists of a few species designed to yield one or two products rather than seeking to produce a broader range of forest goods and services that will also contribute to the well being of local communities.

Conventional approaches to plantation forestry are seldom capable of delivering the multiple values of forests and adequately addressing the needs of all interest groups (e.g. forest-dependent communities and downstream water users). Indeed, such schemes can result in a reduction in the range, quality and volume of forest goods and services, social and economic dislocations and an increased vulnerability to climate change and other natural perturbations. There is an urgent need to both improve the quality of forest restoration and rehabilitation at the site level and to find effective ways to undertake these activities in the context of broader environmental, social and economic needs and interests.

Lamb and Gilmour present approaches to restoring and rehabilitating the vast areas of degraded, fragmented and modified forests which cover much of the world. They argue that by applying best practice at the site level it is possible to enhance socio-economic and ecological gains at the landscape level. This approach is consistent with the ecosystem approach called for in the Convention on Biological Diversity. The ecosystem approach is based on the realization that:

- land management has on-site and off-site impacts on ecosystems and people and therefore must be undertaken within the limits of ecosystem functioning;
- viable species populations and healthy ecosystem processes cannot be contained within small units of land measured in tens or hundreds of square kilometres, particularly when these areas are disconnected; and
- conservation planning and action must take place across whole landscapes and involve multiple interest groups.

IUCN – The World Conservation Union and WWF – The Conservation Organization have been working with a range of other partners since 1999 to promote an approach called "Forest Landscape Restoration". Their aim, through both practical projects and the provision of credible policy advice, is to promote ecological integrity and enhance human well-being in deforested or degraded forest landscapes by:

- offering an approach to forest restoration that includes improving rural livelihoods;
- producing a wide range of goods and services, rather than simply planting trees;
- linking forest restoration and rehabilitation activities at the site level with the environmental, social and economic needs at the landscape and ecoregional level;
- recognizing and attempting to balance land-use trade-offs; and
- providing a multi-sector approach that ensures the participation of interest groups in decision-making.

Much needs to be done to turn Forest Landscape Restoration from an idea that is implemented in a few pilot areas into mainstream practice that is adopted and promoted by governments and the private sector. Nevertheless, we hope that the approach can enhance the contribution of forests to rural poverty reduction, increase the productive capacity and commercial viability of existing land-use systems, minimize long-term, environmental and economic risk, improve ecosystem services, ensure greater habitat connectivity, mitigate against threats to forested areas and enhance biodiversity conservation.

This book provides an important contribution towards the objectives of Forest Landscape Restoration and is essential reading for practitioners and decision makers involved in forest restoration.

Dr. William Jackson — Director, Global Programme, IUCN

Stewart Maginnis — Head, Forest Conservation Programme, IUCN

Dr. Chris Elliott — Director, Forests for Life Programme, WWF International

Chapter 1

Introduction

Large areas of the world's forests have been lost or degraded and landscapes everywhere are being simplified by current land-use practices (Dobson, Bradshaw and Baker 1997). In many tropical countries increasing areas of forest or woodland are cleared for agricultural use. The same is true in some temperate countries although, for the most part, land-use patterns there have stabilized over the last century. In many temperate countries, however, agricultural practices are intensifying. Small family-owned farms are being replaced by larger industrial operations owned by corporations, and forest remnants and hedgerows are being removed to allow for larger-scale operations. In both tropical and temperate regions, therefore, landscapes are being homogenized. Ironically, there are also increasing areas of abandoned land in both tropical and temperate areas. In some cases the previous forms of agriculture were unsustainable and farmland was abandoned when productivity declined. In other cases, particularly in western Europe, social and economic changes (including reductions in agricultural subsidies) have led to the abandonment of previously productive agricultural land.

Agricultural expansion and intensification have decreased the overall area of forest and woodland, simplified the structure of the remaining forests and broken up forest areas into smaller and more isolated fragments. The consequences of these changes, seen both on-site and off-site, include the following:

- on-site reductions in landscape productivity because of increasing losses of nutrients and soil;
- downstream impacts, such as reductions in water quality through increased sedimentation and changes in water yield; and
- widespread reductions in biodiversity and the supply of various ecological goods and services.

Such changes, and others likely to occur in the near future, are described by Vitousek et al. (1997) and Tilman et al. (2001). In some cases the effects of a loss of forest cover (e.g. erosion) are almost immediate. Other changes (e.g. salinisation, biodiversity loss) take a long time to become evident. The cumulative effects of the release of carbon once sequestered in biomass and soil organic matter are likely to contribute to long-term changes in the global climate.

These biophysical changes have both social and economic impacts, with the most immediate effects being felt by communities that depend on forests for part or all of their livelihood. Forest resources provide food, medicines and firewood, resources that now have to be obtained from more distant forests. And as forest areas are reduced pressure on the remaining forests increases even more.

1.1 Responses

There have been various responses to these losses in forest cover. In some relatively small areas attempts have been made to re-establish the original forest communities. More commonly, reforestation has been carried out using large- or small-scale plantation monocultures. Most of these plantations consist of exotic species and most involve a remarkably small number of species. For example, a limited number of species from just four genera (*Pinus, Eucalyptus, Acacia* and *Tectona*) account for the majority of tropical plantations. Plantations commonly produce just industrial timber or firewood, although some have been specifically established for other purposes such as desertification control, salinity prevention or slope protection. Forest regrowth occurs in some degraded landscapes but there have been only limited attempts to manage these naturally regenerating forests, at least in the tropics.

These responses to deforestation and to the rapid increase in the area of degraded lands are usually inadequate. Reforestation has been carried out at a fraction of the deforestation rate and the new forests provide only some of the goods and services provided by the original forests. Most new forests, for example, are established simply to provide industrial timber; they benefit governments or large corporations rather than local communities. Many reforestation schemes do offer some functional benefits, such as watershed protection, but their simple composition and structure mean that they rarely contribute significantly to biodiversity conservation. Further, new forests are not always located in places with the largest areas of degraded land.

The overall effect of this process of forest degradation is a reduction in human well-being and a loss of biodiversity and ecological goods and services. The fragile state of the world's forests (particularly tropical forests) is widely acknowledged and has been the subject of debate for several decades. But little seems to change. Within a decade most of the world's forests will probably have been subject to some form of harvesting at least once. The only exceptions are likely to be those forests in steep otherwise inaccessible areas and those in securely protected areas. By and large, the remaining forests in most countries will then be secondary, fragmented and degraded or simplified. This is the starting point for this report. A number of questions now arise:

- What are the options for the world's forest landscapes?
- What do we want our forest landscapes to look like in the coming decades?
- What goods and services do we want them to provide?
- How are we going to manage the vast areas of landscape with degraded, fragmented and modified forests?

The aim of this report is to address the last of these questions in detail, while giving some attention to the other three. The report will focus on how and why forest cover could and should be re-established in many settings, and the ecological and socio-economic rationale for doing so.

Chapter 2
Degradation

Badly degraded sites are easy to recognize. Repeated disturbances or over-exploitation have removed much of the original vegetative cover, some of which may have been replaced by exotic weeds. Wildlife has been lost and pest species may have been introduced. Erosion is often widespread, perhaps with landslips and gullies forming on steeper slopes. Air pollution can cause tree death as well as more subtle changes to forest health and can do so over very large areas (Fanta 1997). Degraded forests have lost much of their productivity and biodiversity as well as many of the ecological goods and services they once provided. But are less disturbed sites degraded? In fact, just when does a forest become "degraded"? What is the threshold condition beyond which degradation occurs?

The term "degradation" is taken to mean a loss of forest structure, productivity and native species diversity. A degraded site may still contain trees (that is, a degraded site is not necessarily deforested) but it will have lost its former ecological integrity. The Food and Agriculture Organisation of the United Nations (FAO) has defined forest degradation as changes within a forest that affect the structure and function of the stand or site and thereby lower its capacity to supply products or services. In practice, however, degradation is much more subjective; people can have quite different perceptions about the same landscape. For example, a wildlife enthusiast may see an impoverished forest, while a forester sees a productive forest regenerating after logging. Similarly, a forester may see a degraded forest while a shifting cultivator sees a piece of prime agricultural land. Almost inevitably, "degradation" is partially in the eye of the beholder. Not all landholders or managers will necessarily agree that degradation has occurred; even if they do, they may disagree about the most appropriate response (Figure 1). These contrasting perceptions make it hard to define and measure degradation, and to obtain definitive statistics on its regional, national or global scale.

2.1 Deforestation

Most global statistics on degradation are based not on assessments of degradation but on deforestation. FAO (2001) defines deforestation as the conversion of forests to another land use. For several decades FAO has attempted to assess the deforestation rates of the world's forests. This was a hugely difficult task because of incomplete and inconsistent data from different parts of the world. It was not until 2000 that FAO was able to attempt a global estimate of deforestation using a common set of definitions for both industrialised and developing countries. It estimated that, in the decade between 1990 and 2000, the gross annual deforestation rate was 13.5 million ha, with most of the loss of natural forests occurring in tropical countries. Slightly higher estimates were made by Mathews (2001), who argued that the annual loss of natural tropical forests was probably closer to 16 million ha.

The overall decline in forest cover was less than these figures imply because regrowth and plantation establishment on previously cleared land partly compensated — in area if not in quality — for the loss of natural forest. Thus the net deforestation rate in tropical countries was estimated (by FAO 2001) to be 12.3 million ha per year, while the net forest cover increased in non-tropical countries by 2.9 million ha per year over the same period. The global net annual deforestation rate was

Figure 1. Deforested landscape at old copper mine and smelter, Queenstown, Tasmania.

Although the site is obviously degraded many people in the community are opposed to rehabilitation because tourists come to the area to see the "moon landscape". Local residents wish to retain the current status of the town's degraded environs as a tourist attraction. Photo by David Lamb.

estimated to be 9.4 million ha. Regrowth on abandoned agricultural lands in both tropical and non-tropical countries was 3.6 million ha annually and plantations were established by afforestation of cleared land at an annual rate of 1.6 million ha. Another 1.5 million ha of plantations were created by clearing forested lands (Table 1). By the end of 2000 the total global plantation area was estimated to be 187 million ha, most of it in Asia.

Table 1. Annual global transition to natural forest, plantations and other use, 1990–2000

From	To natural forest i.e. regrowth	To plantations	To other land uses
		(million ha)	
Natural forest			
tropics		1.0	14.2
non-tropics		0.5	0.4
global		1.5	14.6
Plantations			
tropics	ns		ns
non-tropics			
global	ns		ns
Other land uses			
tropics	1.0	0.9	
non-tropics	2.6	0.7	
global	3.6	1.6	

Note that "forest" is land with a tree canopy cover of more than 10 per cent
Source: FAO 2001; ns = not significant

Determining the rate of deforestation depends, of course, on the definition of "forest". FAO originally defined "forest" as non-agricultural land with a tree cover of at least 20 per cent. This definition was changed in 2000 to land with a tree cover of at least 10 per cent, meaning that land previously categorized as "woodland" was now "forest". FAO recalculated the 1990 data to make them comparable with the 2000 figures, and concluded that the net rate of deforestation had probably decreased, although this was mainly due to regrowth and plantation establishment rather than a reduction in gross deforestation rates. Mathews (2001) suggested that rates of natural forest loss had probably worsened in all tropical countries except in Latin America and that more forest was lost in the 1990s than the 1980s.

Much of the land that is cleared is presumably used for agriculture. Estimates measure the conversion rate but not the amount of degraded land needing or available for rehabilitation. Agriculture practised on fertile soils is likely to be more sustainable than that practised on poor soils. Unfortunately it is increasingly the poor soils that are being cleared (Dobson, Bradshaw and Baker 1997). This suggests that a significant proportion of these newly cleared lands are at risk of becoming degraded in future. The role of new agricultural technologies in modifying the current rates of deforestation is extensively discussed by Angelsen and Kaimowitz (2001).

2.2 Measuring degradation

It is even more difficult to measure global degradation than it is to measure deforestation. Even defining which areas to measure is a subjective process. Simple measurements (such as the amount of forest area lost) do not account for the more complex effects of degradation, such as fragmentation or an increase in the ratio of perimeter to area (the so-called "edge effect"). A 1988 estimate of the extent of degraded tropical lands was 2,077 million ha, much of which was desertified drylands (Grainger 1988). This area was larger than the total known forest area of the tropics (FAO 1993). Wadsworth (1997), recognising two forms of degraded forest, estimated that, worldwide, there were 494 million ha of "cutover tropical forests, and 402 million ha of tropical forest fallow". The International Tropical Timber Organisation (ITTO) distinguishes between three types of degradation:

- degraded primary forest (resulting from excessive and damaging timber exploitation);
- secondary forest (spontaneously regrowing on land that had been largely cleared); and
- degraded forest land (which is so degraded that forest regrowth has not occurred and which is now mostly occupied by grasses and shrubs).

Based on a variety of sources, the ITTO estimated there were 500 million ha of degraded primary and secondary forest and 350 million ha of degraded forest land in the tropics; they further estimate that 300 million people use these lands to make a living (J. Blaser, pers. comm.).

While global assessments of degradation are inherently difficult, regional accounts can be more feasible. One method involves assessing the area of former forest lands that are now grassland or shrubland and which might be available for reforestation. Based on this approach some estimates of degraded land in the four lower Mekong countries (Thailand, Vietnam, Cambodia and Lao PDR) are given in Box 1.

Box 1. Deforestation, degradation and reforestation, Lower Mekong

The four lower Mekong countries of Cambodia, Lao PDR, Thailand and Vietnam in South East Asia have all experienced high levels of deforestation and forest degradation during recent decades. The reasons for this are varied, but include logging (legal and illegal); expansion of agricultural activities (government sponsored and spontaneous); war; building of infrastructure such as roads and dams; and shifting cultivation. Accurate statistics are difficult to obtain but the estimates made by FAO (1995) and shown in Table A for the ten-year period from 1980 to 1990 suggest that more than nine million ha of forest was lost in the four lower Mekong countries.

1a. Change in natural forest, lower Mekong countries, 1980-1990

Country	Area (000s) 1990	Annual change (000s) 1980-1990
Cambodia	12,163	–131
Lao PDR	13,173	–129
Thailand	12,735	–515
Vietnam	8,312	–137
Total	46,383	–912

Source: FAO (1995)

In fact, much of the area designated as forest land in the national statistics of many countries in the region may have little or no tree cover. The example from Vietnam in Table 1b is typical of the situation across the region.

1b. Categorisation of forest land in Vietnam in 1995

forest class	with tree cover (000s)	without tree cover (000s)
special-use forest	700	200
protection forest	2,400	3,300
production forest	6,200	6,200
Total	9,300	9,700

Source: MOF (1995)

1c. Hectares of land potentially available for rehabilitation

Country	land available (000s)	% of total area of country	% of area of natural forest
Cambodia	2,600	15	28
Lao PDR	8,700	38	70
Thailand	2,306	5	23
Vietnam	9,700	30	120
Total	23,306		

While there may be some debate over these figures, it is clear that an enormous area of land in these four countries has some potential for rehabilitation (in Vietnam this area exceeds that of residual natural forest). Of course, this does not imply that all of this potentially available land is unused, unclaimed or totally unproductive. Much of it provides subsistence products such as fuel wood, charcoal, building material and non-timber forest products.

Source: Gilmour, Nguyen and Tsechalicha 2000; FAO 2001.

This global and regional information reveals the huge land-use changes underway. These changes have profound effects on the forest biota as well as on the human populations dependent on forests. Greater efforts are needed to ensure that degradation is prevented and that further deforestation is only undertaken where subsequent land use is likely to be sustainable. It is also important to help forests recover on some of these degraded lands.

Chapter 3

Addressing degradation

Degradation needs to be addressed in a variety of ways and at a range of scales. While site-level interventions are important, they need to be coordinated with effective planning at the landscape level.

The most appropriate group to undertake landscape-level planning will vary from setting to setting. In some countries a medium-level administrative-political unit (shire, canton or district) may have the mandate for land-use planning. There may be ad hoc groupings of these units for important regional or national initiatives. On occasion, there may also be national-level planning initiatives aimed at restoring natural vegetation throughout an entire country. The National Heritage Trust funding and the Landcare movement in Australia in the past decade are examples of national initiatives which have included major elements of landscape- and site-level rehabilitation. This report focuses on site-level considerations, both biophysical and socio-economic, although some reference is made to landscape-level aspects.

This chapter focuses on the key aspects of biophysical and human well-being, and their links to each other. These are important considerations in planning and implementing forest rehabilitation initiatives, particularly at the site level. The chapter provides a conceptual overview of the biophysical options for intervening in a natural system to change short- and long-term outcomes.

3.1 Biophysical aspects

Some degraded ecosystems are able to recover naturally (see Box 2) but many do not. There are several possible reasons for this: too few of the original plant and animal biota remain at the site, some component of the biophysical environment such as soil fertility has changed, or repeated disturbances preclude successional development. Even at sites where natural recovery is taking place, the process may be slow. This increases the chance of further disturbances and degradation. For these reasons human intervention may be needed to either initiate the recovery process or to accelerate the rate at which it proceeds.

Box 2. Will degraded sites recover without intervention?

Many heavily degraded forest ecosystems can recover from disturbances. The process is referred to as a succession and most ecological textbooks include descriptions of the processes involved. Examples of successions are common but several preconditions must be met if successional recovery is to occur:

- The disturbing agent or agents must be removed. If disturbances such as fire, timber harvesting or grazing continue, succession is interrupted and recovery is not possible.
- Plants and animals must remain at the site or in the region as a source of new colonists. Not only must they be present, they must also be able to move across the landscape and recolonise the degraded area. The more distant these source populations are and the greater the degree of biological impoverishment in the intervening landscape, the slower the recolonisation process. Conversely, the more forest fragments or "stepping stones" in the intervening lands the faster the process will be.
- Soils at the site must also remain reasonably intact. If severe erosion has taken place or if fertility has been depleted the soils may no longer be suitable for the original species and a new community, possibly exotic species able to tolerate the changed environment, may take over.
- Weed species or animal pests must be excluded if the original community is to be re-established.

These preconditions might seem like formidable obstacles but large-scale examples of forest recovery on seemingly degraded landscapes have occurred. See Case Studies 8.1, 8.3 and 8.12.

There are three broad categories of degraded land:

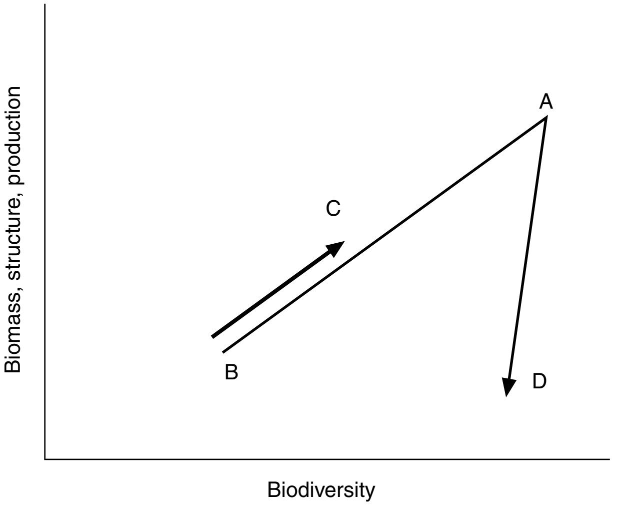
- the most severely degraded land has lost much of its original biodiversity and most of its structure, biomass or site productivity. It is represented by point B in Figure 2a.
- a second common category is land occupied by woody regrowth that has developed on a site after an earlier disturbance. This might have been some form of agricultural clearing after which the land

was abandoned. The site now has some of its former diversity although it is dominated by early successional species and usually has fewer plant or animal species representative of mature forest. The second category is represented by point C in Figure 2a.

- degraded primary forests have experienced a very intense disturbance, such as heavy logging, which has drastically altered the forest structure and reduced the biomass. However, some residual trees remain and many of the primary forest tree species will still be present, represented by saplings or seedlings. The third category is represented by Point D in Figure 2a.

Chokkalingam et al. (2001) provide a more detailed typology of types of degraded tropical forest.

Figure 2a. Different forms of forest degradation



An undisturbed forest is represented by position A, where it has a certain level of biodiversity as well as biomass, structure or production. Extensive clearing can take it to point B, where it will have lost a large proportion of this biodiversity as well as much of the biomass, structure and productivity. It may or may not recover unaided to C (e.g. becoming secondary regrowth forests). Some forms of intensive logging can cause the degradation of primary forest while still leaving a significant amount of the biodiversity (point D).

A variety of approaches can be used to overcome these forms of degradation. In some cases the objective is to restore the original ecosystem and recover the former biodiversity; in others the aim is simply to use the site for some productive purpose such as agriculture. These different approaches have fostered a confused terminology (see Box 3):

- this report uses the term “restoration” only for those situations where the intent is to recreate an ecosystem as close as possible to that which originally existed at the site. The site then contains most of the original plant and animal species and has a structure and productivity matching that originally present;
- the term “rehabilitation”, on the other hand, is used where the original productivity or structure is regained as well as some, but not all, of the original biodiversity. This might be because commercial imperatives demand the use of certain agricultural or timber species to justify the rehabilitation effort or because the site has become unsuitable for some of the original species; and
- the term “reclamation” is used for situations where productivity or structure is regained but biodiversity is not. In fact, native species may not be used at all. In such cases there are few, if any, benefits to landscape biodiversity but there may be social or economical advantages or functional gains such as improved watershed protection.

The three approaches differ in the extent to which they enable the original biodiversity to be regained. They are similar, however, in that they all seek to establish a productive and stable new land use.

Box 3. Definition of terms used in discussions of forest restoration

Landscape level

Forest landscape restoration: A process that aims to regain ecological integrity and enhance human well-being in deforested or degraded forest landscapes.

Site level

Reclamation: Recovery of productivity at a degraded site using mostly exotic tree species. Species monocultures are often used. Original biodiversity is not recovered but protective function and many of the original ecological services may be re-established.

Rehabilitation: Re-establishing the productivity and some, but not necessarily all, of the plant and animal species originally present. For ecological or economic reasons the new forest may include species not originally present. In time, the original forest's protective function and ecological services may be re-established.

Ecological Restoration: Re-establishing the structure, productivity and species diversity of the forest originally present. In time, ecological processes and functions will match those of the original forest. The Society for Ecological Restoration defines it as "the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed".

Human well-being

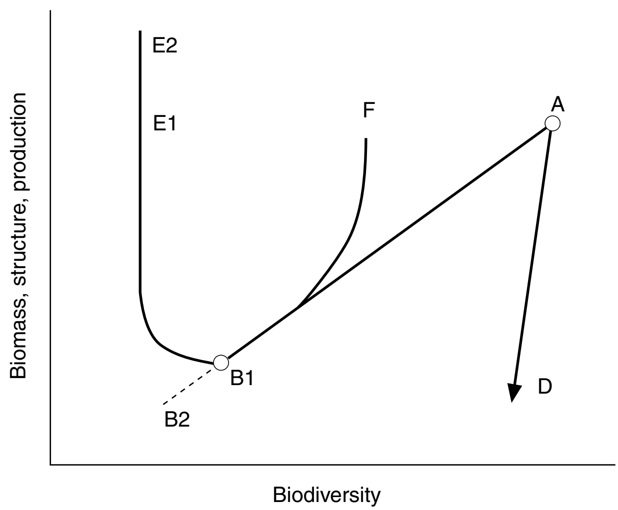
Ensuring that all people have a role in shaping decisions that affect their ability to meet their needs, safeguard their livelihoods and realise their full potential.

Ecological integrity

Maintaining the diversity and quality of ecosystems, and enhancing their capacity to adapt to change and provide for the needs of future generations.

The difference between approaches is illustrated in Figure 2b. In the absence of human intervention the degraded forest at point B may gradually recover some species richness and biomass and move slowly towards its original condition (A). The rate at which this occurs depends on the speed with which species are able to colonise the site; it might be accelerated by human intervention (i.e. restoration). Alternatively, recurrent disturbances (e.g. wildfires or grazing) may further degrade the system and more species may be lost, pushing the system towards point B2. Reclamation is represented by point E, where a tree plantation or crop monoculture has been established. This may have recovered the original biomass (E1) or perhaps even exceeded it (E2) because of site preparation and fertiliser use. Rehabilitation is represented by point F. In this case structure and biomass and some, but not all, of the original species richness have been recovered. Each of these three alternatives (A, F or E) might, theoretically, be applied to any of the several forms of degraded land described above. Some of the more common approaches used in various field situations are described in Chapter 6.

Figure 2b. Ecological restoration, rehabilitation and reclamation



If left untreated, the degraded forest (at B1) may degrade further over time to B2 (e.g. following repeated wildfires). Ecological restoration seeks to return the forest to position A; reclamation takes it to E1 or E2 (if site is improved with ploughing or fertilisers) and rehabilitation to F.

There has been some debate over whether restoration is ever possible (see Box 4). In practice the question is probably not that important. In most field situations the large extent of degraded land and limited resources often mean that a modest increase in the biodiversity of indigenous species through some form of rehabilitation is the most that can be achieved. Indeed, in many cases social circumstances may make this the preferred option, because of major trade-offs between restoration and human well-being. Attempts at ecological restoration might only be feasible in specialized situations.

3.2 Human well-being aspects

The ecological model described above can be complemented by a similar model that describes the relationship between the quality of ecosystem restoration and the improvement that this brings to the well-being of humans living in or near the new forest area.

The quality of restoration refers to the extent to which ecosystem integrity has been regained. It includes ecological authenticity (e.g. ecological naturalness, viability, health) as well as the functional effectiveness of the restoration process (e.g. the extent to which watershed protection is established, key ecological processes are regained or the populations of biota are able to reproduce, etc.). Ecosystem integrity is promoted more by restoration than by rehabilitation.

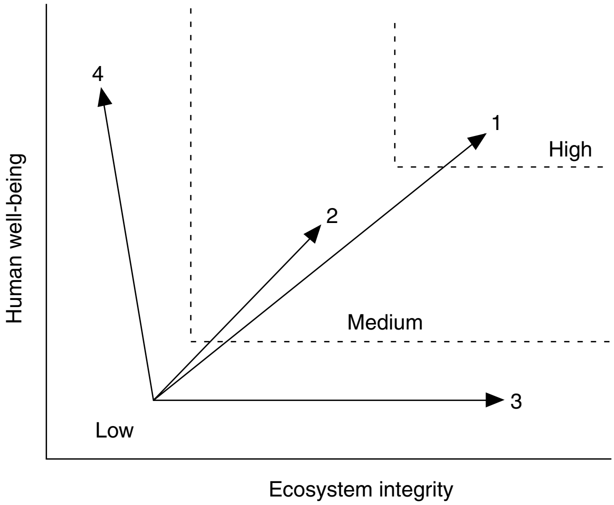
The term "human well-being" is necessarily broad, and covers not only benefits such as the market value of forest products (e.g. timber or non-timber forest products) and other ecological services such as watershed protection but also a broader range of benefits that flow from them. The elements of human well-being are described by Fisher, Dechaineux and Keonuchan (1996):

- economic benefits in the form of access to material goods (assets, capital, labour availability, credit and availability of cash);
- quality of life factors such as health, education, culture and access to services;
- equity, meaning how fairly well-being is distributed to different individuals and groups (equity does not imply equality); and
- risk and power relations, which are likely to affect the rate at which new activities can be adopted.

Unlike ecosystem integrity, human well-being is likely to be promoted more by rehabilitation than by restoration.

The term “forest landscape restoration” incorporates both ecosystem integrity and human well-being. The relationship between these two aspects and the trade-off that might be necessary is shown in Figure 3.

Figure 3. Ecological integrity of restored or rehabilitated ecosystems and human well-being



The highest quality of landscape restoration is at point 1 where ecosystem integrity and human well-being are both improved. Position 2 represents a less successful outcome. Positions 3 and 4 are less likely to be sustainable in the longer term. It should be noted that this human well-being model has yet to be validated, though it does appear to be conceptually sound. Figure 3 is adapted by Jackson from Prescott-Allen (2001).

At Position 1 intervention has produced improved ecosystem quality as well as generating a substantial improvement in human well-being. This is clearly the most desirable outcome.

At Position 2 intervention has yielded some modest improvements in ecosystem integrity and human well-being but these are not as good as at Position 1.

At Position 3 ecosystem integrity has substantially improved but there have been no matching gains in human well-being. This means the biodiversity gains might run the risk of being unsustainable over the longer term for purely social reasons. For example, a restoration project in a heavily populated area that involved planting trees for biodiversity purposes, but which contributed no other short-term benefits to poor farmers, might run the risk of being burned or grazed. Similarly, natural regrowth forest managed solely to foster biodiversity might be "accidentally" cleared for agriculture. A better option might be to encourage some of the more commercially attractive species in the regrowth (e.g. by some judicious thinning) so they could be harvested at a later date.

At Position 4 human well-being has improved but environmental conditions have not changed. In fact, they may have even declined further. In this case the gains may be short-term and potentially unsustainable for ecological rather than social reasons. This might be true where most of the original landscape is cleared and used, say, for intensive agriculture.

There are, of course, examples where intensive agriculture is relatively successful. But there are increasing numbers of examples in highly simplified landscapes where it is not. Just how much complexity or biological diversity is needed in such landscapes is currently the subject of intensive research (e.g. Hobbs and Morton 1999, Lefroy et al. 1999, Kaiser 2000).

The two conceptual models (Figures 2b and 3) suggest that several definitions are needed to distinguish between the various objectives a land manager might wish to consider. These now include reclamation, rehabilitation, ecological restoration and a collective term, forest landscape restoration (Box 3).

4.1 Ecological reasons

If a network of protected areas exists, why is it necessary to be concerned about restoration or rehabilitation? Why not use degraded lands solely for production (i.e. use only the approach referred to earlier as reclamation)? This approach has been widely utilized and can be financially successful, although it can have unintended negative consequences (Table 2).

Table 2. Advantages and consequences of reforestation using monocultures of exotic species

Advantages	Potential negative consequences
• potentially good supply of high-quality seed (sometimes genetically improved meaning tree form is good) • Known nursery technology for raising seedlings • known site and environmental requirements • known silvicultural systems for managing plantations • potentially high productivity • tree timber properties well-known • can choose species tolerant of extremely poor soils or degraded sites	• reduction in range, quality and quantity of goods and services supplied to local people by new plantation • reduction in ecosystem services, especially for water regulation, nutrient cycling and wildlife habitat • increased susceptibility to climate and other environmental changes • limited opportunities for collaborative management • loss of biodiversity and of opportunities to restore it • more frequent outbreaks of pests and diseases • problems with alien species becoming invasive

After Ingles and Jackson 2001

There are several reasons to undertake forest landscape restoration. One is to provide the goods and help re-establish those ecological services or functions no longer being provided by the new forms of land-use. Industrial monoculture plantations produce wood but do not provide a variety of timbers or the forest products such as fruits, nuts or medicinal plants used by many rural communities. Plantations may be effective in sequestering carbon or helping restore hydrological cycles to overcome salinity, but they are not always as effective in preventing erosion on the slopes of hills above agricultural areas, protecting riparian strips or restoring soil fertility.

A second reason for undertaking forest landscape restoration is to restore some degree of biodiversity to degraded landscapes (Elliott et al.

2000). It is unlikely that any network of protected areas will be able to protect all existing biodiversity. Such reserves represent a small proportion of most landscapes and in many countries there is limited capacity to increase the number or size of them. Meanwhile the remaining undisturbed areas outside these reserves are being increasingly fragmented and homogenized as large-scale agriculture and industrial timber plantations spread across the landscape. Restoration offers a means of counteracting these trends towards landscape simplification. It can also ensure that species and ecosystems — across a large area — are more resilient and adaptable to change.

At a regional scale, forest landscape restoration is often likely to be needed to achieve more sustainable forms of land use. Many large areas of land became degraded because previous agricultural practices were unsustainable. Production was lost as fertility declined, salinity developed or weeds, diseases or pests became established. New agricultural systems are needed to replace these unproductive areas; more diverse landscapes are likely to be a necessary component of such systems (Hobbs and Morton 1999, Lefroy et al. 1999).

The decision about which approach to use at a particular site — restoration or rehabilitation — is always complicated. As noted earlier, restoration may only be possible in recently disturbed landscapes where most of the original biota remains (although even then it may be problematic; see Box 4). In landscapes that have been heavily used for a long time it may be unrealistic to aim at restoration because some original species will have been lost and other exotic species will have been naturalised. The extent of disturbance is also important: the choices available in a patchy landscape containing many forest remnants will probably be different than those in a landscape where extensive clearing has taken place and industrial-scale agriculture is practised.

Box 4. Is ecological restoration ever possible?

Restoration, as defined in Box 3, is a difficult undertaking, both in principle and in practice. There is some question as to whether it is even possible. The definition of restoration implies that the identity and population sizes of the plants and animals once present at a particular site are known. This is rarely the case. In many situations the best that can be done is to infer the nature of the original ecosystem from previous descriptions or remnants of communities. The definition also implies that these communities were static and would have remained unchanged over time. But this, too, is unlikely to be the case. Many communities undergo successional change, often over a period of time involving hundreds of years. Even mature ecosystems commonly exist in a state of dynamic equilibrium; changes occur in their composition, even in the absence of degradation. These difficulties mean that restoration can be both an uncertain goal and a shifting target.

Restoration can also be difficult for other reasons. Our knowledge of ecological processes is imperfect and our capacity to predict, let alone direct, ecological successions is limited. In many cases chance events such as weather or the timing of flowering or seeding have a major effect on the way successions develop. This means it might be difficult to achieve a particular outcome even if the target could be ascertained. Further, the large numbers of plant and animal species present in many communities mean that the ecology of species is poorly known. This makes it difficult to assist or encourage them to re-enter a degraded site.

The target might also become unattainable because some of the original species have become extinct. Exotic species may have become naturalised after a long period of human intervention. Such is likely to be the case, for example, with the ecosystems of Europe and the Mediterranean basin or in China. In these cases simply fostering species-rich communities might be a more appropriate goal. In other situations the extent of topsoil loss, site exposure or salinity levels may be so great that restoration would be too expensive even if the technical means were available.

Social constraints may also apply. Traditional owners or users of degraded lands may be unwilling to agree to restoration because it is not a goal they share or because they believe that it will lessen their rights to future use. In such cases intervention from outside persons or organisations is unlikely to succeed.

These problems mean that attempts to "ecologically restore" forests, as defined in Box 3, may at times be unrealistic. It may be more appropriate to aim at more modest goals, such as recreating a forest with a large species diversity and a structure and function similar, but not necessarily identical, to that originally present.

4.2 Socio-economic reasons

Forest landscape restoration incorporates both biophysical and socio-economic values; that is, ecosystem restoration as well as the changes in human well-being associated with it. It is important to consider the social and economic impacts of forest restoration initiatives, particularly the effects on people living in or near the restored forest area.

A substantial amount of reforestation has taken place with the intent of overcoming deforestation or land degradation. Much of this effort involved fast-growing exotic tree species, planted, in many cases, after clearing shrublands or secondary regrowth. These reforestation efforts may have brought some benefits but often the improvements in well-being have not been as great as expected. New plantations were often established solely for industrial timber users and provided few of the goods traditionally used by communities; where new plantations replaced regrowth or secondary forests a large number of traditional resources disappeared. Forest landscape restoration differs in that it seeks to bring greater social and economic benefits to local communities (Box 5).

Box 5. Forest dependence and decision-making

In many developing countries large populations of rural people live near forests and depend on them for subsistence and, sometimes, for commercial purposes. Many of these communities have had a close and long-standing association with the forests; until relatively recently, resource management in more remote regions was left largely in their hands. Often there were local institutional arrangements that defined access and use rights to the forest.

Forests were often nationalised by colonial and post-colonial governments. This legally disenfranchised local communities, although in many cases they retained usufruct rights extra-legally. As state control spread, local communities came into closer contact with government officials. Tensions increased, particularly where upland land-use practices did not conform to those of lowland (mainly ethnic majority) farmers. Often, government officials didn't appreciate the importance of forests to local communities in terms of food security, income, nutrition, employment, energy sources and overall well-being. The large-scale exploitation of commercial timber from the forests during the past few decades brought few benefits to upland communities, who became even more removed from mainstream development.

The current emphasis on rehabilitation of degraded forests provides opportunities to build new relationships between governments and local communities, based on collaboration rather than confrontation. This will require significant changes in attitudes and working relationships, as well as a continuing evolution of policy. Progress is likely to be slow, partly because of entrenched attitudes in the bureaucracy. Nonetheless, there seems to be an inevitability about the general direction of policy, with governments throughout much of the world devolving more rights and responsibilities to various members of civil society.

Forest landscape restoration also seeks to foster a more participatory form of forest management. One of the lessons of development and of general land-use planning and management during recent decades is that technical solutions alone can rarely resolve complex natural resource management problems. Virtually all land-use planning and management involves people as well as the biophysical landscape. Forest rehabilitation at both the site and landscape levels will affect different people in different ways. The practical reality is that, in many parts of the world, communities living adjacent to (or even within) forests are the de facto if not the de jure managers. Any approach that fails to involve people or take account of their various interests is unlikely to succeed.

Significant changes are taking place in most countries in the way that central governments perceive and carry out their mandates of rural land-use planning and management. There is a shift towards decentralisation of government functions and some devolution of authority. In some cases this results in a shift in local decision-making and action to local communities. This brings into sharp focus the interactions between rural communities, the government and forests (Box 6).

Box 6. Restoration in the Buxa Tiger Reserve, India

India's Buxa Tiger Reserve, on the borders of Nepal and Bhutan, contains 37 forest villages, 25,000 people and around 100,000 cattle. It was initially protected in 1879 (the first reserved forest in India) and was included in Project Tiger in 1987. The reserve has serious social and ecological problems, and forest restoration is urgently needed. When commercial logging ceased in Buxa in 1987, it removed a major source of income for many villagers. The local forestry department (funded by the World Bank since 1997) is unwilling to move the villages outside the reserve. Since the villagers still live in the reserve, and have no alternate source of income, they have continued illegal felling, which has increased the overall rate of degradation. Any efforts at sustainable forest restoration must consider these socio-economic realities.

Chapter 5

When and where to intervene

Both landscape- and site-level considerations must be taken into account when deciding where to intervene. At the landscape level, a useful beginning for decision-making could be to identify remnant forests, especially those with high conservation value (critical environmental and social values). These could be used as starting points around which to carry out site-specific interventions. Interventions at one or more sites to achieve the greatest functional benefits across the landscape as a whole is discussed further in Chapter 7.

At the site level, restoration can be carried out on a range of locations, from severely degraded sites (e.g. by mining) to those that are only slightly disturbed and need only a few years of protection before recovery is underway (Hobbs and Norton 1996). Restoration that re-establishes biodiversity is difficult to achieve and is only feasible when certain ecological preconditions can be met (Box 2). It also requires that a majority of the land owners or land users agree on the need for restoration and have the financial and other resources to undertake it. If these ecological, social and economic constraints cannot be overcome then some form of rehabilitation or reclamation might be more appropriate. This can recover productivity and some functional benefits even if it is unable to restore most of the biodiversity.

5.1 Ecological factors

The choice of where to intervene depends primarily on the purpose of the proposed reforestation (some common locations for restoration and rehabilitation are shown in Table 3). In many degraded landscapes the primary purpose of intervention is to provide functional benefits (such as soil and water conservation) rather than to restore biodiversity. In such cases, reforestation might target riparian strips to stabilise streamsides or target steep hillsides and areas with eroding soils. Reforestation might also be carried out at saline or waterlogged sites. In some situations treating relatively small areas that are severely degraded can have a disproportionately large benefit for the landscape as a whole. Examples are landslip areas, erosion gullies, and old mine sites; they may be a source of sedimentation or pollutants that affect large parts of the landscape. The extent of degradation at these sites may require planting of specialised species able to tolerate the prevailing conditions before many of the original species can be restored.

Table 3. Sites or landscape areas to target for forest landscape restoration

Area	Reason
Riparian areas	• to protect stream banks from erosion; to improve water quality; to create habitats for riparian species
Steep areas and erosion-prone sites	• to stabilise soil surfaces and prevent erosion and landslides
Saline or waterlogged areas	• to re-establish hydrological cycles and lower water tables; to reduce land and river salinity; may require tolerant species to be introduced first before other species can be re-established
Mine sites	• to stabilise these sites and prevent them becoming sources of water sedimentation, acidification or heavy-metal pollution
Degraded areas in or buffer areas around protected areas	• to re-establish habitats of species being protected; to eradicate habitats of weed species; to reduce edge effect
Habitats of particular species	• to increase the availability of habitat and resources for vulnerable or threatened species, thereby allowing an increase in their population sizes; to create habitats in more easily protected areas
Offshore islands	• to foster populations of endangered species without native or introduced predators
Corridors between protected areas or forest fragments	• to provide linkages between forest areas; to provide opportunities for species movement and genetic interchange
Buffer strips within and around plantations	• to create linkages between areas of natural vegetation; for firebreaks or watershed protection
Over-logged or secondary regrowth forests	• to hasten recovery of biodiversity and/or productivity
Other degraded areas (e.g. abandoned agricultural lands, sites with infertile soils, general agricultural matrix between forest remnants)	• to increase landscape heterogeneity, biodiversity and sustainability; some of these sites may require specially adapted species (e.g. nitrogen fixers) to ameliorate soils before reintroducing native species

In many deforested rural landscapes the focus of treatment is on the provision of goods (such as firewood or medicinal plants) and ecological services. Rehabilitation in the form of small farm woodlots or the protection of regrowth areas near to the homes or villages of the rural communities might be the best option.

Where biodiversity is the primary focus then protected areas, established to conserve significant areas of biodiversity, are obvious targets. Some of them may contain degraded areas because of land-use practices prior to their establishment. Restoration will restore the integrity of the whole protected area and prevent it from being a source of weeds or pests. Protected areas may have boundaries with large populations of invasive weeds or pest species. Restoration can improve the effectiveness of these buffer areas and perimeters.

Habitats of particular endangered or vulnerable species are another high priority. An increase in the availability of such habitats may allow the populations of these species to increase as well. In some cases the endangered species may need to have habitat restored in specialised conditions, such as isolated offshore islands, to avoid naturalised predators that are impossible to remove from the mainland (Towns and Ballantine 1993). Of course the habitats required by some species may not be necessarily suitable for other species; some deliberate trade-offs may be needed. A balance must be struck between fostering the populations of one particular species and maximising the overall species diversity at a site.

Restoration might also be carried out to facilitate the movement of plants and animals across a landscape. This could be done by using existing forest fragments as starting points and establishing additional small forest patches to form a series of "stepping stones" between larger forest areas. Alternatively, corridors could be created to link isolated remnants of natural forest. Corridors are clearly preferable for those species unable to cross non-forested areas.

Both approaches have value in facilitating genetic or demographic interchange, and may be especially useful in linking remnant forest areas at different altitudes to facilitate movement of elevational or seasonal migrants. There has been some debate about whether corridors achieve the benefits assumed by their proponents (e.g. Simberloff et al. 1992). Much of this debate concerns animals rather than plants and centres on the width of the corridors that are needed to avoid edge effect. There is general agreement that linkages enhance conservation outcomes (Bennett 1999). Linkages and landscape heterogeneity can also be fostered by the development of buffer strips or corridors within and around industrial timber plantations. In these situations they are commonly created as firebreaks or to help protect watersheds but they can bring significant biodiversity benefits as well.

Often, a number of different approaches might be used (see Chapter 6). In general it is preferable to treat large areas rather than small ones because of the significance of edge effects and because many species need large areas to achieve viable population sizes. The shape of the areas may also matter; it is usually preferable to treat large broad areas rather than long thin areas, again because of the edge effect. But there are many circumstances where these generalisations may be incorrect. Small restoration projects, if they are strategically situated, often have considerable value. Likewise, long but comparatively narrow riparian strips are often key targets for ecological restoration.

5.2 Socio-economic factors

It is always difficult to choose where to invest limited resources, particularly when so many areas deserve attention. Is it better to devote a lot of resources to a small but highly degraded area, or to a much larger area that is not so severely degraded? Fertilisers can improve soil fertility and herbicides can eradicate weeds. But the more resources used, the more expensive the operation becomes. It may be preferable to use these resources to treat a larger but less degraded site. There is a certain irony in this; the most degraded areas may never get treated.

Because of the importance of integrating both biophysical and human well-being aspects into forest landscape restoration, there must be a strategic focus in deciding where to take action. It is best to focus — at least initially — on areas where there is a degree of local interest in restoration, particularly if success will depend on aspects under the control of local people, such as protection from grazing animals.

An example of this last scenario is found in Nepal. Community interest in small-scale local reforestation efforts was an important indicator in deciding where to use scarce resources. If there was little local interest, experience indicated that success would be unlikely, in spite of the outside perception of importance or need (Gilmour and Fisher 1991). Further, success tends to breed success. Once the benefits of restoration have been demonstrated, previously disinterested communities frequently develop a strong interest in becoming involved, although there have to be tangible benefits to compensate for their efforts. In Nepal, a small external stimulus was able to trigger a significant local involvement; over a decade this turned into a large-scale undertaking that transformed the landscape across much of the Middle Hills region of Nepal. Another successful restoration initiative was carried out in the Shinyanga region of Tanzania in East Africa, where there was a significant improvement in local benefits and in ecological integrity (see Case Study 8.12).

5.2.1 Likelihood of change

The extent to which planned interventions are likely to lead to changes (real or perceived) in local communities' access to existing natural resources is an important factor. An example of this comes from Papua New Guinea, where most land is owned by traditional land owners. It is difficult for government agencies or other external bodies to undertake any form of reforestation, even on clearly degraded grassland sites, because land owners are suspicious that this is the first stage in a government attempt to seize control of their land. Under these circumstances any approach to reforestation to overcome degradation necessitates extensive negotiation.

5.2.2 Impact of the intervention on local livelihoods

Imperata grasslands are found throughout the tropics. The species is widely regarded as a useless weed, and these grasslands often become the target of reforestation projects. Many local communities do get some benefit from these grasslands, however (Dove 1986). Reforestation that reduces the amount of grasslands may have a negative impact on local communities unless there is compensation of some sort.

5.2.3 Equity considerations

Local communities may not be the major beneficiaries of restoration activities. The real beneficiaries may be downstream water users, or national or international urban dwellers who value the enhanced biodiversity resulting from the restoration. In fact, the adjacent communities may bear many of the costs associated with the restoration, and thus become worse off. Equity aspects of restoration initiatives need to be addressed from the outset.

5.2.4 Additional risks

It also has to be determined if local communities are likely to be exposed to additional risks, such as increased fire hazard, potential reduction of dry season water supply, increased predation of crops by wildlife, or increased threat to life or property by increases in large animal populations.

While landscape and site benefits of restoration activities may be acknowledged and monitored, adverse impacts or unintended consequences can also occur and tend to be overlooked. This relates to some extent to the equity considerations mentioned previously. Frequently, local people bear the costs and risks of restoration activities, while the benefits accrue elsewhere. This needs to be taken into consideration in planning and implementing restoration activities.

Restoration should ideally be considered in a landscape context, particularly to address landscape-scale problems such as salinity and loss of biodiversity. While this may be possible in a planning sense, it is much more difficult to implement activities on a landscape scale because on-the-ground activities are commonly constrained by patterns of land ownership. Consequently these are often tackled in a piecemeal fashion that limits success.

Chapter 6

Approaches at the site level

6.1. Biophysical considerations

As noted earlier, a variety of methods can be used to overcome forest degradation. In many, if not most cases in the past, the most common approach has been to simply restore economic productivity (e.g. Moffat and McNeill 1994, Adjers et al. 1995, Gutkowski and Winnicki 1997). Other alternatives are now possible. Some approaches attempt "complete" ecological restoration; others have the goal of production gains together with improvements in biodiversity and ecosystem function (e.g. watershed protection, reductions in salinity) that lead to more sustainable forms of production. Overviews of the issues and some of these alternatives are given in Bradshaw and Chadwick (1980); Rodwell and Patterson (1994); Banerjee (1995); Goosem and Tucker (1995); and Elliott et al. (2000); Allen, Brown and Allen (2001) and Zedler et al. (2001).

The specific approaches described below are grouped into methods that foster biodiversity restoration (section 6.2) and those that foster biodiversity and production (section 6.4). The time it takes to achieve the objectives at a particular site using these various methods will vary; some are likely to be relatively quick while others may last beyond a human lifetime. Each approach has advantages and disadvantages, depending on the prevailing ecological and socio-economic circumstances. Any work should be undertaken with a full understanding of how the treated area will be integrated within the broader regional landscape, especially in terms of those components of the landscape that may affect the long-term functioning of the restored site.

6.1.1 Preconditions

In the case of ecological restoration, several preconditions must be met before recovery is possible, irrespective of the method used (see Box 2). Only then may it be feasible to attempt restoration. A key issue is deciding how much intervention is needed beyond simply protecting the site from further disturbances; that is, how many species must be deliberately brought to the site and how many can be relied upon to colonise unaided?

One of the practical difficulties facing land managers is that most communities contain a small number of relatively abundant species and a larger number of species represented by relatively few individuals. These less common species may be invariably present in small numbers (i.e. they are always rare) or they may be widespread elsewhere and uncommon only at this particular site. Less common species make a significant contribution to the overall biodiversity at any site; consequently, ecological restoration can only be achieved if they can be reintroduced. The dilemma is how to do this. Since it can be expensive to raise seedlings of such species, the usual response is to rely on natural dispersal from intact forests. This can be slow and is often problematic (Maina and Howe 2000). This is especially the case when the site being treated is small and distant from a source of colonists. Small areas have a high proportion of edge effect and are often prone to weeds, especially in the initial stages of restoration. It is frequently difficult for the limited populations of many species in these small areas to be self-sustaining. Larger areas close to a source of colonists are less likely to face this difficulty.

Where the preconditions referred to do not exist then it might be more appropriate to carry out some form of rehabilitation or reclamation that uses more tolerant species or has a more modest biodiversity target. In such cases some form of site preparation involving ploughing or ripping to improve soil physical properties or hydrological functioning may be necessary. Work may also be needed to identify nutrient deficiencies and develop fertilizer regimes to correct them (Bradshaw and Chadwick 1980). Sometimes special treatments are needed to manage or reintroduce mycorrhizae or nitrogen-fixing bacteria (Allen, Brown and Allen 2001).

Extensive testing may be required before determining which species to use. Native species from the immediate area are clearly most desirable but exotic species may be appropriate in some situations. An obvious example is when the site has become too degraded to permit native species to recolonise it. Where forests are being rehabilitated rather than restored the choice of species should take into consideration the domestic or commercial attractiveness of these plants to local communities as well as their potential to become invasive weeds. Some species that might be used are outlined in Table 4.

Table 4. Potential key plant species for restoration or rehabilitation

Species type	Purpose
• native species	• to enhance biodiversity
• species attractive to frugivores	• to encourage seed dispersal
• species forming mutualistic relationships with animals	• to foster wildlife populations
• poorly dispersed species (e.g. large fruit)	• to facilitate their colonization
• rare or threatened species	• to increase their populations
• fast-growing species	• to occupy site and exclude weeds
• species tolerant of poor soils	• to facilitate rehabilitation
• nitrogen-fixing species	• to improve soil fertility
• economically or socially beneficial plants	• to provide economic "goods"
• fire tolerant trees	• to use in fire-prone landscapes, create new forests or form buffers around restored forests

Some situations might require a two-stage approach, with stage one using tolerant, exotic species to modify the site, facilitating the recolonisation of native species in stage two. For example, the site fertility might be enhanced using a short-lived, exotic, nitrogen fixer that eventually enables native species to be re-introduced. Or a saline water table might be lowered using a salt-tolerant exotic species able to transpire large amounts of water. Once the adverse site conditions were ameliorated, native species could be replanted. These more complex approaches invariably require more physical and financial resources as well as a detailed understanding of the ecological processes involved.

Rehabilitation that seeks to improve landscape biodiversity and functioning while generating productive output is especially difficult. A trade-off is usually needed between these two objectives and the "correct" balance will depend on the ecological and socio-economic circumstances. One advantage of rehabilitation over restoration is that by offering a financial yield it allows larger areas of land to be treated.

But who decides the balance between production and the restoration of diversity or ecological function at a particular site? To what extent should individual land owners or managers be expected to manage their land to achieve broader regional goals? And how might these site-by-site decisions be integrated to achieve the desired outcome at the landscape level? These issues will be considered after first discussing some of the options available to land managers at a site level.

6.2. Interventions at a site level that focus on biodiversity restoration

6.2.1 Passive restoration

In this case restoration is achieved by simply protecting the site from further disturbances and allowing natural colonisation and successional processes to restore ecosystem biodiversity and structure. This approach is best suited to situations where degradation is not extensive and residual forest patches remain or some advanced forest regrowth is already present. Consequently, the best locations are likely to be places where previous disturbances occurred in the past and some recovery has already occurred. On the other hand, recently disturbed sites where the disturbances were slight or short-lived may also be suitable because they are more likely to have a larger pool of residual seedlings, seed in topsoil or old but live stumps. Sites close to patches of intact forest are also favourable because colonization by plants and animals is likely to be faster. Sites with scattered residual trees that can act as perches for frugivorous birds able to disperse seeds are also suitable. Passive restoration is especially advantageous when there are limited financial resources available to land owners or managers. This means it may be one of the few approaches that can be attempted across large areas

The word "passive" is something of a misnomer because protection does require some direct action. This mean the approach has several potential disadvantages. First, long-term protection of the site from disturbances such as fire is not necessarily cheap. Likewise, eradicating weeds and pest animals can also be difficult and expensive (Berger 1993, Saunders and Norton 2001), and failure to remove them can limit natural regeneration of native species and successional development. There are several other potential problems with the passive restoration approach. If the original disturbance has permanently altered the local environment (e.g. topsoil has been lost) full recovery may be impossible. Recovery is also likely to take a long time in such circumstances, meaning there may be a higher risk of accidental disturbances such as wildfire or further weed invasion. There may also be a risk that people do not recognize a regenerating forest but instead see an economic opportunity in the form of apparently unused and unoccupied wasteland. Nonetheless, this approach is probably the most common, and in many situations it is the only one feasible.

Reference: Nepstad, Uhl and Serrao 1991; Swaine, Hawthorne and Orgle (1992); Watkins (1993); Berger (1993); Aide et al. (2000) and Case Studies 8.1 and 8.6.

6.2.2 Enrichment planting

Not all regrowth or secondary forests have high levels of biological diversity. Many have been disturbed so many times in the past that only a small number of relatively common species remain. In these cases it may be useful to supplement biological diversity by reintroducing certain key species to hasten the process of natural recovery. For example, it might be necessary to quickly increase the population of several particular plant species that would find it difficult to re-establish under the passive restoration approach. These might be endangered plant species, plants with large seeds that are poorly dispersed or plants needed by a particular wildlife species.

In some situations exotic monoculture timber plantations have been established but the management objective has changed from exclusive timber production to production plus conservation or sometimes just conservation alone (e.g. Ashton et al. 1997). Enrichment plantings can also be used in situations where exotic monoculture timber plantations have been established but the management objective has changed to production plus conservation or just conservation. Gaps or strips are opened up in the canopy and seedlings of the desired species are planted into them, or seed is directly sown below the plantation canopy. The size of the canopy opening would need to be adjusted to match the tolerances of the species being underplanted. This approach allows some gradual harvesting of the original plantation species, which provides income. It also ensures that a protective forest cover protects the watershed and excludes weeds. The extent to which further canopy openings are created (potentially threatening the underplanted species when the trees are felled) will depend on ecological and economic circumstances.

Reference: Ashton et al. (1997).

6.2.3 Direct seeding

In many cases, the rate of natural succession is limited by the slow dispersal of seed across degraded landscapes. An obvious way to accelerate such successions is to deliberately reintroduce the seed. Various forms of direct sowing have been used: in some cases the seed has been broadcast or sown by hand; in others it has been sown from aircraft. Usually the seed must be sown on bare soil so that it can establish quickly in weed-free conditions. Seed reintroduction has been highly developed for use in commercial forestry following post-logging burns; it has also been widely used in mine site rehabilitation projects immediately after mining has ceased and before weeds have become established. It can be carried out after sites have been burned or following a herbicide treatment program to eradicate existing ground cover and shrubs (this might involve limited spraying on strips along which seed is subsequently broadcast or might necessitate complete weed eradication).

The advantage of direct seeding is its low cost; there is no need to raise seedlings in nurseries and they can be spread across the landscape easily, including sites that might be difficult to reach when carrying boxes of seedlings. There are several disadvantages, however. There must be no weed competition at the time the seeds are sown, meaning it may only be possible to use the technique in certain specialised situations. In addition, only certain species can be introduced to a site in this way since large amounts of seed are often needed. In many cases only a small proportion of the seed broadcast is usually able to germinate and thrive. Some seed will be lost to seed predators, some will fail to germinate under field conditions and some seedlings will die because of dry weather soon after germination. While such losses can be overcome by increasing sowing rates, seed supplies are often limited, especially seed of uncommon species. Such species may need to be raised in nurseries and planted rather than be directly sown.

Reference: Mergen et al. (1981); Allen (1997)

6.2.4 Scattered tree plantings

Another way to accelerate successions is to foster the structural complexity that attracts seed- or fruit-dispersing fauna into the degraded landscape from nearby intact forest. One method involves planting small numbers of scattered, single trees or clumps or rows of trees, which form perches for birds. Seedlings are produced from seed shed below the perch trees. Eventually the clusters of seedlings grow up to form trees and become bird perches themselves. The clumps of trees enlarge and the process continues. The trees initially planted might be one or more species with seed not dispersed by animals (e.g. species with large fruit or seed or wind-dispersed species) or those where fruiting only occurred infrequently. The approach is probably most useful in abandoned farmlands with grasslands or shrubs and at sites without many trees.

This approach is comparatively inexpensive since the trees are widely spaced and large numbers of seedlings are not needed (although the closer the spacing between the trees or clumps the faster the landscape would be revegetated). The disadvantage is that it depends on the majority of plant species being dispersed by wildlife. It is therefore appropriate only where there is enough wildlife able to cross the degraded lands or where few species are wind–dispersed. Another disadvantage is that the revegetation rate beneath scattered trees is likely to be slow since many newly germinated seedlings must compete with grasses and weeds. Janzen (1988) described a similar approach in a situation where most tree species were dispersed by wind rather than wildlife. In that case wind-dispersed species were planted across the landscape in rows perpendicular to the prevailing winds and the rows were spaced at a distance equivalent to the average dispersal distance of the seed. Wind dispersal ensured subsequent blanket coverage of the site by tree seeds.

Reference: Nepstad, Uhl and Serrao (1991); Guevara et al. (1992); Toh, Gillespie and Lamb (1999).

6.2.5 Close-spaced plantings using limited numbers of species

A variant of the approach above is to use more closely spaced plantings of a small number of species able to attract seed-dispersing birds. These early plantings act as “nurse trees”. The approach has been referred to as the framework species method (Goosem and Tucker 1995, Kirby et al. 2000). Although the planting density is high (1000 trees per ha, or even more), which means the treatment cost is higher than the scattered planting approach, the total cost is reduced by the small number of species used. This eliminates the need to collect seeds from a large number of species and raise them in the nursery. One option is to plant species from early successional stages, which will create the conditions for the later arrival of a more diverse community. Alternatively, species might be chosen because they are tolerant of the site conditions or because they are attractive to wildlife and are able to reproduce quickly and spread across the site.

The advantage of this approach is that once the trees are established, they soon out-compete grass and weeds, making it easier for the species brought in by seed-dispersing animals to become established. The approach is especially suited to areas close to intact forest that can act as a source of seeds (and wildlife); this allows additional species to be recruited quickly. Methods that rely on seed-dispersing birds to reintroduce the original plant species may, of course, also result in a number of weed species being brought to the site. In all these methods, therefore, some maintenance is needed in the early years to ensure that weeds do not dominate the succession.

References: Goosem and Tucker (1995); Tucker and Murphy (1997); Reay and Norton (1999).

6.2.6 Intensive ecological reconstruction using dense plantings of many species

Rapid revegetation of degraded areas is perhaps most easily achieved by intensive planting of a large number of tree and understorey species. One of the earliest examples of this approach was in deciduous woodland in Canada in 1886 (Larson 1996).

More sophisticated versions of the approach in temperate woodlands are described by Rodwell and Patterson (1994) for the United Kingdom. Although the objective is to establish diverse plant communities Rodwell and Patterson recommend using pure clumps or clumps of only two or three tree species rather than more intimate mixtures because of the difficulties of matching complementary species. The spacing between clumps can also be varied to create gaps. The understorey and tree species used depend on the sites and soil types.

Tropical forests have a much larger number of species and a similar approach — described as the maximum diversity method by Goosem and Tucker (1995) — uses more intimate mixtures and denser plantings and attempts to restore as much as possible of the site's original botanical and structural diversity. Again, care is needed in choosing the species to plant. Those which might be used include fast-growing species able to exclude weeds, poorly dispersed species, species forming mutually dependent relations with wildlife and, possibly, rare or endangered species that might be present only in small numbers or in small geographic areas. Since the method bypasses the normal successional sequence the species used should come mostly from late successional stages, rather than early pioneer species. On the other hand, some short-lived species able to create canopy gaps and regeneration opportunities can be useful. A range of life forms should be included (e.g. trees, shrubs, herbs etc.). Although large numbers of species can be used the method is usually still only able to use some of the plants occupying a particular site; this means that colonisation from outside is still necessary. Dense plantings of up to 4,000 plants per ha can be carried out.

In both temperate and tropical conditions the method has the advantage of quickly establishing a large number of species, all of which can be inoculated with appropriate mycorrhizae in the nursery. This makes it especially suitable for areas needing rapid restoration, such as areas in and around national parks or other protected areas. It may also be useful in areas where natural recolonisation is slow because of isolation from intact forest remnants.

The method has several disadvantages, however. The growth rate of plants in such dense plantings can be slow because of competition and many of the original species may die. This is a particular problem in tropical sites. Also, while some species may need to be introduced to the succession in a particular sequence, incomplete knowledge about the ecology of most species and ecosystems makes it difficult to know how to do this. In such cases follow-up plantings may be needed to accelerate the rate at which additional plant diversity is added. The greatest disadvantage of this approach is cost; it can be very expensive to collect the seed and raise such a large variety of species in a nursery and plant them out in large numbers. Consequently it is usually only suitable in specialized circumstances.

References: Miyawaki (1993); Goosem and Tucker (1995); Rodwell and Patterson (1994); Shear, Lent and Fraver (1996); Kooyman (1996); Tucker and Murphy (1997); Parrotta and Knowles (1999) and Case Study 8.2.

6.2.7 Intensive ecological reconstruction after mining

Areas that have been mined have special requirements. They invariably have extensive soil damage requiring treatment to restore soil fertility. There may also be chemical or physical problems. On the other hand, mining commonly generates sufficient funds to finance more intensive restoration than might otherwise be possible. Further, the size of many mines is small in comparison to many other degraded sites, meaning that sometimes there is only a short dispersal distance from intact forest cover. Some mining companies have opted for forms of reclamation using exotic species (e.g. pastures for grazing or exotic tree plantations), believing restoration to be too difficult. In other cases, however, miners have found the most stable long-term land use after mining is a native vegetation cover and have chosen to undertake restoration.

There are several key considerations that can help accelerate the rate of recovery after mining irrespective of the approach adopted. One is to ensure that topsoil is removed and stockpiled before mining begins so that it can be spread back over the site prior to revegetation. This topsoil contains much of the nutrient capital of the site as well as seeds and mycorrhizae. It is an extremely valuable resource whether the objective is reclamation, rehabilitation or restoration. Lengthy periods of stockpiling usually cause adverse changes in the density and composition of soil seed stores as well as in microbial properties. This means that topsoil can only be stored for six months or less.

The second factor that can improve the rate of recovery is to avoid creating soil conditions during mining that might make revegetation difficult. For example, many mines generate tailings containing materials that are damaging or toxic to plant growth. These materials may be saline or include heavy metals or pyrites that generate high levels of acidity. These problems should be identified at an early stage in mine development and design; often they can then be dealt with by burying the materials at depth beneath other mine tailings or overburden. The cost of doing this may be low if the problem is recognised in the design phase of the mine's development but very high once a mine has commenced operations. Conditions limiting plant growth, such as low levels of topsoil fertility or poor soil physical conditions, also need to be identified and dealt with by fertilisers, ripping etc. Once mining is complete it is necessary to reconfigure the topography of the site to minimize wind or water erosion and re-establish drainage lines. Revegetation after mining can be done by planting seedlings or by direct seeding, as described earlier.

Reference: Bradshaw and Chadwick (1980); Mulligan (1996) and Case Studies 8.4 and 8.5.

6.3. Directing ecological successions

What all these approaches have in common is that successions are initiated or accelerated without any clear knowledge of the direction they may take (Luken 1990, Weiher and Keddy 1999). It is assumed that other plant species will colonise the sites over time from nearby forest remnants. It is also assumed that animals will be able to migrate to and reoccupy these new communities once appropriate habitats are formed. In fact, however, the large number of uncertainties make it difficult to predict outcomes.

6.3.1 The "founder effect"

This term refers to the extent to which the initial populations — which species, how many species, density and genetic variability — affect successional development. Will small differences in one of these factors or in the life histories of the species chosen make large differences in the rate of successional development? And what difference might an exotic species rather than an indigenous species make? The evidence to date on the consequence of using exotic species rather than indigenous species is equivocal, although it is apparent that in some extreme cases only exotic species will tolerate the degraded site environment. It is also clear that the relative proportions of the species in the initial community are very important. An example is the restoration of land after mining at Stradbroke Island in Australia (Figure 4a).

Figure 4a. Forest restored after mining, Stradbroke Island, Australia

Patches of acacia dying at the end of their normal life cycle.

A large number of species were reintroduced to the site as seedlings and by direct seeding. A nitrogen-fixing acacia was included in the mix of directly sown species (at 700 gm of seed per ha) in order to improve soil fertility. While all the new species grew well, the acacia grew at the fastest rate and shaded out most of the other species (Figure 4b).

Figure 4b. Restored forest in an acacia-dominated site

The risk of fire has increased because of the large fuel load created by the dead trees. The acacia have also bequeathed a large store of dormant seed in the topsoil.

When the short-lived acacia began to die after ten years few other species remained (Figure 4c). Current practice now uses only 30 gm of acacia seed per ha and community development is more successful.

Figure 4c. Monoculture of acacia seedling regeneration

A subsequent wildfire at the site resulted in a monoculture of acacia seedling regeneration that dominated the few other remaining species.

6.3.2 Distance from intact forests

Species differ in their ability to disperse and colonise new sites. Some species are extremely successful at doing so and are able to cross over large areas of highly degraded landscape while others are not. One outcome of restoration, then, might be that a newly restored site is colonized by just a few common native species or exotic weeds rather than a more diverse range of species from the original community. All weeds are potentially difficult but some are more problematic than others. The most difficult are weeds that might replace key indigenous species (e.g. keystone species that have an important role in the maintenance of community composition) or those that have the capacity to persist indefinitely as sizeable, sexually reproducing or clonally spreading populations. Weeds that alter community structure or function (for example, a nitrogen-fixing species that alters soil fertility levels) are particularly problematic. They may out-compete less common native species and eventually lead to a decline in overall species richness. A similar pattern might occur in the case of exotic wildlife species (Maina and Howe 2000).

6.3.3 Wildlife

Wildlife is often the focus of restoration projects. But while many animals are intimately involved in key ecological processes such as pollination and seed dispersal, knowledge of trophic relationships or precise habitat requirements is generally incomplete. Neither is wildlife's role in successional development well understood (Majer 1989). Where the habitat requirements of particular wildlife species are known it may be possible to manipulate the plant community to provide these conditions sooner rather than later. It appears that some degree of structural complexity is required before wildlife species will colonise a site. In some cases it might be possible to add habitat attributes such as nest boxes, old logs or even piles of stones to provide structural features before they become available within maturing forests. If certain wildlife species are no longer present in the landscape their reintroduction can be very difficult (Bowles and Whelan 1994).

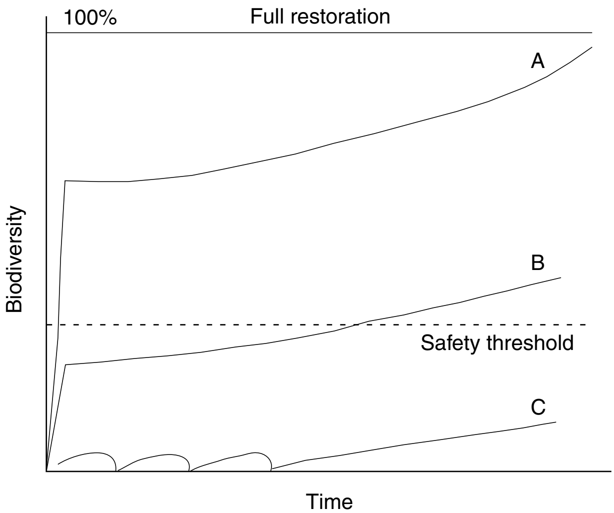
6.3.4 Disturbances

At some point in the restoration process the natural disturbance regime must be allowed to develop to prevent successions from being diverted or stagnating. For example, while restoration projects in fire-prone landscapes often require fire protection in the first few years to ensure seedlings become established, at some stage fires must be allowed or be reintroduced to ensure that normal successional processes continue to operate. Local experience will be needed to determine when to switch from fire protection to fire introduction. In other situations different forms of intervention may be needed.

6.3.5 Recovery rate

The overall rate of restoration is usually a function of management inputs. Extensive site preparation and the planting of a large number of trees, for example, is likely to mean the rapid onset of canopy closure, weed exclusion and recreation of the normal forest microclimate. This will then either facilitate the arrival of further colonists or at least reduce the extent to which they will be inhibited from colonizing (see line A in Figure 5). A more modest number of species and individuals means the process of colonization and canopy closure will take longer (line B). This means the site will be exposed to a longer period of risk from disturbances such as wildfires or grazing that will return it once again to its degraded state. Sites which are left to recover unaided are exposed to this risk for an even longer time period (line C). In some situations the magnitude of the risk from disturbances such as fire may mean that recovery will never occur.

Figure 5. Rate of recovery of biodiversity



The rate of recovery depends on the resources devoted to restoration. When large numbers of species are planted and substantial resources are applied (A) the rate of recovery towards the original degree of biodiversity may be rapid as additional species colonise from outside. With fewer species and more limited resources (B) there is more time before the system crosses a "safety threshold" (i.e. when the canopy closes), leaving the site exposed to risks of further disturbances such as fires or grazing. If the site is left to recover unaided (C) there is an even higher degree of risk and it may or may not recover.

6.3.6 Ecological "surprises"

In many cases things don't happen as planned. Direct seeding may fail because predators harvest all the seed. Successions may become dominated by a small number of aggressive species causing competitive exclusion and a decline in biodiversity. Trees established to attract seed-dispersing wildlife may become focal points for weed colonisation. The removal of exotic herbivores may allow grass fuel loads to increase and fire regimes to change (e.g. Russell-Smith, Ryan and Durieu 1997). In all cases constant monitoring is needed to ensure that restoration continues as planned (monitoring is discussed further in Chapter 9). Some propositions arising from these various methods are given in Box 7.

Box 7. Some generalizations concerning ecological restoration

Proposition 1. The future state of any restored forest is heavily dependent on the current state (i.e. the species initially present, sown or planted at the site).

Corollary: small changes to initial environmental conditions (e.g. rainfall, soil fertility) can cause successional trajectories to diverge rapidly, making it difficult to predict outcomes.

Corollary: disturbances are capable of changing successional trajectories (e.g. fires or grazing animals can remove particular plant species from a site).

Corollary: feedback loops can be significant (e.g. canopy development enables seed-dispersing birds to enter the succession, thereby accelerating the rate at which new plant species enter the community).

Proposition 2. The more plant species that can be initially reintroduced the faster the subsequent succession.

Corollary: the more species present the greater the structural complexity at a site is likely to be and the more likely it is to be attractive to a wider range of wildlife species.

Proposition 3. Some plant species combinations are unlikely to be successful.

Fast-growing species with dense crowns may exclude some slower growing species unless the latter are especially shade-tolerant or canopy gaps are either present or frequently created.

Proposition 4. An initial (planted) community of pioneer and early secondary species will be short-lived and will not likely be self-sustaining. It is not necessary or even desirable to attempt to simulate natural successional patterns by initiating restoration projects using only pioneer species. In many (though not all) cases, species from the functional groups found in later stages of successions can also be grown in the open in early stages of community development. In many natural successions their delayed colonisation may be as much a consequence of their limited dispersal abilities as their physiological tolerances. This means that many species from mature successional phases can often be planted in relatively open, old-field situations.

Corollary: plantings of species from functional groups represented by fast-growing pioneer and early secondary species may be useful as a means of quickly eradicating weeds. Ideally there should be forest remnants nearby from which species from more mature successional stages and other functional groups will colonise. If not, such species can be sown or underplanted beneath this initial canopy.

Proposition 5. The sequence in which species are reintroduced to a site is important in determining the assembly trajectory.

At a basic level this is obvious; for example, trees are necessary before epiphytes can colonise a site. But at a more fundamental level some important "structuring" species may be needed early in a successional sequence. If they aren't present then some of the other directly sown or planted species may fail and disappear. This doesn't mean that all primary forest species must be planted beneath a canopy of early secondary forest species. Rather, facilitation and inhibition can occur during successions and influence successional trajectories.

Corollary: the species most able to "structure" a succession are likely to be those that rapidly modify the physical environment or those with large numbers of mutualistic relationships with other plant or animal species.

Proposition 6. The rate at which restoration occurs depends on the extent of the existing environmental stresses.

Sites with strongly seasonal climates or low soil fertility are likely to be more difficult to restore. Frequent but unpredictable stresses (e.g. fires, droughts) make it particularly difficult to reassemble new communities. Once restored, however, such communities may buffer some of the stresses (e.g. the more humid microclimate within a new forest may limit the spread of fires).

Corollary: It may be necessary to use some non-native species at highly degraded sites that the original species are now unable to tolerate. These can ameliorate the site conditions (e.g. nitrogen fixers that improve soil fertility) and facilitate the subsequent re-entry of native species.

Proposition 7. Animal are important seed dispersers, particularly in many tropical regions, and thus have an especially important role to play in restoration ecology.

Corollary: the propagules of species dispersed by animals will have certain attributes (e.g. fleshy fruit, seed with arils, mostly small to medium fruit size) that make them attractive.

Corollary: certain plant species will be unlikely to be dispersed by wildlife and will need to be introduced. These include species with propagules lacking animal-attracting features, those with large fruit or those that fruit infrequently as well as rare species.

Corollary: few wind-dispersed species are likely to reach and colonise a site once the canopy closes.

Proposition 8. The rate at which additional plant species enter a site once restoration has been initiated depends on the distance from sizable intact forest remnants. It also depends on the extent to which populations of animals capable of dispersing seed from these remnants remain in the landscape.

Corollary: little colonisation is likely at isolated sites or in landscapes where only small forest fragments remain and restoration of tropical forests is rarely feasible at such sites (although it may be possible to re-establish species-rich forest communities).

Corollary: the nature of the vegetation matrix separating the restored site and intact forest will influence the rate at which seed dispersal and colonisation occur. A matrix containing shrubs and scattered (perch) trees is likely to foster faster seed dispersal than a treeless grassland.

Proposition 9. The attractiveness of a site to animal seed dispersers affects the rate at which they bring seeds of new species.

Structurally complex sites are likely to be more attractive to a wider range of animal species, but animals are likely to enter the new community in significant numbers only after the canopy has closed. Sites with tall trees are likely to be more attractive than those with only short trees or shrubs and large restored areas are likely to be more attractive than small areas.

Proposition 10. Species colonising a restored site after canopy closure must have some degree of shade tolerance that either enables them to grow and join the canopy or allows them to persist in the understorey until a canopy gap is created.

It is difficult for shade-intolerant secondary species to enter a restored site once canopy closure has occurred. Even primary forest species that colonise after canopy closure may take many years to grow up and join the canopy layer. This means the rate of successional change and progress towards a fully restored state will be slow after canopy closure.

Corollary: Rapid canopy closure reduces the likelihood of (but will not necessarily prevent) weed colonisation. Some weed species may still be able to persist under moderate levels of canopy cover, particularly when that canopy cover is uneven. Alternatively, weeds may arrive at a site and persist in a soil seedbank.

Based on Lamb (2000)

6.4. Interventions providing biodiversity as well as productivity benefits

The primary benefit of the approaches above is the restoration of some or most of the biodiversity. Immediate or direct improvements in human well-being are often limited, although considerable indirect economic and social benefits may develop over time because of the ecological services provided (e.g. watershed protection). The absence of an early direct benefit necessarily limits the number of situations in which ecological restoration might be attempted. It also means that restoration is usually attempted only in relatively small areas.

The most common alternative method of overcoming degradation is some form of reclamation using monoculture plantings of a single species. These species are usually exotic trees that provide a commercial benefit but do nothing to reverse the ongoing trend towards landscape simplification. Some of the advantages and disadvantages are shown in Table 2. A third alternative is the approach referred to earlier as rehabilitation, in which are several other ways to overcome degradation that provide a commercial or socially useful product and also increase biodiversity across the landscape. As well as improving biodiversity, some of these approaches may even offer better production or additional benefits than those provided by reclamation.

6.4.1 Managing secondary forests

Secondary or regrowth forests are often viewed as having little biodiversity value or potential for contributing to rural livelihoods. For example, they are often thought to be exclusively occupied by trees with low timber densities that have little economic value. These assumptions may be wrong. Depending on their origins, they may be able to make a substantial contribution to biodiversity protection and also help provide a variety of goods and services. In addition, the sheer extent of the areas of secondary forest now found in most tropical areas demands that they receive more attention.

Several alternatives are possible depending on the origins of the forest and the range and abundance of the species it contains. One option is to simply protect the forest and manage the harvesting of existing plants and animals. This requires care because of the risk that the forest will degrade further unless harvesting is carefully regulated. On the other hand, careful management might also allow the gradual improvement of resources as well as biodiversity and other ecological service at minimal cost. Another approach might be to foster the growth of certain tree or other plant species within the forest that are commercially attractive by removing or thinning competing trees. This may mean the relative abundance of these favoured species increases over time although the overall biodiversity of the forest will probably be maintained.

Reference: Finegan 1992, Chokkalingam, Bhat and von Gemmingen (2001) and Case Study 8.3

6.4.2 Enrichment plantings

Some forests are degraded by heavy logging. They sometimes lose their most commercially attractive timbers because these were not represented in any advanced growth (i.e. saplings and trees smaller than the cutting limit) or because the advanced growth was damaged by the logging operation (point D on Figure 2a). Such forests may still have significant timber resources, however. Rather than clear-felling and replacement by timber plantations, enrichment planting is a way to enhance commercial productivity while maintaining the sites as essentially "natural" forests. A common method of enrichment is to plant fast-growing and commercially attractive species in the new post-logging light gaps or in strips cut through the forest. Similar forms of enrichment can be used for non-timber species such as fruit or nut trees as well as rattans, medicinal plants or food plants.

This approach has several advantages. It enhances the capacity of the forest to maintain commercial or social productivity by promoting the growth of economically desired species. It also conserves any residual advanced growth or natural regeneration of timber trees. In addition, it maintains much of the residual biodiversity still present and prevents the forest from being cleared for other uses such as agriculture or plantations. The disadvantage of the approach is the risk that fast-growing trees may stagnate once canopy gaps close over and weeds or vines swamp the planted species. Some form of treatment is often required for several years to ensure success.

Reference: Adjers et al. (1995); Tuomela et al. (1995); Montagnini and Mendelsohn (1997); Dawkins and Philip (1998)

6.4.3 Agroforestry

Agroforestry is a form of agriculture that combines complex mixtures of trees and other crops grown in the same area of land. There are a variety of formats. Some involve mixtures of multipurpose trees and food crops; others combine scattered trees and pastures. In most cases a variety of species are used in the farm or "home garden" that differ in canopy and root architecture, phenology and longevity. Some of these different versions of agroforestry are reviewed by MacDicken and Vergara (1990) and Clarke and Thaman (1993).

In terms of overcoming land degradation, agroforestry has some particular advantages, most especially in landscapes where land for food production is limited and where human populations are large or increasing. Agroforestry is able to provide food and agricultural products for these communities in a way that is relatively sustainable. Further, it creates spatial and structural complexity across landscapes and offers the prospect of agricultural sustainability. Some of the most interesting examples of agroforestry occur in Indonesia, where some extremely diverse forests have been established to yield rubber, resin or fruit (see case study 8.9). A description of how highly diverse agroforests such as these might be established even on extensively degraded grasslands is found in de Foresta and Michon (1997).

There are some potential disadvantages. Biodiversity gains are not always as large as those in Indonesia despite the variety of plants used and the inherent complexity of most agroforestry systems. This is because many of the species used are relatively common agricultural crop species, only a few of which may be indigenous to the area. Further, not all agroforestry systems are developed on highly degraded lands; agroforestry may result in a loss of species if, for example, a farmer establishes a new home garden in a species-rich secondary forest or a forest that has been subject to a single logging operation.

Reference: Gouyon, de Foresta and Levang (1993); Michon and de Foresta (1997); Cooper et al. (1996) and Case Studies 8.9 and 8.11

6.4.4 Monoculture plantations using indigenous species

Timber plantations are often established as monocultures using exotic species. There are a number of reasons for this. Such plantations are easy to manage, nursery methods for raising large numbers of seedlings are well-known and silviculture techniques are understood. These species are also fast growing and usually established in the marketplace. They come as a technical "package" that is attractive to plantation managers and to farmers establishing small farm woodlots. Indigenous species rarely have any of these advantages. This means they are usually bypassed when industrial production is required, particularly when native timber can still be harvested from natural forests.

Indigenous species do have some advantages, however; in particular timber quality and price. They may not be able to compete in the high-volume industrial market but are very competitive in more specialised markets. Although their volume increment per year may not be high their value increment can be large. This advantage may increase further if timber supplies from native forests decline (as they have in many tropical forests). Further, many indigenous species are well suited to the climate. Thus there seems to be scope to include native species as part of plantation programs for the financial benefits they may bring. Monocultures might not lead to large benefits in terms of restoring biological diversity to degraded landscapes but will enable indigenous species to be retained in the region and may benefit wildlife that is adapted to or dependent on them.

In some situations, planting native species in plantations can disadvantage land-owners and discourage deforestation. For example, governments in parts of Kenya and other parts of east Africa have declared certain species to be government property even when they were planted by farmers on private land. Likewise, in parts of Australia, land-owners who planted native tree species were prevented from harvesting them because of the loss of community "conservation" benefit this would entail. Such counter-productive activities are a major disincentive to using native species and need to be stopped.

Plantations of indigenous tree species are not the only way to rehabilitate degraded landscapes. Monocultures of exotic tree species may be useful at severely degraded sites, when these are the only species able to tolerate existing site conditions. In some cases it may be necessary to restore site fertility using an exotic nitrogen-fixing species such as acacia before using any native species in plantations. Likewise, salt-tolerant species may be needed in salinized landscapes to lower water tables before planting indigenous species.

Reference: Evans 1992; Farrington and Salama (1996); Butterfield (1996)

6.4.5 Monoculture plantations and buffer strips

A simple means of enhancing the conservation benefits of plantation monocultures is to embed the plantings in a matrix of buffer strips of forest that has been restored by one of the approaches described earlier. This immediately introduces much more spatial complexity to a landscape and helps to increase connectivity. Each strip can be a corridor that enables wildlife to move from one area to another. While there has been considerable debate in recent years about the merits of corridors, there seems to be little doubt of the advantages of enhanced linkages (Bennett 1999). Corridors have other major benefits; e.g. they provide fire breaks and act as streamside filters to enhance water-shed protection. These advantages may help to overcome the perceived disadvantage that they occupy land which could be used for production.

Reference: Bennett (1999)

6.4.6 Mosaics of species monocultures

In many industrial plantations a single species is used across the entire landscape irrespective of landform or soil fertility. Sites are modified by ploughing or fertilising to suit the species. There may be advantages in using more than one species to take advantage of this environmental heterogeneity. By matching species to sites it may be possible to enhance overall plantation productivity and improve landscape diversity. The landscape diversity in a mosaic of two or more plantation species could be further enhanced by surrounding each monoculture by buffer strips as described above. The advantage of this is that plantation silviculture remains simple; the disadvantage is that precise species-site relationships must be known if productivity is to be maximised.

Reference: Lamb (1998)

6.4.7 Mixed species plantations

Plantations are commonly established using a single species monoculture because it is the easiest to manage. Some landscape biodiversity can be increased if mixed species polycultures are used. These might be temporary mixtures where one species is used for a short period as some form of nurse or cover crop (e.g. Keenan et al. 1995), or may be permanent for the life of the plantation. Biodiversity gains from mixed species plantations are usually modest since most of them contain relatively small numbers of tree species. But evidence is growing that there may be production or financial advantages as well as biodiversity gains from using mixed species plantings. These benefits result from better site use, improved tree nutrition and less insect or pest damage. There may also be financial gains from combining fast-growing species (harvested early in a rotation) with more valuable species that need longer rotations. The first harvest provides an initial cash flow and also thins to improve growth of the remaining higher value trees (Table 5).

Table 5. Potential benefits and mechanisms of a plantation mixture

Potential benefit	Mechanism
• reduced between-tree competition, leading to increased productivity	• phenological separation in time • root separation in space (depth) • foliar separation in space (canopy architectural differences)
• reduced insect and pest damage, leading to increased productivity	• micro-environment changes resulting from underplanting (e.g. Red cedar) • target species "hidden" or too distant for disease transfer
• improved nutrition, especially at degraded sites with infertile soils, leading to increased productivity	• inclusion of nitrogen-fixing species • faster litter decay and improved nutrient turnover
• improved financial returns	• early harvest of fast-growing and easily marketed species, leaving slower-growing but more valuable species to develop over time, and allowing improved growth of residual trees

Sources: Ewel 1986; Brown and Ewel 1987; De Bell, Whitesell and Schubert 1989; Binkley 1992; Wormald 1992; Keenan, Lamb and Sexton 1995; Kelty 1992; Montagnini et al. 1995

Plantation mixtures have several disadvantages, however. One is the difficulty of assembling complementary and stable mixtures. Not all species combinations are necessarily compatible and an inappropriate mix of species may lead to commercial failure. Work is needed to identify species that are similarly competitive and therefore complementary. A second problem is that having two or more species in a plantation necessarily leads to more complex forms of silviculture and management. This means that mixtures are likely to be more attractive to smallholders and farm forestry woodlots than large industrial-scale plantations.

Reference: Kelty (1992); Wormald (1992); Montagnini et al. (1995); Dupuy and Mille (1993)

6.4.8 Encouragement of understorey development

In many plantation forests, especially those near areas of intact forest, an understorey of native tree and shrub species will develop over time. A large number of species may colonise, leading to a substantial change in the appearance and structure of the plantation over time (Figure 6). Some weed species may be part of the new community, although many studies have found these to be only a minor component of the total understorey flora. Many of the species are dispersed by animals, indicating that wildlife use plantations for foraging and transit.

Figure 6. Understorey regeneration, northern Queensland, Australia

This understorey has developed beneath the canopy of a 60-year-old tropical plantation of Araucaria cunninghamii. *The site, originally planted as a monoculture, is within 200 m of intact tropical rainforest. Many of the tree colonists have gradually grown up and joined the canopy layer. Photo by R. Keenan.*

Tree plantations established for commercial timber production are eventually harvested. This means that any biodiversity they contain is destroyed. Thus the conservation benefits of industrial or commercial plantations can be seen as short term. But during the rotation the plantation may have helped buffer remnants of intact forest and protected them from further degradation. The plantation may also have extended the habitat of a particular species or provided a link between isolated populations of plants or animals in small remnant areas. Many of these benefits can be reacquired if the plantation is re-established, especially if remnants of intact vegetation remain in the landscape.

In some cases the conservation benefits of the plantation will have increased over the period of the plantation and may now be more valuable than the timber. In this case the managers may chose to develop some form of selection logging that causes less impact than clear-felling, or even change the management objective entirely and manage the enriched plantation for conservation purposes alone.

Reference: Parrotta, Turnbull and Jones (1997) and Case Study 8.7

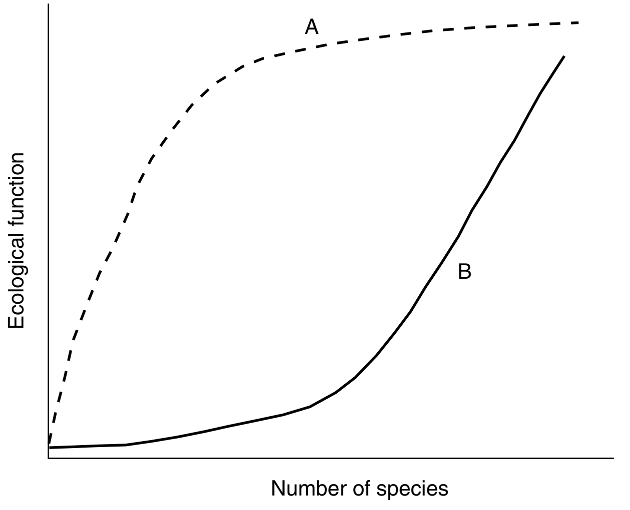
6.5. Managing for goods and other ecological services as well as biodiversity

Forests established to provide goods plus some biodiversity (as well as the functional benefits that this enhanced biodiversity should provide) are often difficult to design and manage. In some cases the problems are scientific. In other cases they are social; they involve value judgements and require trade-offs.

6.5.1 How many species?

Where tree planting is involved a key question is the number of species needed to achieve a particular functional response (Figure 7). In some situations a small increase in species richness might be sufficient to produce the functional response (line A). Thus, watershed protection or a reduction in the water table to improve salinity might be achieved with only a small number of plant species and further increases in species richness may not provide any further benefits. Alternatively, the functional response might only occur after a large number of species are added to the community (line B). Thus, the habitat requirements of a particular animal species might need many plants to provide the structural complexity necessary.

Figure 7. Relationship between number of species and ecosystem function



Two hypothetical relationships are shown between the numbers of species in a plantation mixture and ecosystem function (e.g. production, watershed protection or nutrient cycling, etc.). Line A shows a situation where even small increases in species richness achieve significant functional improvements. Line B shows a case where improvements come only after a larger number of species are added.

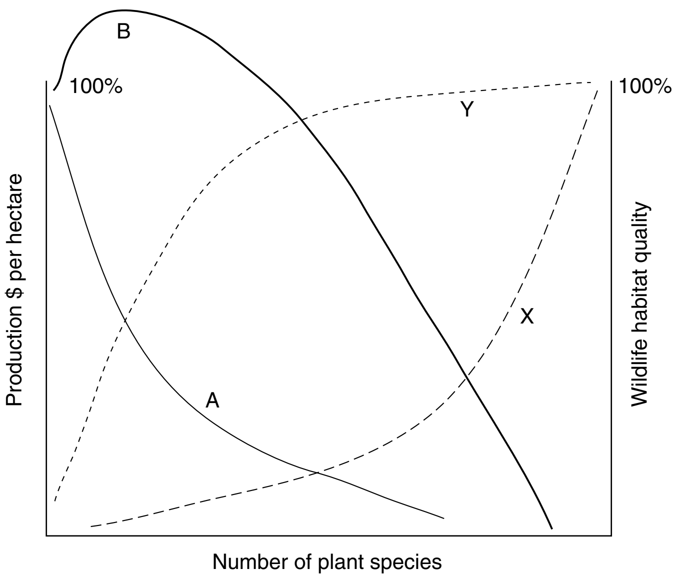
There is much debate over the shape of these curves and the mechanisms at work. Particular attention has been paid to the relationship between diversity and production (some possible mechanisms giving rise to higher levels of production in mixed species plantations were outlined in Table 5). Production increases might be caused by matching species with complementary ecological niches (the "niche differentiation model") or from mixing nitrogen fixers with non-nitrogen fixers. However, there has also been considerable debate about the so-called "sampling" effect, whereby production increases might simply be a consequence of adding more species, therefore increasing the chance of including species that are productive and dominant competitors (Kinzig et al. 2001). Evidence suggests that while the sampling effect may be observed in younger communities the niche differentiation model tends to predominate over time. Much of the empirical evidence has come from studies with short-lived grassland communities that suggest the point of inflexion is around 16 species (a different situation may prevail in forest communities).

In any case, species richness per se may not always be as important as the structural or functional types of species involved (Hughes and Petchey 2001, Diaz and Cabido 2001). For example, watershed protection may be better in a forest with a diverse range of life forms (such as a mixture of grasses, understorey shrubs and trees) than in a multi-species tree plantation. Similarly, more habitats for a larger range of wildlife species are likely to be created by using a variety of plant life forms and structural types than by having a larger range of tree species represented in the forest canopy. In these situations functional outcomes may be only loosely related to the alpha diversity of plants. It is also clear that these relationships can be dependent on scale and that relationships present at small, local scales may not hold at larger, landscape scales. This will be discussed further in Section 7.2.

6.5.2 Trade-offs

Inevitably some trade-offs may be required by managers needing to balance, say, commercial timber production against wildlife diversity. This is illustrated in a necessarily simplistic fashion in Figure 8.

Figure 8. Timber production and wildlife benefits in mixed-species plantations



In Figure 8 the productivity of a plantation with just one species is shown as 100 per cent. A mixed-species plantation may have either an increased or decreased level of timber production compared with this monoculture. A decrease might occur (line A) if incompatible species are mixed. An increase might occur (line B exceeds 100 per cent) if complementary species are combined; this allows production gains through the mechanisms described in Table 5. However, this increase in per-hectare commercial productivity is unlikely to persist with increasing numbers of tree species; at some point the market price of each additional species declines once the most profitable are included. Increased numbers of species then simply dilute the density of the most profitable species in the stand. (This is the reason for the difference in the shape of these diversity-function curves from the hypothetical curves shown in Figure 7). Of course the attractiveness to the grower of using large numbers of tree species will necessarily depend on whether there are markets for more than a small number of tree species and whether commercial timber production is the primary objective of reforestation.

The right axis of Figure 8 shows wildlife habitat quality. The best habitat quality has a large number of plant species. Depending on the wildlife and plant species involved, a small decline in plant species richness may cause a rapid decline in habitat quality (line X). In other circumstances the habitat quality might be unaffected until such time as only a few plant species remain (line Y). Depending on the plant and animal species and, consequently, on these trends, a manager may be able to adopt a compromise that offers both timber production and habitat quality not far from the optimum (intersection of lines B and Y) or be faced with a choice that is suboptimal for both (intersection of lines A and X). Of course, the identity as well as the proportions of particular plant species can make a difference to these relationships. Thus the presence or absence of particular food plants or plant life forms may have a greater effect on habitat quality for certain wildlife species than biodiversity alone. Additional work on exploring such relationships might lead to the design of plantation forests where trade-offs between production and wildlife habitat values are much reduced.

6.5.3 Time before harvest

Another choice faced by managers is when to harvest. In some situations, such as agroforestry, the harvesting operation and direct benefits may be almost continuous or at least annual. Forests used for timber production are different. Many commercial plantations established to provide sawn timber have rotations of around 40 years (although longer or shorter rotations are also common). This is a comparatively short time in ecological terms; many conservation benefits may have only just begun to be acquired. For example, understorey structural complexity may only then reach a stage where habitats are becoming available for some wildlife species.

One option is to simply harvest the forests as originally planned. While this means that any biodiversity benefit is then lost from the site, it can presumably be re-established in the second rotation using profits from the first harvest. In the meantime the surrounding (younger) plantation areas will continue to provide some continued benefits. In this case a previously degraded landscape is now providing a timber yield and some modest biodiversity benefits. These may not be great but the structural complexity of the site (provided by different age classes of forest as well as logged and unlogged areas) has improved from the previous homogeneous state. Alternatively, it might be that since the plantation was established circumstances have changed such that it now has a greater value as a conservation reserve than as a source of timber. Indeed, it would be surprising if social, economic and ecological circumstances did not change over any 40-year period.

Two other possibilities may be available in cases where vigorous understorey development has taken place (Figure 6). One is to carefully harvest the overstorey trees, leaving behind as much as possible of the advanced understorey growth. The harvest pays off the plantation debt, leaving a species-rich community of trees capable of excluding fire-prone grasses and weeds and developing into new forest. This would then be managed as a conservation forest. Alternatively, the site could be managed as a selection forest, with any large trees of commercial value being harvested. Again, this would pay for the cost of reforestation and bequeath a species-rich forest to a former degraded landscape. Both options require trade-offs and a willingness to explore alternatives, which are necessarily dependent on local circumstances.

Table 6 summarizes the various approaches used to overcome forest degradation (described in 6.2 and 6.4). These ratings are necessarily subjective and depend on the ecological context of any particular site.

Table 6. Costs and benefits of various methods of overcoming forest degradation

Method	Relative direct cost	Relative rate of biodiversity gain	Potential ecological services benefit
a) Prime focus on biodiversity restoration			
Passive restoration	low	slow	high
Enrichment planting	low–medium	slow–medium	high
Direct seeding	low–medium	medium	high
Scattered plantings	low	slow	high
Close plantings of a few species	medium	medium	high
Intensive plantings after mining	high	fast	high
b) Prime focus on production and biodiversity			
Managing secondary forests	low–medium	medium	high
Enrichment plantings	low–medium	medium	medium–high
Agroforestry	medium-high	medium	medium
Monoculture plantations with buffers	high	slow	medium
Mosaics of monocultures	high	slow	low-medium
Mixed species plantations	high	slow	medium
Enhanced under-storey development	low	slow	medium–high

6.6. Socio-economic considerations

The following sections address some of the key social and economic factors that need to be integrated with biophysical factors in any serious consideration of forest restoration.

6.6.1 Reconciling interests of different stakeholders

In many parts of the world, civil society (such as NGOs and community groups) is demanding a greater say in the way natural resources are used and benefits accruing from them are distributed. This adds to the pressure for government staff and private-sector operators to become more transparent in their decision-making and to involve a wider range of stakeholders. In addition, managers across both public and private sectors realise that participatory approaches are likely to produce more viable outcomes than the centralised decision-making of the past.

There are many autonomous and interdependent participants in the increasingly complex institutional environment described above. A variety of groups with an interest in forest outcomes (broadly described as pluralism) is a growing reality at local, national and international levels (Anderson, Clement and Crowder 1998). This has broad ramifications for forest policy, and for approaches to planning and management. For example, at the local level, such as a forestry district, many groups have a legitimate interest in the results of forest planning and the implementation of field programmes. These might include forest department staff, staff of other government departments (particularly agriculture and livestock), villagers, local authorities, conservation NGOs, forest industry organisations, etc. Acknowledging the differences between the interests of these groups opens the way to building dynamic institutional frameworks for sustainable forestry.

While most of the concepts outlined in Box 8 are valid, two require comment. Anderson, Clement and Crowder contend in point 3 that "no group/organisation can claim a superior or absolute scenario". The reality, however, is that a group with particular economic or political strength frequently does dominate weaker groups. This needs to be recognised and managed. Point 6 states that "conflicts are inevitable and cannot be resolved but managed". While conflicts need to be managed so that they do not escalate to intractable positions or violence, experience indicates that in many circumstances conflicts can indeed be resolved (Gilmour and Fisher 1991). The practical reality is that if the interests of different groups of people cannot be reconciled, with agreement to comply with a set of rules governing resource management, then long-term sustainable management is unlikely.

Box 8. Key concepts for pluralism in sustainable forestry

1. Different groups have and always will have different experiences, positions, opinions and objectives on sustainable forest management and rural development.
2. Groups are individual and independent. There is no single, absolute and permanent solution to any substantive natural resource management problem, and there is no single, absolute, sustainable management land-use scenario for any given land unit (there are numerous "sustainable scenarios").
3. No group/organisation can claim a superior or absolute scenario.
4. Sustainable forestry and rural development decision-making is no longer the sole mandate of expert authorities.
5. A system of organisational checks and balances is necessary to avoid errors of a narrow single-entity management system – this is the positive aspect of "bounded conflict".
6. Conflicts are inevitable and cannot be resolved but managed.
7. Equity in decision-making is a distant but worthy ideal.
8. Platforms, mediators and facilitators are often needed to provide the conditions for negotiation and cooperation needed for sustainable forest management .
9. Communication is essential and helps participants understand their differences better.
10. Consensus is unlikely but progress can be achieved without it.
11. Approaches to sustainable forest management that aim at consensus are often misguided and unsustainable.
12. Proactive approaches and new processes of sustainable forest management decision-making in pluralistic environments are emerging, but more experience is needed.

Source: Anderson, Clement and Crowder (1998)

A different approach was well articulated by the Centre for International Forestry Research (CIFOR) team members during their development of criteria and indicators for sustainable forest management (Colfer et al. 1999). They argue that while all stakeholders have legitimate interests in forests, there are both ethical and pragmatic reasons for forest managers to attend more closely to the needs of some stakeholders. They propose a method to determine relative importance that places all stakeholders along a continuum of potentially beneficial involvement in forest management. The criteria used to rate them are proximity to the forest; pre-existing rights; dependency on the forest; poverty; local knowledge; culture/forest link and power deficit.

In this new management environment of multi-stakeholder engagement and decentralisation/devolution, the role of government staff is changing. There is a shift from an emphasis on direct control over forest management or ecological restoration (often with strong policing and licensing functions) to an approach that facilitates a process of broad-based participation in management by key interest groups. The direct authority and responsibility for forest management decision-making is often passing to others (or at least being shared by others). This requires a more participatory style of management, involving a range of stakeholders with different interests in forests. It is a management style for which few government officials are trained. The traditional training of forest managers focused on technical aspects of management: silviculture, inventory, harvesting and marketing. The more participatory style of management requires additional skills, most of which relate to understanding and applying social processes (dealing with "people" issues) and facilitating change by working with a wide range of stakeholders.

6.6.2 Tenure and access

Sub-optimal use and management of forest landscapes in much of the world can be partially explained by the tenure regime under which forest users operate (see Box 9).

Box 9. Tenure systems

Tenurial systems include the following components:

- rights and privileges that exist to use particular natural resources; and
- arrangements made to regulate or control access to natural resources.

The more insecure forest users feel with regard to their long-term rights to use a particular resource, the more incentive there is to exploit it to the maximum over the short term without considering its sustainability. Land users require long-term secure rights to use and harvest a piece of land before they will invest time and effort in sustaining its long-term productivity. As a result of past land alienation policies, a significant portion of much of the developing world's forest lands now falls within the public domain, and has become a de facto open access resource. If the people using these resources have no enforceable legal or customary rights (to cultivate, graze or collect forest products) they have no incentive to conserve the productive potential of the resources (soil, water, vegetation and animals). Tenurial systems (Box 10) are therefore important in any aspect of natural resource management.

Box 10. Aspects of tenure systems

- The effectiveness of natural resource management depends on who believes they hold rights to the resource, who recognises these rights, and how access is controlled.
- There are formal (de jure) and informal (de facto) tenurial systems.
- The lack of recognition of customary rights, removal of rights, or other tenure conflicts can contribute to resource degradation.
- Tenurial systems that are widely accepted and formally recognised and supported provide confidence and incentives for the conservation and effective management of natural resources.
- Natural resource management must be based on secure and agreed access and use-rights.

In many countries it is unlikely that any real progress can be made toward sustainable forest management or forest landscape restoration until tenure issues are addressed and resolved. Experience suggests that resolution will only come by engaging key interest groups in a participatory and constructive dialogue with a commitment to an equitable outcome (see 6.6.1). In addition, forest rehabilitation has to be seen in the context of integrated rural development, particularly in the case of communities that depend on forests for part of their livelihood income (this includes the use of forest land for shifting cultivation).

6.6.3 Economic incentives for tree planting

According to FAO statistics (FAO 2001), there are 187 million ha of plantations world wide; 17 per cent of industrial wood comes from plantations and 10 per cent from fast-growing plantations (the focus of much transfer funding from the public to the private sector). The proportion of wood coming from plantations is likely to rise to around 45 per cent in the next 30-40 years. The commercial attraction of plantations includes relatively low wood costs, an increased ability to choose resource location and the homogeneity of wood and fibre. The potential public benefits include increased domestic supply, industrial development, increase in tree cover and reclamation of degraded land.

Incentives for plantation establishment are a well-established tool in many countries, but they remain controversial (Bazett 2000). They have a number of advantages:

- they can kick-start an industrial sector, e.g. in Brazil and Chile;
- they promote inter-regional competition, e.g. in Latin America;
- they create a competitive advantage (temporary advantages that help the early developers); and
- they help support plantation development where private net returns are low.

There are also some well-known disadvantages:

- equity issues (the people who benefit most tend to be the rich); and
- they lead to oversupply, which drives down prices, fosters misuse and corruption and results in increased land values (in Chile, land prices in plantation areas have increased by a factor of ten or more).

There are a number of different types of incentives, both direct and indirect. Direct incentives include the following:

- direct subsidy payments for planting and establishment;
- tax exemption or reduction (Brazil provides a good example);

- freedom from income and/or land tax (examples include the USA and UK); and
- cheap loans, as in the case of Indonesia.

Indirect incentives include the following:

- market and technical assistance (training, provision of nursery seedlings etc.); and
- concessions (e.g. Indonesia allocates concession land).

Financial incentives for establishing commercial plantations appear to be losing their appeal for governments, and are considered more appropriate for social forestry enterprises. Many restoration initiatives could fall into this category as they frequently address primarily social issues rather than purely economic and industrial aspects.

6.6.4 Institutional arrangements for managing restoration

Management of forest landscape restoration activities is normally carried out by the owner of the land or the person or group with recognized management authority. In cases where this is uncontested there may be no need for any special institutional arrangements, although a range of stakeholder interests must be recognized and managed. In many parts of the world, however, restoration activities take place on sites which are managed as common land. This may be irrespective of the "legal" situation (see Boxes 9 and 10). In such cases the resources may be treated as open access or common property regimes. It is quite common for functional institutional arrangements (indigenous management systems) to be in place for managing access and use rights for common property, although it is also common for these arrangements to be unknown to the government agencies which have the de jure mandate for management. It makes good sense to look for any institutional arrangements that are in place for managing natural resources, and to build on them for restoration activities. This sounds eminently sensible, but in fact is rarely done. Quite frequently it is assumed that no institutional arrangements exist, and that there is a need to create and impose a new institutional structure on local communities. This can destroy pre-existing arrangements, and may not provide a sustainable alternative. It is always much better to build on what is already there.

Chapter 7

Approaches at the landscape level

The approaches described previously are all aimed at specific sites. The diversity of land use and land ownership across most landscapes means it is rarely possible to use just one of these approaches over large areas. More commonly, a variety of approaches are undertaken at different sites across a landscape and restoration or rehabilitation must be integrated with other land-use activities such as food production. So how can the desired functional outcomes be achieved across larger areas? There are several key issues to be considered.

7.1 How much of a landscape should be restored or rehabilitated?

It is difficult to be precise about how much of a landscape should be treated to achieve particular functional outcomes. It depends, at least in part, on the nature and extent of degradation. Treatment might not be warranted in a landscape with only 20 per cent of the original forest cover cleared, while some intervention is probably necessary in a landscape with, say, only five per cent of the original forest cover remaining. The decision will also depend on the degree of degradation within these cleared areas and the extent of changes to the hydrological cycle, the rate of soil erosion or the processes fostering biological diversity.

Landscape ecologists have traditionally been concerned with the way forest fragmentation affects the flows of energy, water, nutrients and various materials across landscapes (e.g. Forman 1995). These concerns have led to generalisations about the principles of managing land use (e.g. Forman 1995, Dale et al. 2000). More specific studies of the effects of different types of restoration or rehabilitation on key ecological processes have also been done; for example, a number of studies have explored how secondary salinity (i.e. induced by forest clearing) might be controlled in agricultural regions. Some of these suggest that elevated water tables might only be lowered by widespread plantings of deep-rooted trees (Hatton and Nulsen 1999), forcing a choice between reforestation and agriculture. Other studies have shown that on sloping land, belts of trees planted along contours can reduce ground water recharge and minimize competition with crops (Stirzaker, Cook and Knight 1999; White et al. 2002). Research has also been carried out on the extent and effectiveness of different forms of reforestation to reduce wind or soil erosion or provide buffers or filters along riparian areas.

The proportion of the area required to maintain biological diversity over landscapes is less clear. As natural forest losses have mounted and fragmentation has taken place ecologists have debated the threshold for forest cover below which biodiversity losses (and subsequent ecological functioning) might occur. Although there is no absolute threshold condition a value of 30 per cent has been suggested from several studies in different parts of the world (e.g. Andren 1994, McIntyre, McIvor and MacLeod 2000, Peterken 2000, Flather and Bevers 2002). This proportion has also been used for conservation planning by Sattler and Williams (1999) to define ecosystems that have lost too much of their original area and are now "of concern".

It is not just the proportion of the area that is important but the size of the remaining forest fragments, their spatial arrangement and their degree of connectivity. Small and isolated forest fragments are likely to be much less effective in protecting biodiversity than larger forest patches; these, in turn, are more likely to be more effective if linked by a series of corridors (Bennett 1999, Peterken 2000). This means an ideal situation might be a landscape in which forests occupy around 30 percent of the area and are well-distributed and well-connected. The remaining 70 per cent could be used for other purposes. The biota particularly at risk in such landscapes are the poorly dispersed species restricted to mature successional stages; these might need special consideration.

A target area of 30 per cent may be a formidable task to reforest in a highly degraded landscape but some initial strategic directions might help work towards this target. One approach is to try to enlarge or enrich any small residual forest fragments or regrowth areas remaining in the landscape. This will help maintain existing populations of plants and animals, which can then colonise any subsequently reforested areas. Another option is to foster a system of strategically placed corridors or stepping stones between these fragments to enhance connectivity. This will help species enlarge their distribution across the landscape and recolonise former degraded areas. Corridors and stepping stones were discussed in 5.1 and most of the areas listed in Table 3 might contribute to a landscape network. Bennett (1999) and Peterken (2000) discuss these issues in more detail.

7.2 Generating diversity at the landscape scale

Many land owners trying to balance production and biodiversity may use relatively uncomplicated planting designs rather than more complex, multi-species plantings containing high levels of diversity. This means that local or site-level diversity (known as the alpha diversity) may be relatively low, especially in small patches. On the other hand, provided land owners do opt for a variety of approaches (e.g. not every land owner just planting woodlots of Eucalyptus), the cumulative diversity present across the landscape (the gamma diversity) resulting from these many separate management decisions may be significant. The relationship between alpha and gamma diversity is illustrated in Figure 9.

Figure 9. Effects of reforestation on alpha and gamma diversity

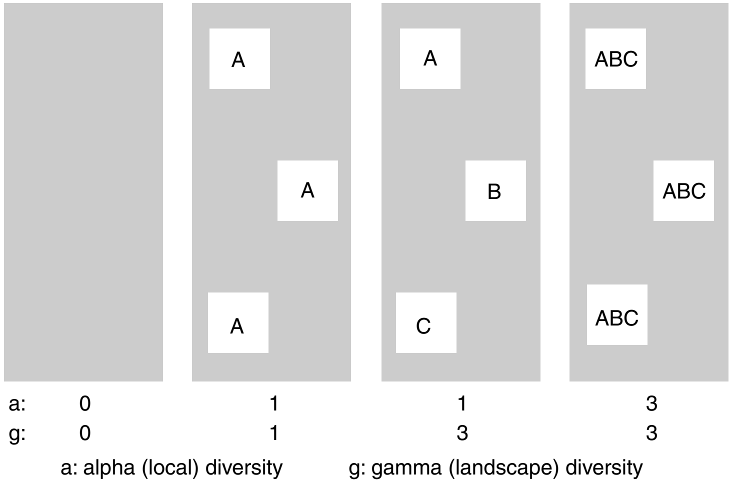


Figure 9 shows four degraded landscapes. Three of them have been partially reforested; one is in its initial degraded state. The first of the reforested sites has monocultures of species A while the second has a mosaic of monocultures of species A, B and C. This means that the alpha diversity in these two sites is similar but the gamma diversity has increased in the landscape as a result of the three different plantations. The fourth landscape has several multi-species plantations. These increase the alpha diversity but not the gamma diversity.

From a silviculture perspective, monoculture plantations are easier to manage than species mixtures. If the gamma diversity is the same, is there any benefit from having a higher alpha diversity at a particular site? The different forms of diversity have different functional consequences, and the answer to this question depends on the primary management objectives and the function that is most important. If the main objective is to re-establish biological diversity, then plant alpha diversity does matter and restoration must aim to restore the original plant species richness and structural complexity that will allow both plant and animal species to recolonise and reproduce at the site. If, on the other hand, the objective is re-establish site production and only some of the original biodiversity then the sacrifice of alpha diversity for the sake of gamma diversity may be acceptable.

The answer to the question also depends a good deal on the landscape context. What is the degree of fragmentation? How far apart are the patches of residual forest? Some species benefit from patchiness or spatial heterogeneity and the juxtaposition of contrasting habitats (e.g. forest and grassland) because of the extent of the transition or boundary zones they provide. But the size of these patches — what Forman (1995) refers to as the landscape grain size — also affects the type of species that will establish within the patches. A fine-grained landscape or one made up of small patches suits generalist species but not those requiring larger areas of more specialised habitat. Ideally, then, a range in patch sizes is advantageous although it is the forest specialist species that are more likely to be at risk than the generalists. Most situations probably require more than one approach and Forest Landscape Restoration (as defined in Box 3) will often involve protection of forest remnants as well as reclamation, restoration and rehabilitation at the site level.

These biophysical uncertainties also underpin a more difficult social dilemma: how can a variety of small, site-level decisions made by individual land managers be integrated to produce the best functional outcome at a landscape level? Very few planners or land managers appear to have successfully addressed this issue.

Chapter 8

Case studies

There are many examples throughout the world where degraded forests have been restored, including both small sites and large areas. Some have been the result of conscious intervention to achieve a certain restoration outcome; some have occurred "naturally" as a result of abandonment of land uses which had previously caused substantial forest loss; some are the unintended consequences of planned interventions aimed at a different outcome. The following case studies highlight important lessons which can inform efforts to engage in more focused, widespread and large-scale restoration activities.

8.1 Natural forest regrowth in northeastern USA

Natural regrowth is a widespread phenomenon and small, localised examples can be found in a variety of temperate and tropical locations. But there are also examples of natural forest regrowth over some very large areas producing forests that now seem "natural". For example, since the early or mid-nineteenth century, forest cover has doubled in Switzerland and France and tripled in Denmark (Mather 2001, Kuechli 1997). Much of the recovery was due to natural regeneration. A similar large-scale recovery appears to have occurred over the last two hundred years in an extensive area of rainforest in Nigeria (Jones 1956) as well as elsewhere in west Africa (Fairhead and Leach 1998) following the cessation of agriculture.

Perhaps the best known example of large-scale natural forest regrowth is that which occurred in the northeastern United States. Though forests are now widespread in the region and appear to be old-growth, many are, in fact, comparatively recent (less than 200 years old). Much of the area was cleared for agriculture during the first waves of European settlement. Many of these farms were established on lands that were marginal for agriculture and settlers moved off when better agricultural land was later found farther west. Forest regrowth subsequently occurred over large areas, presumably because of the presence of many small areas of remnant vegetation. In most situations no particular effort was made to facilitate or encourage this process. Recovery began in New England as early as 1840 and in the central Atlantic states after 1880. Though it is difficult to estimate the total area involved it is clearly large. Williams (1988) quotes estimates of more than one million ha of farmland being reforested in New England alone between 1880 and 1910.

Several studies show that the nature of the new forests is a consequence of the previous land-use history (Motzkin et al. 1996; McLachlan, Foster and Menalled 2000). At one site in Massachusetts, for example, pine now dominates areas that had been ploughed; oak is more common on sites that were not ploughed. The difference appeared to be associated with soil changes as well as dispersal and re-establishment of certain species (Motzkin et al. 1996). The forests in this area now contain a diversity of plant species including uncommon varieties, although this heterogeneity exists despite a homogenous edaphic environment. Overall the age of the dominant trees and the apparent stability of the forests masks the extent to which they are different from the original, pre-European forests and are a product of a cultural landscape.

Main lesson: Natural recovery can occur over large areas with minimal input; however, the resultant forest will not always be identical to that once present.

8.2 Restoration of temperate forest in Canada

One of the earliest modern examples of forest restoration is that carried out in the deciduous hardwood forest region of eastern Canada in 1886 (Larson 1996). The date is interesting because the restoration predates most of the earliest scientific studies on the ecology of successions. The site was an old gravel pit and it appears to have been reforested to demonstrate how rapidly and efficiently a complex forest cover could be restored to degraded land. Altogether 14 species were planted at the site in a mixture. These included local deciduous hardwoods and conifers as well as several exotics *(Acer platanoides, Fraxinus excelsior, Larix decidua, Picea abies, Pinus nigra* and *Tilia cordata)*. Some 2300 saplings of these 14 species were planted in rows spaced 2.5 m apart. No subsequent site management was carried out apart from some early pruning. The nearest natural forest was 500 m away.

By 1930 around 85 per cent of the site had a sparse canopy, 31 per cent of which was coniferous. By 1993 the canopy cover had increased to 95 per cent but the conifer comprised only 5 per cent of that. The site, then 107 years old, contained 220 trees with a diameter at breast height (dbh) exceeding 30 cm. Of the original 14 canopy-forming tree species, 10 were still present. Two new species had colonized. A diverse understorey of woody and herbaceous plants contained 36 species, most of which were reproducing. Some of the canopy trees were regenerating and were represented in the under-storey but *Picea, Larix* and *Pinus* were absent. Measurements suggest *Juglans nigra* (native) and *Acer platanoides* (exotic) will dominate the site in future. All new tree regeneration was found in areas with no conifers.

The patterns of community structure that have evolved over time at the site are different from those in the native forests of southern Ontario but changes are leading to the development of a forest with a similar structure and appearance. One recent measure of the success of the planting is the fact that local authorities mistakenly listed the site as an important natural forest remnant within the local city boundary.

Main lesson: Even modest levels of reforestation can initiate the development of high-quality forest given sufficient time.

8.3 Community initiated forest restoration in Nepal

In Badase village in the Middle Hills of Nepal, northeast of Kathmandu, three separate indigenous forest management systems were identified during an investigation of local responses to forest loss and degradation (Gilmour and Fisher 1991). One of these systems related to two patches of natural forest covering the slopes on both sides of a valley. The two forests were managed by a local committee from about 1981 to 1986. Although the user groups for the two forests are not exactly the same, there is considerable overlap and the same committee managed both forests. The land was legally under the management control of the Forest Department, but the local community had exercised de facto management control for several decades. The forests were managed as common property resources.

Local informants indicated that a shortage of forest products by about 1981 led them to hire a local forest watcher, paying for the service with the proceeds of a collection of one or two rupees from each user household. A committee was formed to manage the forests. Thus, this local system had two formal organisational elements: a local forest watcher paid by collection from user households, and a management committee. The main purpose of the organisation was to allow a degraded forest to regenerate by protecting it. Management practices were clearly developed with this objective in mind. These were the main silviculture elements:

- users could collect dry branches, grass and fodder, but had to have approval from the village leader (who was a member of the user group) to cut trees for timber;
- cutting green grass was not permitted in the monsoon period since it is the crucial period for regeneration of grasses and tree seedlings; and
- children were not allowed to cut grass at any time, the stated reason being that children are careless or inexperienced and might cut tree seedlings as well as grass.

These rules were simple, but provided a sound formula for allowing the degraded forest to regenerate. They allowed a type and intensity of utilisation that would not interfere with regeneration. The existence of healthy broad-leaf forests on both slopes of the valley, replacing what was once low shrubland, attests to the effectiveness of these controls.

Main lessons: Local communities are able to initiate and manage effective restoration activities where they have a vested interest in the outcome, as long as they have secure access and use rights. They can also develop simple but effective institutional arrangements to manage the forests and distribute benefits.

8.4 Maximum diversity plantings on mined land in Brazil

A large open-cut bauxite mine at Trombetas in Para' state in central Amazonia is located in an area of relatively undisturbed evergreen equatorial moist forest. A reforestation program has been developed to restore the original forest cover to the greatest extent possible. The project has treated about 100 ha of mined land per year for the last 15 years (Parrotta and Knowles 2001).

There are several key steps. First, the mined site is levelled and topsoil is replaced to a depth of about 15 cm using topsoil from the site that was removed and stockpiled (for less than six months) prior to mining. Next, the site is deep-ripped to a depth of 90 cm (one meter spacing between rows). Trees are planted along alternate rip lines at two-metre spacings (2,500 trees per ha) using direct seeding, stumped saplings or potted seedlings. Some 160 local tree species were tested for their suitability in the program and more than 70 species from the local natural forests are routinely used (Knowles and Parrotta 1995).

After 13 years most sites have many more tree and shrub species than those initially planted because of seed stored in the topsoil or colonisation from the surrounding forest. Not surprisingly, the density of these new colonists was greater at sites near intact forest but dispersal was evident up to 640 m away from old-growth forest. The new species, most of which have small seed, would have been brought to the site by birds, bats or terrestrial mammals. Large-seeded species may be dispersed to the site later when habitat is more suitable for the wildlife that will bring them. If not, they may need to be re-introduced.

Several reforestation approaches have been tried, including natural regeneration and commercial timber plantations. Comparisons between these different approaches showed the rate of species accumulation varying depending on treatment. The greatest diversity was measured in the mixed native species treatment (around 130 woody plant species in 0.25 ha), higher than in sites left to regenerate naturally or planted using mixed plantings of commercial species. Weeds such as grasses were effectively excluded by the shade created by the dense canopy cover of the mixed native species community (there had been concern that shorter tree longevities in the natural regeneration and tree plantation designs could allow grasses and weeds to persist, making these methods more risky). Overall the reforestation program has been extremely successful in facilitating the re-establishment of both plants and animals at the site, although more time will be needed before composition and structure begin to resemble those of the nearby intact forest (Parrotta and Knowles 1997, Parrotta and Knowles 1999).

Main lesson: It is possible to restore high levels of plant and animal diversity to degraded tropical forest sites relatively quickly if sufficient funds are available and natural forests remain nearby. Recovery of structural and spatial complexity resembling that present in the original forest will necessarily take more time.

8.5 Reforestation of mountains deforested by pollution in Japan

The Ashio copper mine is located in the mountains of Tochigi Prefecture. The mine began operations in 1610; with an associated refinery, it became one of the largest copper mines in Japan (Akiyama 1992). Production intensified in 1876 but the mine and its refinery eventually ceased operations in 1973. Forests in the surrounding mountains were lost throughout this period because of industrial pollution from the smelter and from timber harvesting carried out to fuel the refinery.

Various attempts to reforest were undertaken. These intensified in 1956 when pollution declined following the installation of a new flash smelting production process. At that time many of the mountain slopes were bare and much of the topsoil had been lost. There were 2,145 ha of mountain landscape classified as seriously damaged with no vegetative cover, 2,725 ha of moderately damaged forest and 4,470 ha of slightly affected forest. Apart from the damage to the forests there was extensive pollution in the rivers draining from the site caused by industrial waste and massive erosion.

The decision was made to try and re-establish the natural forests. Forests in the area contain maple, chestnut, beech, birch and oak; hemlock is found at higher altitudes. Although seed from these species was available there were two key problems. One was the short growing season; the cold winters last from September to May. The second was that most of the steep slopes had little topsoil remaining except in small crevices. This was initially dealt with by making vegetation blocks. Straw, soil, fertilizer and grass and tree seed were mixed, covered in newspaper and pressed into small blocks. The blocks were carried by workers on their backs up into the mountains and placed in furrows in rows along contours and fixed in place with willow branches. The blocks were watered from barrels of water carried in to the sites on workers' backs. The following spring, after the grasses had germinated and bound the soil, seedlings of leguminous trees or black pines were planted. Using this method trees became well established after five or ten years. The technique was not appropriate to all sites, however, and a second method was developed using larger vegetation bags that contained more soil. Gauze bags were filled with 3.6 kg of soil, seed and fertilizer. These were carried up by hand and placed in rows about one metre apart along contours and fixed in place with U-shaped iron stakes. Both approaches were successful but were obviously very labour-intensive. They were also difficult to use in steep and remote areas in the mountains. The third approach used a helicopter to spread grass and tree seeds and fertilizer. The mix was held in place by an asphalt emulsion, also sprayed from a helicopter.

A large area has been treated and now has an extensive forest cover, although the untreated mountain areas are still extensively deforested. Over the years the reforestation scheme has used a number of grass species and up to 27 tree species (established at densities of up to 5,000-7,000 trees per ha). Species selection depended on the extent of pollution at a particular site. Many of the planted trees die in the first season; often, up to 50 per cent of trees have to be replanted the following season. Some of early plantings are now ten metres tall and wildlife has begun to recolonise the sites (the Japanese antelope population in the Ashio area is now among the largest in country). The increase in wildlife has brought its own problems since some animals are causing extensive damage to trees and tree seedlings. This issue remains unresolved.

Main lesson: Even extremely degraded sites can be reforested provided resources are available. At such sites, however, complete recovery may be impossible.

8.6 Pest control and the recovery of threatened wildlife in New Zealand

Habitat loss and fragmentation have caused a decline in New Zealand's indigenous plant and animal species. This loss has been exacerbated by the large numbers of exotic plants and animals introduced by human colonists. These species have caused changes to the structure and composition of forest and grassland communities and have led to a dramatic decline in the vertebrate fauna, most especially birds (for example, 49 per cent of New Zealand's non-marine endemic birds are now extinct).

A vigorous restoration effort has been made to combat these changes (Saunders and Norton 2001). One component of this restoration program is the use of offshore islands to protect threatened birds from introduced predators (Towns and Ballantine 1993). Restoration has begun with the eradication of predators; some 15 mammals and two birds have been eradicated from 140 islands around the New Zealand coast. The pests removed include species such as rats, cats, brushtail possums, goats and rabbits. Islands up to 2,000 ha in size have been successfully treated. A larger range of carnivorous and herbivorous pest species are present on the two mainland islands of New Zealand and similar eradication programs have been carried out there as well, most especially in protected areas that form “islands” surrounded by a sea of farmland. In both situations pest species have been eradicated by trapping and poison baiting, including aerial baiting.

Some striking successes have been achieved in recent years, and are described by Atkinson (2001) and Saunders and Norton (2001). It is clear, however, that mainland “islands” will be an ongoing problem, especially where a core habitat area is located within a larger complex of similar habitat. Addressing the problem is likely to be expensive.

Pest removal has resulted in an increase in the populations of a number of threatened animal species. At many sites native plants are also recovering and regenerating after herbivores such as deer, possum and goats were controlled. In some cases it was necessary to translocate the plants or animals needed to re-establish or augment a population. Around 50 taxa, mainly birds, have now been translocated. Translocation has been particularly important when offshore islands are used as safe sanctuaries. There are risks involved, however, especially without a complete understanding of the ecology of the species involved. Translocations don’t always work; the new habitat may not be appropriate, or there may be negative interactions with species already on the island. While offshore islands will continue to be the focus of attention for threatened species, on mainland “islands” the emphasis is shifting from improving the populations of single species to the restoration of whole ecosystems because of the scale of the problem. Fortunately, the successes to date mean that members of the public have a growing interest in participating in the programs.

Main lesson: pest and weed eradication alone can sometimes restore species diversity to “islands” relatively quickly, particularly on offshore islands that can provide safe habitats, free from introduced predators, for vulnerable native species.

8.7 Understorey development beneath plantation monocultures in Australia

Plantations of the conifer *Araucaria cunninghamii* and the hardwood *Flindersia brayleyana* grow well in the humid tropics of northeast Australia. Monoculture plantations of these two native rainforest timber species are expected to have rotations of approximately 50 years. They may acquire significant numbers of tree species in their understories over time, especially if they are established close to intact rainforest. Surveys by Keenan et al. (1997) showed just how diverse these understories can be. Species-area curves in the in *A. cunninghamii* plantations, which are more than 55 years old, found up to 35 woody plant species had colonised a sample area of 300 square metres while surveys in *F. brayleyana* plantations of a similar age found around 65 woody plant species in similar sample areas. Overall, more than 350 species were counted in these plantations including trees, shrubs, vines, epiphytes and herbs. This complex understorey development was found in plantations up to 200 m from intact forest. In some cases the colonists had grown to join the canopy level, transforming the plantation from a simple monoculture to a polyculture. Similar observations in a range of other tropical plantations throughout the world are described in Parrotta, Turnbull and Jones (1997).

These changes give rise to several questions. One is whether this degree of colonisation would have occurred without the plantation trees. The answer undoubtedly depends on the starting point and whether grasses were then present. In the Australian case plantations require intensive weed control for the first few years until canopy closure occurs. In the absence of plantation trees the weeds would not have been controlled and successional development would undoubtedly have taken much longer. In addition, fires were excluded from the site, which prevented further disturbances once successional development began. Thus the plantations had a catalytic effect.

A second question is whether the understorey development affected the growth of the plantation trees. In the early stages it probably had minimal impact, but this would change over time as more of the colonists grew up and joined the canopy, effectively increasing the tree density. Plantations are usually thinned to reduce competition and maximise growth of the straightest and most vigorous trees. Colonisation therefore meant increased competition. Subsequent measurements at some of these sites showed the negative effects of this competition on plantation tree growth (P. Brown; pers. comm.) suggesting that managers will face trade-offs when deciding to manage for biodiversity as well as production.

Main lesson: Plantations can be catalysts for the recolonisation of very large numbers of plants, especially when there is natural forest nearby. This raises the possibility that older plantations can provide some significant regional biodiversity benefits as well as production benefits. Some trade-offs may need to be made to reach a balance between these two outcomes.

8.8 Assisted natural regrowth in Nepal for conservation and development

One of the most successful plantation species in the middle hills of Nepal is the indigenous chir pine *(Pinus roxburghii)*. It is a hardy pioneer species that occurs naturally at elevations of around 1,300 m. Many of the sites with potential for restoration are heavily grazed eroding grasslands with shallow stony soils. Chir pine is one of the few species that can survive and grow on these sites. It is also easy to handle in low-technology nurseries, making it well suited for small village nurseries. Attempts to grow more desirable broadleaf species in large-scale plantings on such sites have largely failed (Gilmour and Fisher 1991). This is particularly the case in the drier locations, although some success has been achieved in some of the moister areas with species such as utis *(Alnus nepalensis)*.

If a plantation area is protected from grazing, a range of tree and shrub species often invades soon after establishment, particularly on moister northern aspects. The invading species dramatically increase the biodiversity of the site and add to its productive potential for the village forest users. Chir pine acts as a pioneer species, returning the site to forest which can then be manipulated silviculturally to provide the goods and services people need.

An example of this is found in a series of studies undertaken in a forest about 40 km northeast of Kathmandu (Gilmour et al. 1990). Three waves of regeneration followed planting with chir pine. The first developed as coppice from stumps which were remnants of the original forest. The protection from regular cutting and grazing which accompanied the planting allowed coppice shoots to survive, and these became an early component of the stand along with the pines. Most of the coppice shoots were *Schima wallichii*, a widespread broadleaf tree which produces high-value firewood, construction material and leaves for animal bedding.

The second wave consisted of seedling regeneration which germinated about five years after plantation establishment (age was determined from growth ring counts). As in the first wave, the dominant species was *Schima wallichii* (*Schima* seeds are small and are probably distributed by birds). Although the plantation would not have had a closed canopy after five years, the site must have improved enough to provide a suitable habitat for *Schima*.

A dramatic change in species composition began at about 12 years, when the canopy closed. The third wave of regeneration occurred at this time, and included a large number of very useful fuel and fodder species. The most notable of the newcomers was *Litsea polyantha*, which is highly valued for its leaf fodder. It regenerated at high densities and by plantation age 14 years it covered the forest floor at a density of about 1,600 per ha with a mean height of 22 cm. Other valuable species which appeared at the same time included *Fraxinus floribunda, Cedrela toona, Castanopsis indica, Prunus cerasoides* and *Michelia champaca*. Future silvicultural practices, as well as the actions of forest users, will determine whether these valuable species become dominant components of the stand.

Main lesson: Restoration can often start with low technology and low-cost options, relying on natural ecological process to provide added biological diversity over time. Social controls over cutting and grazing are essential to obtain a diverse species mix.

8.9 Agroforestry and biodiversity conservation in Indonesia

There is a wide range of agroforestry systems in Indonesia, particularly in the outer islands. These systems provide 80 per cent of the rubber latex produced and exported by Indonesia, about 95 per cent of the various fruits marketed in the country, between 75 and 80 per cent of the dipterocarp resin traded in and outside the country, a significant portion of rattans and bamboos, an immense part of the firewood consumed in the country, and the majority of such items as medicinal plants and handicraft material. Moreover, they ensure the self-sufficiency of most rural households by providing supplementary foods, fuelwood and light and heavy construction material.

These systems are not home gardens, but more extended systems that have evolved from previous clearings in natural forests (Torquebiau 1984; Michon and de Foresta 1995, 1997). The main reason they were established was to provide monetary income for rural households. Enhanced biodiversity is a secondary benefit, not an aim as such. They demonstrate the value of ecological and technical control — as well as socio-cultural control — of resources. This has been achieved not through the domestication of species, but by a total reconstruction of the original ecosystem. Table 7 compares the species richness and abundance of a rubber estate, a rubber agro-forest and a primary forest.

Table 7. Species diversity in different forms of agroforestry in Indonesia

Category	Number of species			Frequency		
	Rubber estate	Rubber agro-forest	Primary forest	Rubber estate	Rubber agro-forest	Primary forest
Trees	1	92	171	28	247	258
Lianas	1	97	89	5	228	219
Tree seedlings	0	26	45	0	170	72
Epiphytes	2	28	63	2	51	261
Herbs	2	23	12	2,000	217	84
Total	6	266	382	2,035	913	897
Trees (except rubber)	0	91	171	0	189	258
Total (except rubber)	5	265	382	2,007	855	897

Source: Michon and de Foresta 1995

These agro-forestry systems are characterised by the manipulation of individual plants, the maximum use of natural processes of reproduction and production and the multiple use of the various resources present in these new forests. This results in integrated management of a complex ecosystem.

The integrity of agro-forestry structures is ensured through a dominant private tenure system complemented by overall control by extended families or clans. Radical transformations, clear felling and sale of individual agro-forest plots must be approved by these superior councils, who ensure a respect for tradition and for future generations.

Main lesson: Sophisticated agroforestry systems that resemble natural tropical forests can be established and managed over large areas of the landscape to provide both ecological and economic benefits as long as appropriate social controls are in place.

8.10 Reforestation of Fijian grasslands

The relationship between reforestation and stream flow has always been difficult to prove. Anecdotal evidence and traditional knowledge often points to a reduction in stream flow following deforestation, and a corresponding increase in stream flow (particularly in the dry season) following reforestation. The science of forest hydrology tends to take the opposite view, one that is supported by numerous controlled small catchment experiments in both tropical and temperate environments. A well-documented study in Fiji demonstrated quite clearly that there was a measurable and significant increase in soil water use after grassland had been converted to *Pinus caribaea* plantations. This change in hydrology was a direct result of increased water use by the pines compared to the grassland; less soil water was available to make its way into stream flow.

The measured water use, or transpiration, for 132 days (about 72 per cent) of the dry season was 79 mm for the grassland and 288 mm for the mature pine forest. There was also a difference in rainfall interception between the two vegetation types, with 39 mm recorded for the grassland and 94 mm for the mature pines. The annual stream flow from the forested catchment was 288 mm; the annual stream flow from the grass-covered catchments was estimated to be at least 540 mm. This suggests that there was a reduction in water yield of at least 50 per cent, much of it during the dry season, after the establishment of the pine plantation (Waterloo 1994). These findings accord with water yield studies in the wet tropics of Australia, where removal of 67 per cent of the tree cover in a rainforest catchment resulted in an increase in annual water yield of 10 per cent (293 mm), most of it during the dry season (Gilmour 1977).

The example from Fiji demonstrates that not all impacts of reforestation are necessarily beneficial in terms of human well-being. In Fiji, where local people are dependent on using stream water for domestic use, they could well be disadvantaged by reforestation initiatives.

Main lesson: Not all impacts of reforestation are positive. Frequently substantial costs are borne by local communities, while benefits accrue to distant communities.

8.11 Reforestation in heavily populated landscapes of Kenya

It is commonly assumed that increases in human populations inevitably lead to deforestation. In fact, the situation is often more complicated than this. Kenya provides an example of an increasing population helping reforest part of the countryside. Kenya has a limited area of natural forests and good agricultural land. In the early 1990s its population grew at the rate of over three per cent per year. These statistics suggest that forest degradation would be widespread and Kenya did lose 0.5 per cent (93,000 ha) of forest cover annually between 1990 and 2000. This notwithstanding, an aerial and ground survey in areas with high agricultural potential found a strong correlation between rural population density and planted trees, with much more woody biomass in areas with high population densities (Bradley, Chavangi and van Gelder 1985; Holmgren, Masakhan and Sjoholm 1994). Further, the rate of planting exceeded the rate of population growth while the extent of native vegetation in the region remained constant (over the six-year period ending 1991). At a national level the volume of planted trees in farmland was greater than the industrial plantations under government control and the amount of woody biomass was greater than that in natural forests.

There appear to be several reasons for this. Forest products such as fuelwood and poles were not available to farmers outside their farm area so the best way to acquire these products was to grow them on their own land. But perhaps more importantly, farmers have well-established tenure over their land; they have the security of knowing they will benefit from any reforestation activity they undertake.

Much of this reforestation was undertaken with exotics such as fast-growing eucalypts, meaning there was not a direct contribution to national biodiversity conservation (Holmgren, Masakhan and Sjoholm

1994). In other cases on-farm hedgerows may have a considerable diversity of indigenous species (Backes 2001). These forms of reforestation undoubtedly reduced pressure on the remaining natural forests, which were therefore able to contribute ecological services.

Main lesson: Reforestation can occur in areas with high rural population densities, provided farmers have security of tenure.

8.12 Reintroduction of traditional agricultural practices in Tanzania

The Sukuma people are pastoralists living in the semi-arid Shinyanga region of northwest Tanzania. The region has 600-800 mm annual rainfall, although it varies greatly from year to year. This part of Tanzania is occupied by forests and miombo woodlands; high population densities (up to 42 persons per sq. km) exert significant pressure on land resources. Many farmers or communities have traditional enclosures (known as ngitili) reserved for dry-season grazing and browsing (Ed Barrow, pers. comm.). This encourages vegetation to regenerate and provides browse and fodder later in the dry season when they are scarce. Despite the enclosures, however, much of the original woodland in the region has been lost because of overgrazing and firewood harvesting. Tree clearance accelerated between 1920 and 1940 when forests in the region were cleared to eradicate tsetse fly. This practice continued until the early 1980s and established a basis for much agricultural expansion, including cash crops such as cotton and tobacco.

Traditionally, *ngitili* were located near home compounds and fodder collected from them was used to support calves, old animals and oxen, which could not follow the rest of the herd. Ownership, management and tenure rights of *ngitilis* were governed by customary law. The practice was widespread; at independence in 1961, almost every family in the region had a *ngitili*.

The system broke down when the *Ujamaa* (Villagisation) Act was introduced in 1975. The act relocated farmers from traditional villages to newly created settlements. Their main household assets, including houses, farms and *ngitilis*, were abandoned. This concentration of large numbers of people and livestock in small areas increased the pressure on farm and grazing lands. While the new village structure was easier to administer it disrupted traditional mechanisms for adapting to local ecological conditions, such as droughts, and led to breakdowns in traditional soil conservation practices.

With the gradual decline of the villagisation program after the 1980s and the emphasis on in-situ conservation practices by the government soil conservation program, previously owned *ngitilis* are being re-established or restored. Some new communally managed enclosures are being established as well. More than 18,000 enclosures covering some 88,000 ha of land were established between 1980 and 2001. These have allowed a significant increase in forest regrowth throughout the region. Many of the shrubs and trees are original *miombo* woodland species, although some exotics have been planted in the reserves and on farmland. There is no evidence about whether these regenerating plant communities match those once present. In some places, however, there is a high diversity of native species in the regrowth, with up to 23 tree species in less than 0.5 ha. This regrowth is important both for the resulting fodder and timber trees and because many *ngitilis* are now the source of important traditional medicinal plant species. A variety of mechanisms and management practices has been used in different communities in order to establish the new reserves. In many communities grazing is prevented for up to five years to ensure that restoration begins. A range of methods is used to manage the regrowth once it has become established; for example, some community-managed *ngitilis* have controls to regulate pruning or tree harvesting.

There are several reasons why the program has been a success. One is that people have regained ownership and control over their lands and resources. Another is that the reservation system was once part of the community's traditional land management practices. This made it comparatively easy to re-instate (which required the government to put in place an enabling and supporting policy and a legal framework). It was also strongly helped by the re-introduction of many traditional and customary legal mechanisms that previously operated at the village level. Rules have been developed to meet community needs, rather than being imposed by higher levels of government.

Main lesson: Rural farmers and villagers can restore very significant areas provided the incentives are right and the legal framework — both traditional and institutional — is supportive.

8.12 Large-scale reforestation in Korea

The extensive forests that existed in Korea in the 19th century were severely degraded by over-cutting in the period of Japanese occupation (between 1910 and 1945). During this time the average stand volume declined from 100 cubic m ha^{-1} to 10.6 cubic m ha^{-1}. Deforestation was so extensive that reforestation became a national priority.

Reforestation commenced in 1959 and expanded with a series of national Forest Development Plans. The first of them was undertaken between 1973-1978. It was a turning point in Korean forestry, reforesting one million hectares of forest in a period of only six years. The land used for reforestation belonged to a variety of land-owners including national and provincial governments, industrial companies and private land-owners. The plan had several elements. First, a strict program of protection was established for the remaining forests, particularly those in mountain areas. Second, a number of zones were identified in which to carry out intensive forest development. Reforestation was undertaken in these zones to increase conservation benefits and improve rural incomes. There was also an emphasis on ensuring that rural communities had access to sufficient fuelwood for their needs. Third, fast-growing species (such as hybrid poplars, black locust, alders and *Lespedeza*) were used, so that benefits would be received as quickly as possible. Finally, the national government sought wide participation and involvement by the community as a whole and provided financial subsidies to encourage this participation.

A slight change of emphasis took place in each of the three subsequent plans. The Second Forest Development Plan (1979-1987) continued the protection activities of the first plan but gave greater emphasis to reforestation for larger-scale commercial purposes. The Third Forest Development Plan (1988-1997) focused on rational land use and on the creation of superior timber resources. Efforts were also made to distribute forest products. The current plan (1998-2007) concentrates on achieving sustainable forest management. It marks the end of government-led reforestation; from this point on the program will become more self-regulated and will have less government involvement.

In the last 30 years, as a result of these programs, over four million hectares of new forest have been re-established in Korea. In the early stages of the program the emphasis was on forests for timber production; this emphasis has changed over time and the current proportion is now around 50 percent for timber production, 30 percent for protection and conservation purposes and 20 percent for other purposes, such as agriculture or building. The forests contain over 20 tree species including native oaks (e.g. *Quercus acutissima, Q. mongolica, Q. variabilis, Q. dentate*) and pines (*Pinus densiflora, P. koraiensis, P. thunbergii*) as well as exotic species such as pitch pine-loblolly pine hybrid and larch (*Larix kaempferi*). The forests supply wood for community and industrial purposes provide ecological services, such as slope and watershed protection.

Main lesson: large-scale reforestation is possible if national governments, industry and communities make a commitment to it. Success depends on thorough planning, a long-term funding commitment and community support and involvement.

Chapter 9

Criteria for success

In most situations an outcome at a particular site is said to be successful when the stated objective has been achieved without compromising the environments and rights of other land users. The situation is more complicated than it seems, however. Just how closely must the restored site attributes match those of the target? Must it be a 100 per cent match, or is 80 per cent sufficient to achieve “success”? And how can success be defined in the case of rehabilitation projects involving complex mixes of biological, physical, social and economic outcomes?

In fact, these issues are probably less important than more immediate questions that must be confronted by managers much earlier in the recovery process. At these stages the key question is whether a successful outcome is still likely with the present management regime or whether some form of corrective intervention is necessary. Restoration and rehabilitation commonly take many years to achieve. Both involve successional processes that are unpredictable in their nature and the impacts of any reforestation program on the communities of land users are not always as expected. Assuming that rehabilitation goals remain constant — and this might not be always the case — are there ways to monitor the recovery process and its social consequences so that managers can intervene, if necessary, to re-establish the direction and rate of successional development? What are the early warning signals of failure?

A number of possible criteria are shown in Table 8. These are not expressed as absolute numbers but rather as values relative to what might be expected if the site were developing appropriately. In each case an appropriate trigger for taking remedial action (e.g. replanting) will need to be decided.

Three types of indicators might be used to monitor ecological trends:

- indicators of landscape stability;
- program efficiency; and
- flexibility.

The first type of indicators relate to landscape stability. Apart from the most obvious indicator of all — whether or not the site is still subject to disturbances — criteria include structural elements such as the extent of plant cover or tree density, the heights of plants and the extent to which the community is developing an understorey as well as an overstorey. Some measure of the health or vigour (i.e. growth rate) of these plants might be appropriate.

The second component of stability involves the composition of the community, such as numbers, identity and abundance of various plant and animal species, including weeds and pest species. Determining the presence or absence of particular life forms (e.g. herbs, grasses, shrubs, vines, palms etc.) might also be useful. A particularly crucial indicator may be whether these various species are reproducing in situ or whether they are dependent on seed sources from outside.

The third component of stability involves indications that the new plant community has developed appropriate functional responses and has stabilised the soils or improved the quality of water in streams draining the catchment. In the case of rehabilitation projects involving a production element, some indication of production results (e.g. whether the timber yields are adequate) might be appropriate.

The second ecological category of indicators measures the efficiency of the program. Is the new community self-sustaining or is it still dependent on supplements and inputs such as fertilisers or weed control? Success might also be measured by a third category, flexibility, which indicates the capacity of the new system to be used for alternative, unforeseen purposes such as recreation, gathering herbs or mushrooms or protecting particular wildlife species.

These indicators will not be appropriate in all situations and more specialised factors might be needed in certain conditions. Where the habitat of an endangered wildlife species is recreated specific measures might have to be developed for that species. Likewise, a fire-prone area might require indicators of when fire exclusion is necessary and when fires should be deliberately re-introduced.

Table 8. Potential indicators of success in restoration and rehabilitation programs

Biophysical	Socio-cultural
Stability	
• No further disturbances occur that promote degradation • Adequate plant cover or density across landscape • Vigorous plant growth (e.g. tree height, diameters) • Appropriate community structure (e.g. overstorey and understorey)	• Stable human populations • Stable and equitable land tenure system • Stable land use pattern • Adequate food supply and standard of living • Appropriate balance between tree and agricultural crops
• Appropriate plant species present (including range of life forms or functional groups) • Appropriate wildlife species present (including mutualists) • Declining cover or populations of weeds and pest species • Appropriate trophic diversity (producers, consumers etc.) • Adequate regeneration or reproduction of desired species	• Stable market prices • Stable firewood consumption rate • Stable rate of water use
• Stable soil surfaces • Adequate water quality in streams draining from sites (e.g. reduced sedimentation or salinity) • Adequate crop or timber yields	
Efficiency	
• Decreasing need for inputs such as fertilizers (because of nutrient cycling) • Decreasing need for weed and pest control (because these are scarce or have been excluded) • Decreasing need for irrigation	• Public involvement and participation in program • Income provided to community
Flexibility	
• Increasing kinds of alternative land use possible	• Increasing public ecological awareness (especially in children). • Increasing economic flexibility

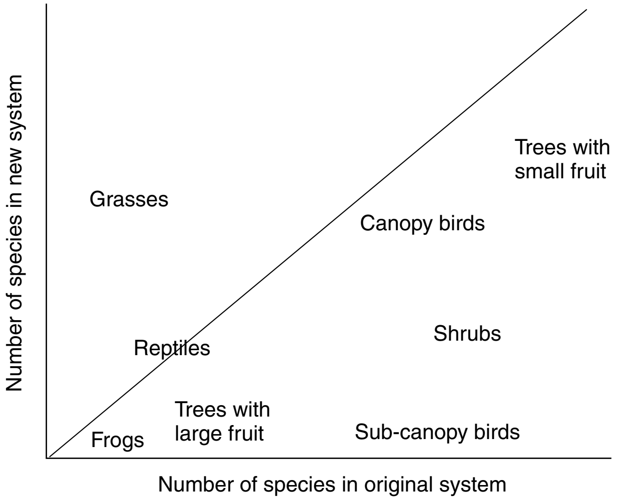
Socio-economic indicators are also shown in Table 8. These are divided into the same three categories: stability, efficiency and flexibility. Stability indicators reveal the extent to which human populations using the new forest and the lands surrounding it do so in a sustainable way. If the human populations are themselves more or less stable and the patterns of land use and food production are constant then the regenerating forest has a chance of being able to develop without further disturbances. If, on the other hand, the human populations are increasing because of in-migration or because land tenure systems are inequitable, there is a much greater chance that land users will be obliged to start using the regenerating new forest in some way (e.g. for firewood collection, grazing or agriculture), and will disrupt the restoration process. At some stage, of course, such use of forest resources may be necessary; if that happens, different indicators (such as stable market prices or rate of firewood consumption) may be needed to measure whether such use is sustainable.

A crucial element for the success of any restoration program is whether the local community is involved in its development and desire its success. The extent to which the community continues to be actively involved in a project is thus an important indicator of its likelihood of success. In addition, a project may cease to mean a cost to the community and start providing direct economic benefits. Public knowledge about ecological issues and the ability this provides the community to respond to changes in the forest condition is another aspect of community involvement.

There are other ways to monitor recovery. One of these, which is appropriate for restoration, is shown in Figure 10. In this case the number of species present in certain life forms is compared with the number of species in these groups normally found in the undisturbed target ecosystem. The example in Figure 10 reflects the fact that some species or life forms have recovered more quickly. A similar approach might be developed using the functional groups or species present in various trophic levels in a system. These types of approaches depend on the presence of nearby undisturbed sites to act as reference areas.

Not all attempts at rehabilitation will succeed. Sometimes recovery will only go so far before the community composition or structure stabilizes at a transitional state that is different from the desired outcome. In many situations this may not matter provided functional outcomes are achieved (e.g. preventing soil erosion, overcoming salinisation).

Figure 10. Monitoring recovery by comparing number of species



Recovery can be monitored by comparing the number of species in different life forms in the developing new system with those present in the original system. Figure 10 suggests that the numbers of reptiles, birds normally found in the forest canopy and trees with small fruit have recovered to near their original condition while there are fewer species of most other life forms than in the original forest. On the other hand, the site now has more grass species.

Chapter 10

Promoting Forest Landscape Restoration

In terms of forest conservation, world attention in the past has focused primarily on two areas:

- the need to conserve a representative range of forest ecosystems in a system of well managed protected areas; and
- the importance of managing the areas of natural forest outside the protected area system in a sustainable manner.

While protected areas and sustainable forest management are and will remain important elements of any forest conservation strategy, the rapidly expanding areas of degraded forest land in many countries around the world also need urgent attention. In parts of Central America, Madagascar, South East Asia and West Africa, rapid deforestation has left such a small part of the original forest area that unless major restoration efforts are undertaken in the near future, many of the forest plant and animal species there are at risk of extinction. The likely impact of climate change on tropical forests in the coming decades makes this threat even more acute. At the same time, it is clear that loss of forest cover and degradation of remaining forests are also massive social problems that compromise the quality of life for many people. Both ecosystem and human well-being have suffered, and will continue to do so, unless concerted action is taken to remedy the situation. Appropriate responses need to be worked out at all levels, from the local to the global. These include raising public awareness, putting forest landscape restoration on the policy agenda and incorporating restoration into land-use planning and action.

10.1 Raising public awareness

It is important to raise public awareness of the extent and consequences of forest loss and degradation, as well as the potential for forest landscape restoration. Deforestation and reduction in forest quality are problems in virtually all regions of the world. The conservation agenda of the past few decades has concentrated largely on the need to stop these degrading processes and save forests, particularly tropical forests. Creating public awareness of the importance of embarking on large-scale and concerted restoration initiatives is probably the first step in any attempt to redirect the expenditure of public funds. These are some of the issues that need to be highlighted:

- the extent of degraded forest land;
- the cost of this degradation in economic and human terms;
- the options available for rebuilding productive forest ecosystems; and
- the benefits in economic and human terms of restoring degraded forest ecosystems.

Some of the messages to be conveyed could be drawn from examples from different ecological regions where forest restoration has been carried out. A lessons-learned segment could include the practical implications of what has been attempted, along with an analysis of the requirements (institutional, policy, legal, tenure, etc.) for successful outcomes.

10.2 Putting Forest Landscape Restoration on the policy agenda

Forest Landscape Restoration must be on the policy agenda at global, regional and national levels. IUCN and WWF have for some years included forest restoration among their strategic objectives at the international level, and this agenda is steadily being taken up at regional levels. A concerted effort to raise the issue of forest restoration or rehabilitation as a positive response to forest loss and degradation in all available policy discussions at all levels will steadily build momentum for change. A targeted approach is probably the most effective, initially targeting those groups likely to be responsive, and then moving on to others.

10.3 Incorporating restoration into land-use planning and action

Forest Landscape Restoration must be incorporated into national, regional and local land-use planning and action. Significant change will not come about until governments and local communities are willing to expend scarce resources on restoration activities. Both small- and large-scale activities should be encouraged. This process can be assisted by setting up pilot projects in a range of ecological regions. Such pilot sites can also be used to show that restoration or rehabilitation is in the interests of both local and national government. While site-level approaches are probably the easiest to demonstrate, significant advances will depend on demonstrating approaches to working at the landscape scale, with its attendant challenges of harmonizing different planning jurisdictions, tenure arrangements and reconciling conservation and development agendas.

Advances in landscape-level restoration will probably be made in areas where there is broad-based acknowledgement of a landscape-level problem that affects most stakeholders across the landscape. Examples include dryland salinity in much of Australia and deforestation in Nepal. In both cases, local communities suffer the effects of the problem, and are ready to acknowledge the need for action. Vietnam has embarked on a five-million-ha reforestation programme in response to the loss of ecological functions and human well-being caused by deforestation and forest degradation across much of the country. A coalition of donor support is rallying to support this initiative.

Chapter 11

Conclusions

Large areas of the world's forests are being simplified and degraded. These changes are causing significant losses of biodiversity and decreases in human well-being. The loss of biodiversity and other ecological services may now be affecting the sustainability of many of the agricultural practices on these former forested lands.

There are a number of ways in which these trends might be countered. The appropriate method to use necessarily depends on the prevailing ecological, economic and social circumstances. Preventing further degradation is crucial, as is preventing the spread of weeds and pest species.

Forest Landscape Restoration renews the provision of goods and services to landscapes. The ecological context determines whether it is feasible to attempt to restore the original forest ecosystem or whether a less ambitious target is more realistic. The economic circumstances determine the level of resources available and whether some form of direct financial return is needed to justify the reforestation effort. This may mean that some form of rehabilitation rather than restoration is the preferred approach. Social circumstances, such as the pattern of land tenure, legal frameworks and community structures, may determine whether the community becomes actively involved in the whole process and works for its success. If they are not involved then any form of Forest Landscape Restoration is unlikely to be successful. Communities must be convinced of the benefits they are likely to gain and be empowered to help achieve these benefits themselves.

In most landscapes a variety of approaches may be needed to accommodate different circumstances and the different requirements of various stakeholders. The treated landscape may then comprise areas of agricultural lands, patches of intact remnant forest and a mosaic of various forms of restored or rehabilitated forest that differ in structural and biological complexity. Ideally, this new landscape will have an enhanced level of biodiversity as well as an improved supply of market or subsistence goods plus some ecological services that collectively lead to a more sustainable form of land use in the future.

It may not be possible to treat all degraded landscapes; degradation may be so advanced and widespread that the costs of treatment are too high. Priorities will need to be developed, and they may be determined by social rather than ecological circumstances. Small-scale projects are probably most effective, especially where deforestation and forest degradation have reached the stage of causing negative effects on communities (either through reduction in access to forest products or emergent problems such as erosion or salinity). Once some initial success is achieved it is often easy to expand a project.

The conversion from invariably adopting reclamation to considering the possibility of rehabilitation or restoration will also be easier if net costs are lower. New technologies, including improved forms of direct sowing, better ways of introducing mycorrhizae or nitrogen-fixing bacteria or more robust methods of matching species with sites, can help reduce costs. New market conditions may also help; a market for high-value native timber species may reverse the trend towards large monoculture plantations of exotic species. Markets for ecological services, such as carbon sequestration, biodiversity or salinity reduction, may also have a profound effect on the scale and form of reforestation practices. Such developments are not always beneficial. They can have unexpected consequences, can lead to more reclamation (e.g. plantations of exotic species) or even cause further deforestation (Angelsen and Kaimowitz 2001). Outcomes may depend on how much original forest remains in a region. Governments will have to balance the rights of land-owners with the legitimate needs of others in the watershed or the wider community.

Our level of understanding about most ecosystems is usually incomplete. Knowledge of the ways in which ecosystems and economic systems interact is even more superficial. This means that surprises should not be unexpected during restoration or rehabilitation and that monitoring is imperative. It also follows that management regimes should allow managers to adapt to change and learn from experience.

Chapter 12

References

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

Aide, T.M., J.K. Zimmerman, J.B. Pascarella, L. Rivera and H. Marcano-Vega. 2000. "Forest regeneration in a chronosequence of tropical abandoned pastures: implications for restoration ecology." *Restoration Ecology* 8: 328-338.

Akiyama, T. 1992. *A Forest Again: Lessons from the Ashio Copper Mine and Reforestation Operations.* Study Group on International Issues No. 13. Tokyo: Food and Agriculture Policy Research Centre.

Allen, E., J.S. Brown and M. Allen. 2001. Restoration of animal, plant and microbial diversity. In S.A. Levin (ed.). *Encyclopedia of Biodiversity.* Volume 5, pp.185-202. San Diego (CA): Academic Press.

Allen, J.A. 1997. "Reforestation of bottomland hardwoods and the issue of woody species diversity." *Restoration Ecology* 5; 125-134.

Anderson, J., J. Clement and L.V. Crowder. 1998. "Accommodating conflicting interests in forestry: concepts emerging from pluralism." *Unasylva* 194, Vol. 49 (3): 3-10.

Andren, H. 1994. "Effects of habitat fragmentation on birds and mammals in landscapes with different prportions of suitable habitat: A review." *Oikos* 71: 355-366.

Angelsen, A. and D. Kaimowitz (eds.). 2001. *Agricultural Technologies and Tropical Deforestation.* Wallingford: CAB International.

Ashton P.M.S., S. Gamage, I.A.U.N. Gunatilleke and C.V.S. Gunatilleke. 1997. "Restoration of a Sri Lankan rainforest: Using Caribbean pine *(Pinus caribaea)* as a nurse for establishing late-successional tree species." *Journal of Applied Ecology* 34: 915-925.

Atkinson, I. 2001. "Introduced mammals and models for restoration." *Biological Conservation* 99: 81-96

Backes, M. 2001. "The role of indigenous trees for the conservation of biocultural diversity in traditional agroforestry land use systems. The Bungoma case study: In situ conservation of indigenous tree species." *Agroforestry Systems* 52: 119-32.

Banerjee, A.K. 1995. *Rehabilitation of Degraded Forests in Asia.* World Bank Technical Paper Number 270. Washington, D.C: The World Bank.

Bazett, M. 2000. Incentives for tree planting. Presentation at a workshop on Forest Restoration, Segovia, Spain, April 2000. Gland (Switzerland): IUCN and WWF.

Bennett, A. F. 1999. *Corridors, Connectivity and Wildlife Conservation.* Gland (Switzerland): IUCN.

Berger, J.J. 1993. "Ecological restoration and non-indigenous plant species: A review." *Restoration Ecology* 1: 74-82.

Binkley, D. 1992. Mixtures of nitrogen fixing and non-nitrogen fixing tree species. In M.G.R. Cannell, D.C. Malcolm and P.A. Robertson (eds.). *The Ecology of Mixed Species Stands of Trees.* pp 99-123. Blackwell Scientific.

Bowles, M.L. and C.J. Whelan (eds.). 1994. *Restoration of Endangered Species: Conceptual issues, planning and implementation.* Cambridge (UK): Cambridge University Press.

Bradshaw, A. and M.J. Chadwick. 1980. *The Restoration of Land: The ecology and reclamation of derelict and degraded land.* Berkeley: University of California Press.

Bradley, P.N., N. Chavangi and A. van Gelder. 1985. "Development research and energy planning in Kenya." *Ambio* 14: 228-236.

Brown, B.J. and J. Ewel. 1987. "Herbivory on complex and simple tropical successional systems." *Ecology* 68: 108-116.

Butterfield, R. 1996. "Early species selection for tropical reforestation: A consideration of stability." *Forest Ecology and Management* 81: 161-168.

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

Chokkalingam, U., J. Smith, W. de Jong and C. Sabogal. 2001. "A conceptual framework for the assessment of tropical secondary forest dynamics and sustainable development potential in Asia." *Journal of Tropical Forest Science* 13: 577-600.

Clarke, W.C. and R.R. Thaman (eds.). 1993. *Agroforestry in the Pacific Islands: Systems for sustainability.* Tokyo: United Nations University Press.

Colfer, C.J.P. with R. Prabhu, M. Gunter, C. McDougall, N.M. Porro and R. Porro. 1999. *Who Counts Most? Assessing human well-being in sustainable forest management.* C&I Tool No.8. Bogor (Indonesia): Centre for International Forestry Research (CIFOR).

Cooper, P.J.M., R.R.B. Leakey, M.R. Rao and L. Reynolds. 1996. "Agroforestry and the mitigation of land degradation in the humid and sub-humid tropics of Africa." *Experimental Agriculture* 32: 235-290.

Dale, V.H., S. Brown, R.A. Haeber, N.T. Hobbs, N. Huntly, R.J. Naiman, W.A. Riebsame, M.G. Turner and T.J. Valone. 2000. "Ecological principles for managing the use of land." *Ecological Applications* 10: 639-670.

Dawkins, H.C. and M.S. Philip. 1998. Tropical Moist Forest Silviculture and Management: A history of success and failure. CAB International, Oxford and New York.

De Bell, D.S., C.D. Whitesell, and T.S. Schubert. 1989. "Using nitrogen-fixing *Albizia* to increase growth of Eucalyptus plantations in Hawaii." *Forest Science* 35: 64-75.

de Foresta, H. and G. Michon. 1997. "The agroforestry alternative to *Imperata* grasslands: When smallholder agriculture and forestry reach sustainability." *Agroforestry Systems* 36: 105-120.

Diaz, S. and M. Cabido. 2001. "*Vive la difference:* Plant functional diversity matters to ecosystem processes." *Trends in Ecology and Evolution* 16: 646-655.

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

Dove, M.R. 1986. "The practical reason for weeds in Indonesia: Peasant versus state views of *Imperata* and *Chromolaena*." *Human Ecology* 14: 163-190.

Dupuy, B. and G. Mille. 1993. Timber Plantations in the Humid Tropics of Africa. FAO Forestry Paper No. 98. Rome: FAO.

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

Evans, J. 1992. *Plantation Forestry in the Tropics. Tree planting for industrial, social, environmental and agroforestry purposes.* Oxford: Clarendon Press.

Ewel, J. 1986. "Designing agricultural ecosystems for the humid tropics." *Annual Review of Ecology and Systematics* 17: 245-271.

FAO. 2001. *State of the World's Forests 2001.* Rome: United Nations Food and Agriculture Organisation.

FAO. 1995. *Forest Resources Assessment 1990: Global Synthesis.* FAO Forestry Paper 124. Rome: United Nations Food and Agriculture Organisation.

FAO. 1993. *Forest Resources Assessment 1990: Tropical Countries.* FAO Forestry Paper 112. Rome: United Nations Food and Agriculture Organisation.

Fairhead, M. and M. Leach. 1998. *Reframing Deforestation. Global analyses and local realities: Studies in West Africa.* London and New York: Routledge.

Fanta, J. 1997. "Rehabilitating degraded forests in Central Europe into self-sustaining forest ecosystems." *Ecological Engineering* 8: 289-297.

Farrington, P. and R.B. Salama. 1996. "Controlling dryland salinity by planting trees in the best hydrological setting." *Land Degradation and Development* 7: 183-204.

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

Fisher, R.J., Rachel Dechaineux and Kheung Kham Keonuchan. 1996. Socio-economic baseline study and evaluation methodology. Consultants' Report 2/96, NTFP Project. Vientiane: Department of Forestry and IUCN.

Flather, C.H. and M. Bevers. 2002. "Patchy reaction-diffusion and population abundance: The relative importance of habitat amount and arrangement." *American Naturalist* 159: 40-56.

Forman, R.T.T. 1995. *Land Mosaics: The ecology of landscapes and regions.* Cambridge (UK): Cambridge University Press.

Gilmour, D.A. 1977. Effect of rainforest logging and clearing on water yield and quality in a high rainfall zone of north-east Queensland. In *The Hydrology of Northern Australia.* Proceedings of the Institute of Engineers, Australia, Symposium in Brisbane 1977: 156-160.

Gilmour, D.A. and R.J. Fisher. 1991. *Villagers, Forests and Foresters: The Philosophy, Process and Practice of Community Forestry in Nepal.* Kathmandu: Sahayogi Press. 212 pp.

Gilmour, D.A., G.C. King, G.B. Applegate and B. Mohns. 1990. "Silviculture of plantation forests in central Nepal to maximise community benefits." *Forest Ecology and Management* 32: 173-186.

Gilmour, D.A., Van San Nguyen and Xiong Tsechalicha. 2000. *Rehabilitation of Degraded Forest Ecosystems in Cambodia, Lao PDR, Thailand and Vietnam.* Bangkok: IUCN Asia.

Goosem, S. and N. Tucker. 1995. *Repairing the Rainforest: Theory and Practice of Rainforest Re-establishment in North Queensland's Wet Tropics.* Cairns (Australia): Wet Tropics Management Authority.

Gouyon, A., H. de Foresta and P. Levang. 1993. "Does 'jungle rubber' deserve its name? An analysis of rubber agroforestry systems in southeast Sumatra." *Agroforestry Systems* 22: 181-206.

Grainger, A. 1988. "Estimating areas of degraded tropical lands requiring replenishment of forest cover." *International Tree Crops Journal* 5: 31-61.

Guevara, S., J. Meave, P. Moreno-Casasola and J. Laborde. 1992. "Floristic composition and structure of vegetation under isolated trees in neotropic pastures." *Journal of Vegetation Science* 3: 655-664.

Gutkowski, R.M. and T. Winniki. 1997. *Restoration of Forests: Environmental Challenges in Central and Eastern Europe.* Dordrecht: Kluwer Academic Publishers.

Hatton, T.J. and R.A. Nulsen. 1999. "Towards achieving functional ecosystem mimicry with respect to water cycling in southern Australian agriculture." *Agroforestry Systems* 45: 203-214.

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

Hobbs, R.J. and D.A. Norton. 1996. "Towards a conceptual framework for restoration ecology." *Restoration Ecology* 4: 93-110.

Holmgren, P., E.J. Masakhan and H. Sjoholm. 1994. "Not all African land is being degraded: A recent survey of tree on farms in Kenya reveals rapidly increasing forest resources." *Ambio* 23: 390-395.

Hughes, J. and O. Petchey. 2001. "Merging perspectives on biodiversity and ecosystem function." *Trends in Ecology and Evolution* 16: 222-223.

Ingles, A. and W. Jackson 2001. Biodiversity and landscape-level planning in forestation programmes. Presented at 21st Century Forum, 4-6 September 2001, Beijing.

Jackson, W. 2000. Ecosystem integrity and human well-being. Presentation at a workshop on Forest Restoration, Segovia, Spain, April 2000. Unpublished.

Janzen, D.H. 1988. Guanacaste National Park: Tropical ecological and cultural restoration. In J. Cairns, Jr. (ed.). *Rehabilitating Damaged Ecosystems.* Boca Raton (Florida): CRC Press, pp.143-192.

Jones, E.W. 1956. "Ecological studies on the rain forest of southern Nigeria. IV. The plateau forest of the Okamu Forest Reserve." *Journal of Ecology* 44: 83-117.

Kaiser, J. 2000. "Rift over biodiversity divides ecologists." *Science* 289: 1282-1283.

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

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

Kelty, M.J. 1992. Comparative productivity of monocultures and mixed species stands. In M.J. Kelty, B.C. Larson and C.D. Oliver (eds.). *The Ecology and Silviculture of Mixed Species Forests.* Dordrecht: Kluwer Academic Publishers, pp 125-141.

Kinzig, A.P., S.W. Pacala and D. Tilman (eds.). 2001. *The Functional Consequences of Biodiversity: Empirical progress and theoretical extensions.* Princeton (N.J.): Princeton University Press.

Kirby, J., S. Elliott, J. Maxwell, D. Blakesley and V. Anusarnsunthorn. 2000. *Tree Seeds and Seedlings for Restoring Forests in Northern Thailand.* Chiang Mai (Thailand): Forest Restoration Research Unit, Biology Department, University of Chiang Mai.

Knowles, O.H. and J. Parrotta. 1995. "Amazonian forest restoration: An innovative system for native species selection based on phenological data and performance indices." *Commonwealth Forestry Review* 74: 230-243.

Kooyman, R. 1996. *Growing Rainforest: Rainforest Restoration and Regeneration.* Greening Australia and State Forests of New South Wales.

Kuechli, C. 1997. *Forests of Hope: Stories of regeneration.* London: Earthscan.

Lamb, D. 2000. Some ecological principles for reassembling forest ecosystems at degraded tropical sites. In S. Elliott, J. Kirby, D. Blakesley, K. Hardwick, K. Woods and V. Anusarnsunthorn (eds.). *Forest Restoration for Wildlife Conservation.* Proceedings of a workshop, January 30 – February 4, 2000, University of Chiang Mai, Thailand, pp 35- 43.

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

Lao-ADB Plantation Forestry Project. 1995. *National Strategy for Sustainable Plantation Forestry in Lao PDR.* Vientiane: ADB.

Larson, D.W. 1996. "Brown's Woods: An early gravel pit forest restoration project, Ontario, Canada." *Restoration Ecology* 4: 11-18.

Lee, Don Koo and DongKyun Park. 2002. *Rehabilitation of degraded land in Korea and combating desertification and reforestation efforts by Korea.* Paper presented at International Expert Meeting on Forest Landscape Restoration, IUCN, Costa Rica, February 27-28, 2002.

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

Luken, James O. 1990. *Directing Ecological Succession.* Chapman and Hall.

MacDicken, K. and N.T. Vergara (eds.). 1990. *Agroforestry: Classification and Management.* New York: Wiley Interscience.

Maina, G. and H. Howe. 2000. "Inherent rarity in community restoration." *Conservation Biology* 14: 1335-1340.

Majer, J. (ed.). 1989. *Animals in Primary Succession: The role of fauna in reclaimed lands.* Cambridge (UK): Cambridge University Press.

Mather, A. 2001. The transition from deforestation to reforestation in Europe. In A. Angelsen and D. Kaimoitz (eds.). *Agricultural Technologies and Tropical deforestation.* Wallingford: CAB International, pp 35-52.

Mathews, E. 2001. *Understanding the FRA 2000.* Forest Briefing Note 1. Washington, D.C: World Resources Institute.

McIntyre, S., J.G. McIvor and N.D. MacLeod. 2000. Principles for sustainable grazing in eucalypt woodlands: landscape-scale indicators and the search for thresholds. In P. Hale, A. Petrie, D. Maloney and P. Sattler (eds.). *Management for Sustainable Ecosystems.* Brisbane: Center for Conservation Biology, The University of Queensland, pp 92-100.

McLachlan, J.S., D.R. Foster and F. Menalled. 2000. "Anthropogenic ties to late-successional structure and composition in four New England hemlock stands." *Ecology* 81: 717-733.

Mergen, F., H. Abbott, W. Mann, F. Moulds, A. Nordmeyer and J. Scott. 1981. *Sowing Forests from the Air.* Washington, D.C: National Academy Press.

Michon, G. and H. de Foresta 1995. The Indonesian agro-forestry model. In P. Halladay and D.A. Gilmour (eds.). *Conserving Biodiversity Outside Protected Areas: The role of traditional agro-ecosystems.* Gland (Switzerland) and Cambridge (UK): IUCN.

Michon, G. and H. de Foresta. 1997. "Agroforests: Pre-domestication of forest trees or true domestication of forest ecosystems." *Netherlands Journal of Agricultural Science* 45: 451-462.

Miyawaki, A. 1993. Restoration of native forest from Japan to Malaysia. In H. Leith and M. Lohman (eds.). *Restoration of Tropical Forest Ecosystems.* Dordrecht: Kluwer Academic Publishers, pp 5-24.

MOF 1995. *Vietnam Forestry: 36.* Hanoi: Agricultural Publishing House.

Moffat, A. and J. McNeill. 1994. *Reclaiming Disturbed Land for Forestry.* Bulletin 110. London: HMSO.

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

Montagnini, F. and R.O Mendelsohn. 1997. "Managing forest fallows: Improving the economics of swidden agriculture." *Ambio* 26: 118-123.

Motzkin, G., D. Foster, A. Allen, J. Harrod and R. Boone. 1996. "Controlling site to evaluate history: Vegetation patterns of a New England sand plain." *Ecological Monographs* 66: 345-365.

Mulligan, D.R (ed.). 1996. *Environmental Management in the Australian Minerals and Energy Industries: Principles and practices.* Sydney: University of New South Wales Press.

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

Parrotta, J. and O.H. Knowles. 2001. "Restoring tropical forests on land mined for bauxite: Examples from the Brazilian Amazon." *Ecological Engineering* 17: 219-239.

Parrotta, J. and O. H. Knowles. 1999. "Restoration of tropical moist forests on bauxite-mined lands in the Brazilian Amazon." *Restoration Ecology* 7: 103-116.

Parrotta, J. and O. H. Knowles. 1997. "Development of floristic diversity in ten-year-old restoration forests on a bauxite-mined site in Amazonia." *Forest Ecology and Management* 99: 21-42.

Parrotta, J.A., J.W. Turnbull and N. Jones. 1997. "Catalysing native forest regeneration on degraded tropical land." *Forest Ecology and Management* 99: 1-8.

Peterken, G.F. 2000. "Rebuilding networks of forest habitats in lowland England." *Landscape Research* 25: 291-303.

Prescott-Allen, R. 2001. *The Well-Being of Nations: A country-by-country index of quality of life and the environment.* Washington, D.C: Island Press.

Reay, S.D. and D.A. Norton. 1999. "Assessing the success of restoration plantings in a temperate New Zealand forest." *Restoration Ecology* 7: 298-308.

Rodwell, J and G. Patterson. 1994. *Creating New Native Woodlands.* Bulletin 112. London: HMSO.

Russell-Smith, J., P.G. Ryan and R. Durieu. 1997. "A Landsat MSS-derived fire history of Kakadu National Park, monsoonal northern Australia, 1980-94: Seasonal extent, frequency and patchiness." *Journal of Applied Ecology* 34: 748-766.

Sattler, P. and R. Williams (eds.). 1999. *The Conservation Status of Queensland's Bioregional Ecosystems.* Brisbane: Environmental Protection Agency.

Saunders, A. and D.A. Norton. 2001. "Ecological restoration at mainland islands in New Zealand." *Biological Conservation* 99: 109-119.

Shear, T.H., T.J. Lent and S. Fraver. 1996. "Comparison of restored and mature bottomland hardwood forests of southwestern Kentucky." *Restoration Ecology* 4: 111-123.

Simberloff, D., J.A. Farr, J. Cox and D.W. Mehlman. 1992. "Movement corridors: conservation bargains or poor investments?" *Conservation Biology* 6: 493-504.

Stirzaker, R.J., F.J. Cook and J.H. Knight. 1999. "Where to plant trees on cropping land for control of dryland salainity: Some approximate solutions." *Agricultural Water Management* 39: 115-133.

Swaine, M.D, W.D. Hawthorne and T.K. Orgle. 1992. "The effects of fire exclusion on savanna vegetation at Kpong, Ghana." *Biotropica* 24: 166-172.

Tilman, D., J. Fargione, B. Wolff, C. D'Antonio, A. Dobson, R. Howarth, D. Schindler, W.H. Schlesinger, D. Simberloff and D. Swackhamer. 2001. "Forecasting Agriculturally Driven Global Environmental Change." *Science* 292: 281-284.

Toh, I., M. Gillespie and D. Lamb. 1999. "The role of isolated trees in facilitating tree seedling recruitment at a degraded sub-tropical rainforest site." *Restoration Ecology* 7 (3): 288-297.

Torquebiau, E. 1984. "Man-made dipterocarp forest in Sumatra." *Agroforestry Systems* 2: 103-127.

Towns, D.R. and W.J. Ballantine. 1993. "Conservation and restoration of New Zealand island ecosystems." *Trends in Ecology and Evolution* 8: 452-457.

Tucker, N.J. and T.M. Murphy. 1997. "The effects of ecological rehabilitation on biodiversity recruitment: Some observations from the wet tropics of north Queensland." *Forest Ecology and Management* 99: 133-152.

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

Vitousek, P.M., H.A. Mooney, J. Lubchencho and J.M. Melillo. 1997. "Human domination of earth's ecosystems." *Science* 277: 494-499.

Wadsworth, F.H. 1997. *Forest Production for Tropical America.* Agriculture Handbook 710. Washington, D.C: USDA Forest Service.

Waterloo, M.J. 1994. *Water and nutrient dynamics of* Pinus caribaea *plantation forests on former grassland soils in southwestern Viti Levu, Fiji.* The Hague: Cip-Data Koninklijke Bibliotheek.

Watkins, C. (ed.). 1993. *Ecological effects of Afforestation: Studies in the history and ecology of afforestation in Western Europe.* Wallingford: CAB International.

Weiher, E. and P. Keddy (eds.). 1999. *Ecological Assembly Rules: Perspectives, advances, retreats.* Cambridge (UK): Cambridge University Press.

White, D.A., F.X. Dunin, N.C. Turner, B.H. Ward and J.H. Galbraith. 2002. "Water use by contour-planted belts of trees comprised of four Eucalyptus species." *Agricultural Water Management* 53: 133-152.

Williams, M. 1988. The death and rebirth of the American forest: Clearing and reversion in the United States 1900-1980. In J.F. Richards and R.P. Tucker (eds.). *World Deforestation in the Twentieth Century.* Durham (N.C.): Duke University Press, pp 211- 229.

Wormald, T.J. 1992. *Mixed and Pure Forest Plantations in the Tropics and Sub-tropics.* Rome: FAO.

Zedler, J.B., R. Lindig-Cisneros, C. Bonilla-Warford and I. Woo. 2001. Restoration of biodiversity: Overview. In S.A. Levin (ed.). *Encyclopedia of Biodiversity*. Volume 5. San Diego: Academic Press, pp 203-211.

IUCN – The World Conservation Union

Founded in 1948, The World Conservation Union brings together States, government agencies and a diverse range of non-governmental organizations in a unique world partnership: nearly 980 members in all, spread across some 140 countries.

As a Union, IUCN seeks to influence, encourage and assist societies throughout the world to conserve the integrity and diversity of nature and to ensure that any use of natural resources is equitable and ecologically sustainable. A central secretariat coordinates the IUCN Programme and serves the Union membership, representing their views on the world stage and providing them with the strategies, services, scientific knowledge and technical support they need to achieve their goals. Through its six Commissions, IUCN draws together over 10,000 expert volunteers in project teams and action groups, focusing in particular on species and biodiversity conservation and the management of habitats and natural resources. The Union has helped many countries to prepare National Conservation Strategies, and demonstrates the application of its knowledge through the field projects it supervises. Operations are increasingly decentralized and are carried forward by an expanding network of regional and country offices, located principally in developing countries.

The World Conservation Union builds on the strengths of its members, networks and partners to enhance their capacity and to support global alliances to safeguard natural resources at local, regional and global levels.

IUCN Forest Conservation Programme
Rue Mauverney 28
CH-1196 Gland, Switzerland
Tel ++ 41 22 999 0263
Fax ++ 41 22 999 0025
E-mail forests@hq.iucn.org

IUCN Publications Services Unit
219c Huntingdon Road
Cambridge, CB3 0DL, UK
Tel ++44 1223 277 894
Fax ++44 1223 277 175
E-mail books@iucn.org

WWF – The Conservation Organization

WWF – The World Wide Fund for Nature is one of the world's largest and most experienced independent conservation organizations, with almost five million supporters and a global network active in over 90 countries.

WWF's mission is to stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature, by:

- conserving the world's biological diversity;
- ensuring that the use of renewable natural resources is sustainable;
- promoting the reduction of pollution and wasteful consumption.

WWF International
Avenue du Mont Blanc
CH-1196 Gland, Switzerland
Tel. ++ 41 22 364 91 11
Fax ++ 41 22 364 53 58

IUCN
The World Conservation Union

WWF