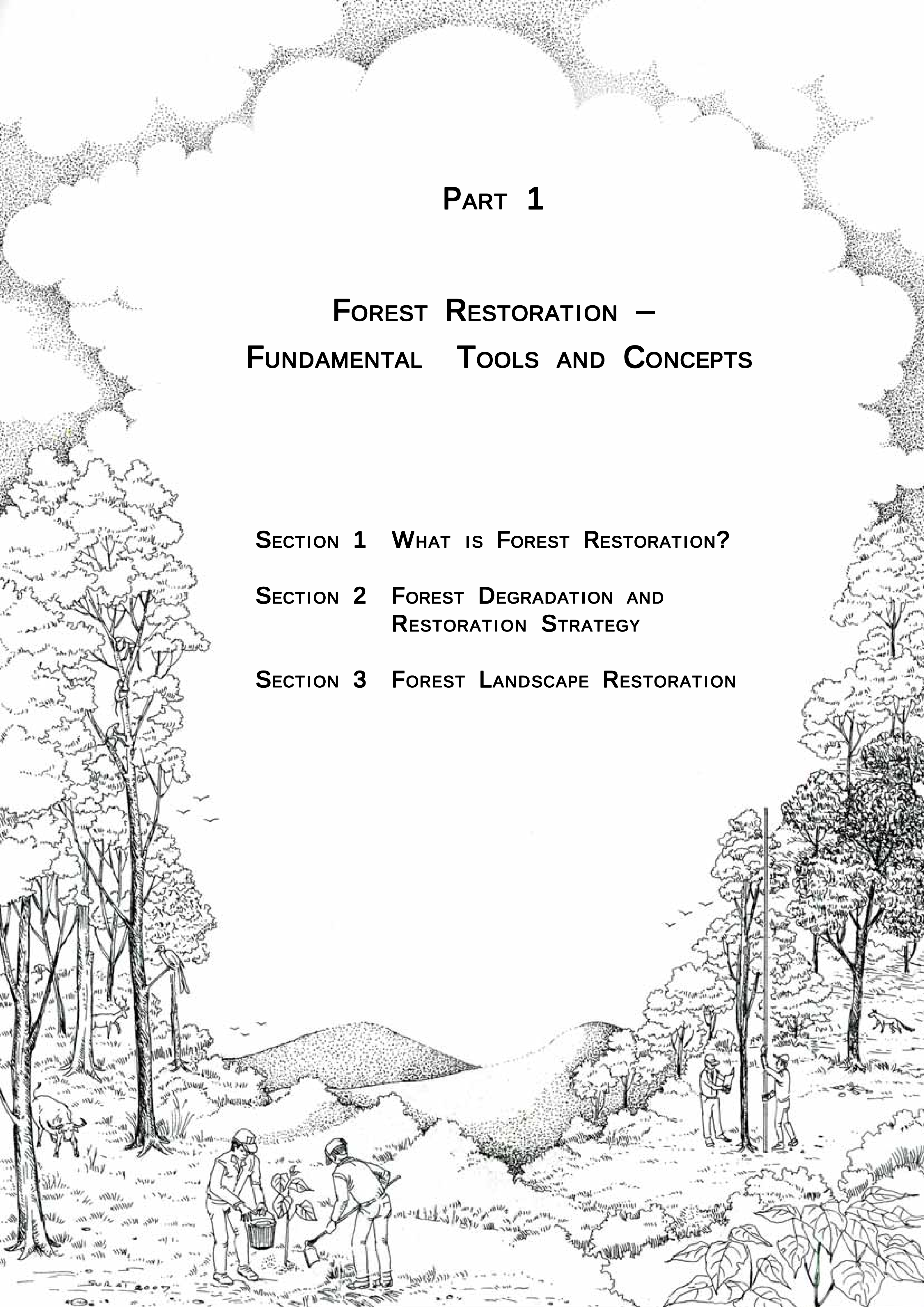
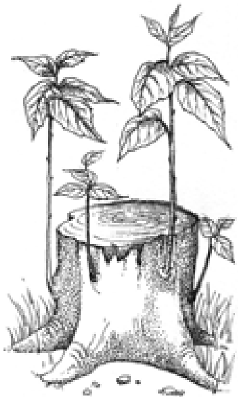
Part 1

Forest Restoration –
Fundamental Tools and Concepts



In degraded forest landscapes, loss of forest products and ecological services, e.g. watershed protection, threaten the livlihoods of villagers as well as biodiversity. Forest landscape restoration addresses these problems (Section 3)



Protecting live tree stumps (left) is just one of many techniques that can contribute to accelerated natural forest regeneration (ANR) (Section 2).

In more severely degraded areas, planting framework tree species (right), and caring for them with weeding and mulching, is carried out to complement ANR measures.

Eight years after being planted with 29 framework tree species, this demonstration plot now supports more than 60 species of naturally regenerating "recruit" tree species. Most of them grew from seeds dispersed onto the site by animals attracted by the planted trees. More than 80 bird species have been recorded in the area, representing about two thirds of the bird community found in the nearest patch of mature forest.

Forest Restoration – Fundamental Tools and Concepts

Section 1 - What is Forest Restoration?

Tropical deforestation – the problem

As the human populations of most developing tropical countries continue to increase, further destruction of tropical forests seems inevitable. The consequences of this, both for human well-being and for wildlife, are catastrophic. Tropical and sub-tropical forests cover only 16.8 percent of Earth's land area (FAO, 2001), yet they are home to more than half the planet's plant and animal species (Wilson, 1988). Their destruction is therefore causing the greatest extinction event in our planet's history. Tropical deforestation is also contributing to global warming, as the carbon formerly stored in the trees is released into the atmosphere. Other environmental impacts such as floods, droughts, soil erosion, landslides, siltation of water courses and losses of forest products all contribute substantially to rural poverty (Schreckenberg and Hadley, 1991; Anderson and Spencer, 1991).

About half of Earth's primary tropical forests have already been lost or substantially degraded and, if nothing is done to reverse this trend, most of the rest may disappear in the next few decades. Worldwide, the area of natural tropical forests (tree cover >10%, not including plantations) declined from 1,945 to 1,803 million ha between 1990 and 2000 AD, averaging about 14.2 million ha (approximately 0.7 percent) per year; about the same rate of decline as during 1980-90 (FAO, 2001).

This destruction has been due to logging for timber and forest clearance to provide agricultural land. Infrastructure development (e.g. roads and dams) has also opened up forests to settlement and fragmented them, so that many remaining forest patches are not large enough to support viable populations of wildlife species; particularly large mammals and birds. As species disappear, the complex web of species inter-relationships, vital for maintaining tropical biodiversity unravels. Plants lose their pollinators and/or seed dispersers; herbivores lose their predators and their populations increase, further threatening plant diversity. As key species are lost, a "cascade" of extinctions leads to collapse of the rich biodiversity of tropical forests (Gilbert, 1980).

Some recovery of tropical forests has occurred, by natural re-generation of secondary forests, sometimes assisted by management interventions or by planting native forest tree species. But a far more widespread approach has been to replace degraded tropical forests with economic plantations, often of exotic tree species (e.g. eucalyptus, rubber, oil palm etc.) or native tree species (e.g. teak, pines etc.). Asia leads the world in this type of reforestation. By 2000, 62 percent of the world's tree plantations were located there; contributing 20 percent to Asia's total tree cover (FAO, 2001). This balance, between destruction of primary tropical forest and its replacement by other types of vegetation, often makes forest statistics confusing. For example “forest cover” figures often fail to distinguish between primary forest (which provides natural habitat for wildlife and a wide range of products and ecological services to local people) and commercial tree plantations (which do not). “Degradation” of primary tropical forests by chopping trees for firewood, cattle browsing, fires etc. also has a significant impact on biodiversity, but it is less easy to define and measure than outright “deforestation”; so, *meaningful* national and global statistics on forest loss are often inaccurate or not available. Regardless of these uncertainties, however, destruction and degradation of Earth’s tropical forest are undoubtedly the greatest threats to terrestrial biodiversity. This problem can only be reversed by devising effective techniques to restore tropical forest ecosystems, where they have been destroyed, and by promoting innovative socio-political mechanisms to ensure that such techniques are put into practice. This manual provides a technical guide to developing sound methods to restore tropical forests, taking into account local conditions. We hope that the development of such techniques will provide a wider range of options for sociologists and politicians to engage people, at all levels of society, in helping to save Earth’s tropical forests and the wealth of biodiversity they support.

Tropical deforestation – what are the solutions?

If deforestation is such a big problem; then reforestation is the obvious solution, but reforestation means different things to different people and there are many different kinds.

“Reforestation” means re-establishing any type of tree cover, including plantations of exotic species, agro-forestry and so on.

“Forest restoration” is a specialized form of reforestation. It means re-establishing the original forest ecosystem that was present before deforestation occurred.

In the short term, it is perhaps over-ambitious to expect that complex tropical forest ecosystems, with their rich biodiversity, can be restored exactly to their original condition; especially because the exact species composition of the original forest may not be known. Rather, forest restoration attempts to re-establish former levels of ecosystem structure and re-instate natural forest regeneration mechanisms, by planting key tree species, which are known to have played a vital role in the ecology of the original forest.

Why are FORRU’s needed?

Since the earliest days of forest science, forestry research has concentrated on increasing yields from various forms of economic forestry. A plethora of papers has been published on how to increase timber yields of a small number of species by silvicultural treatments, disease control, genetic improvement and so on.

Likewise, research on agro-forestry has tended to focus mainly on maximizing economic yields from various mixtures of crops and/or livestock with trees. Even though agro-forestry is promoted as a more environmentally benign form of forestry, compared with single species plantations, very little attention has been paid to the effects of agro-forestry on biodiversity.

In recent decades, researchers have turned their attention to community forestry, which aims to maximize the benefits of forestry to local people; but even with this more socially orientated form of forestry, research has concentrated on attaining sustainable yields of forest products. Whilst the social benefits of community forestry are now accepted, the effects of community forestry on biodiversity has not been adequately determined. This would require monitoring of biodiversity both before and after implementation of community forestry, over several decades in replicated plots; each one paired with a similar but undisturbed reference (control) forest – a difficult experimental design to establish in today's over-crowded landscapes.

With so much emphasis on forestry for human needs, forestry for wildlife conservation has received little attention. Reconstructing highly complex tropical forests requires a different knowledge base to that needed to grow economic trees. Whereas well-funded, research has resulted in sound methods to grow the small number of tree species, deemed to be of "economic value"; the same cannot be said of the thousands of other tropical tree species, which are vital ecological components of wildlife habitats, but which are not commercially exploited.

Forest restoration research units (FORRU's) are needed to fill these gaps in knowledge. Integrating ecological research with socio-economic studies, should enable forest restoration practitioners to balance the needs of wildlife with those of local people; essential if initiatives such as Forest Landscape Restoration (Section 3) are to be successful.

Taxonomic research on tropical forest trees has resulted in lists of tree species for many areas, although the continual discovery of new species suggests that such lists are incomplete. Whilst floras provide detailed species descriptions, ecological information about each species is often cursory. Accounts of pollination and seed dispersal mechanisms; conditions required for seed germination; survival and growth rates of seedlings and use of the trees by wildlife have yet to be published for most tropical tree species.

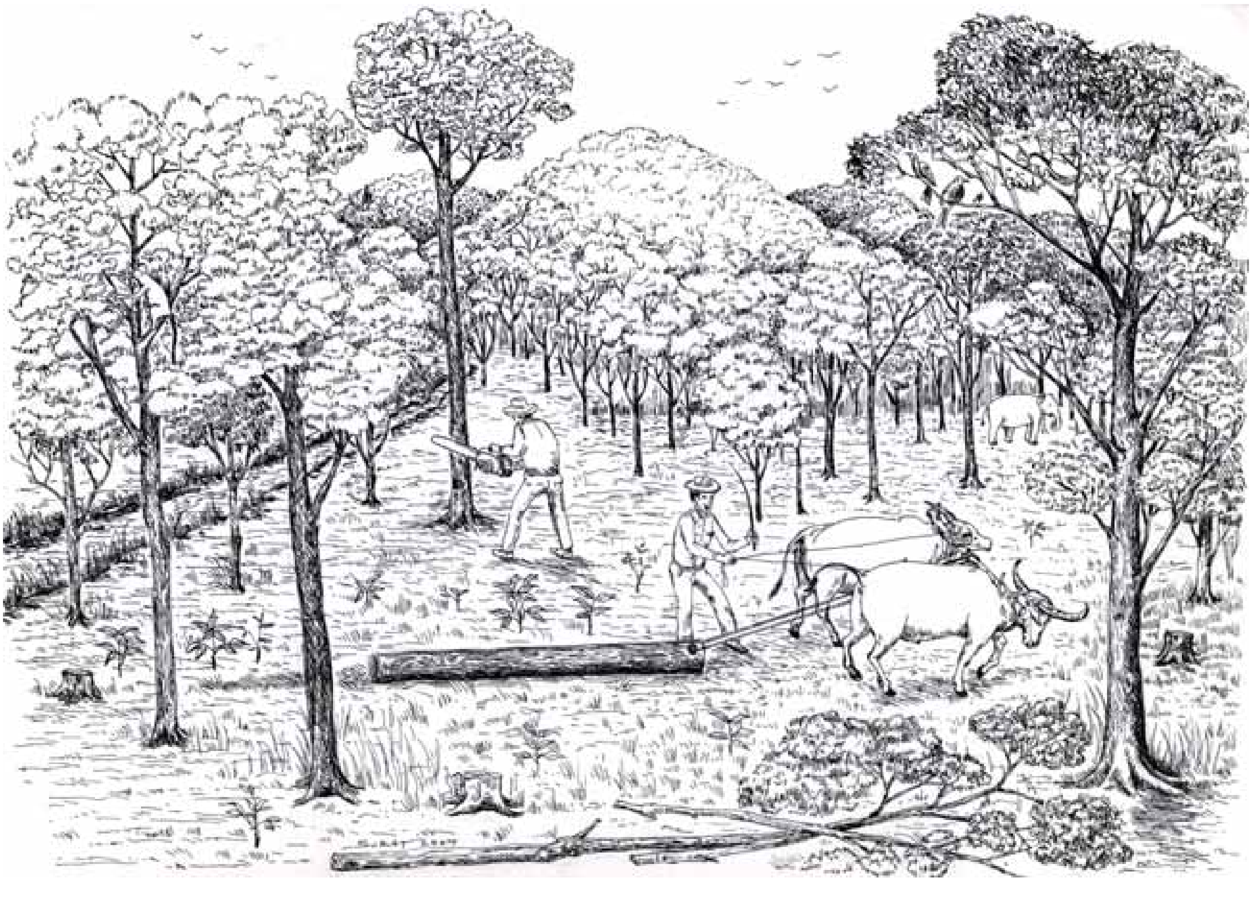
What information should FORRU's generate?

A FORRU's goal is to develop methods to harness and accelerate the natural processes of forest regeneration, so that biodiversity-rich ecosystems, similar to the original forest, can be re-established. This involves gathering ecological data about forest dynamics and the reproductive ecology of as many forest tree species as possible. Such information is then applied to devise effective techniques to re-establish the most appropriate tree species on the most suitable sites. This involves testing horticultural techniques in tree nurseries, as well as assessing the effectiveness of silvicultural practices in field trials.

A FORRU's research program should include: studies of the factors that limit natural regeneration; selection of tree species, which accelerate regeneration; the seasonality of fruit/seed production by forest trees; manipulation of seed dormancy, germination and seedling growth in nurseries; development of silvicultural treatments to maximize tree performance after planting out and monitoring biodiversity recovery. Research on social issues, such as motivation of local people to become involved in forest restoration and the usefulness of indigenous knowledge, should also be carried out, to ensure the practicability of the research results.

Level 1 Degradation

Site factors		Landscape factors	
Vegetation	Trees dominate over herbaceous weeds	Forest	Large remnants remain as seed sources
Soil	Little localised disturbance; remains mostly fertile	Seed dispersers	Common; both large and small species
Sources of regeneration	Plentiful: soil seed bank viable; dense seedling bank; dense seed rain; live tree stumps	Fire risk	Low



Appropriate response for biodiversity conservation	Protect from further disturbance – re-introduce any plant or animal species extirpated by logging; particularly key pollinators and seed dispersers.
Appropriate response for economic yield	Replacement planting with economic tree species removed by logging. Extractive reserves with sustainable harvesting of NTFP's. Ecotourism.

NTFP's=Non-timber Forest Products

Section 2 – Forest Degradation and Restoration Strategy

Approaches to Forest Restoration

In every area, there is a natural sequence of ecosystem succession, which depends on the soil, climate and the availability of seed sources. In the tropics, bare earth is rapidly colonized by herbs and grasses, which are gradually shaded out by shrubs. Short-lived pioneer trees eventually over-top the shrubs and are themselves gradually replaced by shade-tolerant climax forest trees. Forest degradation reverses this sequence, whilst forest restoration accelerates it forwards. The intensity and type of management strategy required to restore the climax forest ecosystem depends on how far back in the successional sequence the vegetation has been "pushed" by degrading factors. There are six critical, limiting, points to look for in the degradation sequence: three pertain to the site being restored and three to the condition of the surrounding landscape.

Site critical points:

- Density of trees reduced enough to allow herbaceous weeds to dominate the site and out-compete tree seedlings.
- Soil erosion proceeded to such an extent that low soil fertility limits tree seedling establishment.
- On-site sources of forest regeneration (seed/seedling bank, live stumps, seed trees etc.) declined below levels needed to maintain viable tree populations of formerly present species.

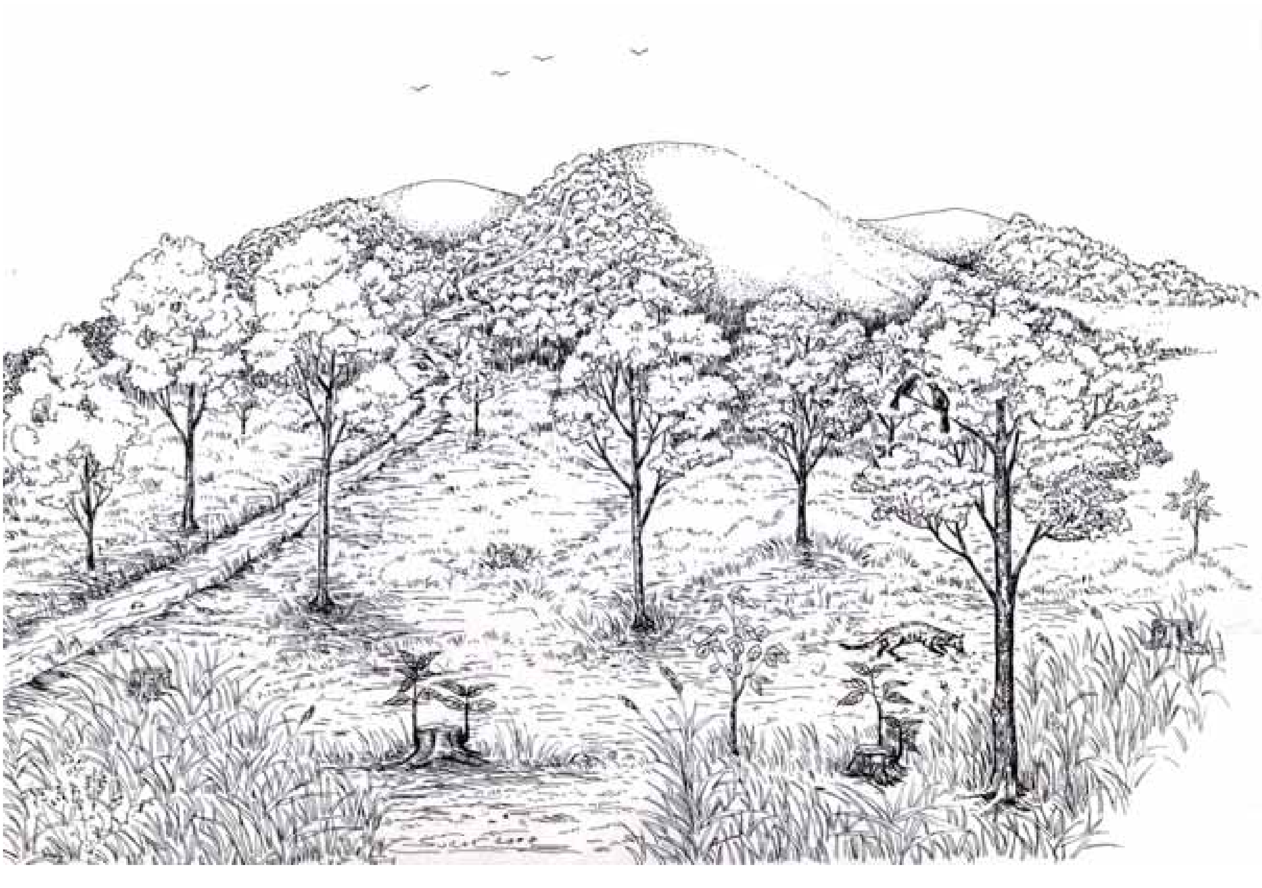
Landscape critical points:

- Remnant climax forest in the landscape reduced below critical levels, such that the diversity of tree species remaining within dispersal distance of the forest restoration site falls below that representative of climax forest.
- Populations of seed-dispersing animals reduced to the point that they are no longer able to transport seeds to the forest restoration site in sufficiently high densities to re-establish viable tree populations.
- Fire risk increased to a point where naturally established trees are unlikely to survive.

Combining these critical points leads to 5 easily distinguishable "levels" of degradation of increasing severity, each one requiring a different restoration strategy. Where remnants of climax forest survive close to the restoration site, and seed-dispersing animals remain common (levels 1-3), approaches that rely on natural seed dispersal are feasible (e.g. ANR and the framework species method). Where natural forest remnants are absent from the landscape (level 4), a wide range of tree species must be planted (e.g. maximum diversity methods). Where soil and microclimate have deteriorated significantly (level 5), it may be necessary to first ameliorate site conditions by planting a "nurse crop", capable of improving the soil, before implementing other restoration methods.

Level 2 Degradation

Site Factors		Landscape Factors	
Vegetation	Mixed trees and herbaceous weeds	Forest	Remnants remain as seed sources
Soil	Remains mostly fertile; erosion low	Seed dispersers	Large species becoming rare, but small species still common
Sources of regeneration	Seed and seedling banks depleted; live tree stumps common	Fire risk	Medium



Appropriate response for biodiversity conservation	ANR - protect forest remnants and prevent hunting of seed-dispersing animals; replant a few primary forest tree species if absent.
Appropriate response for economic yield	Enrichment planting with economic tree species particularly those logged out. Extractive reserves with sustainable harvesting of NTFP's.

Why protect primary forest remnants?

Fundamental to all forest restoration strategies is protection of any remnant primary forest in the landscape. Such remnants provide a bench mark ("target forest"), against which the progress of forest restoration can be compared. They also provide an opportunity to study natural forest regeneration processes (e.g. phenology studies) and they are a source of seeds (genetically suited to local conditions) for the propagation of indigenous forest tree species in nurseries.

Natural forest remnants are also a refuge for animals, capable of naturally dispersing seeds of a wide range of forest tree species into restoration sites. Maintaining primary forest remnants, close to restoration sites, therefore reduces the number of tree species that must be planted in forest restoration projects; and that reduces costs.

Accelerated Natural Regeneration (ANR)

Where degradation is not too severe, forest ecosystems retain a high potential to recover naturally. This potential can be enhanced by accelerated (or assisted) natural regeneration (ANR), which covers any set of activities that accelerate natural processes of forest regeneration. These focus on encouraging the natural establishment and subsequent growth of indigenous forest trees, whilst preventing any factors that might harm them e.g. competition from weeds, browsing by cattle, fire etc. ANR activities, therefore, include weeding, fertilizer application and mulching around existing trees, excluding cattle from the site and preventing fire, attracting seed dispersers (e.g. by erecting bird perches) and direct seeding (FORRU, 2006, and Part 4, Section 5).

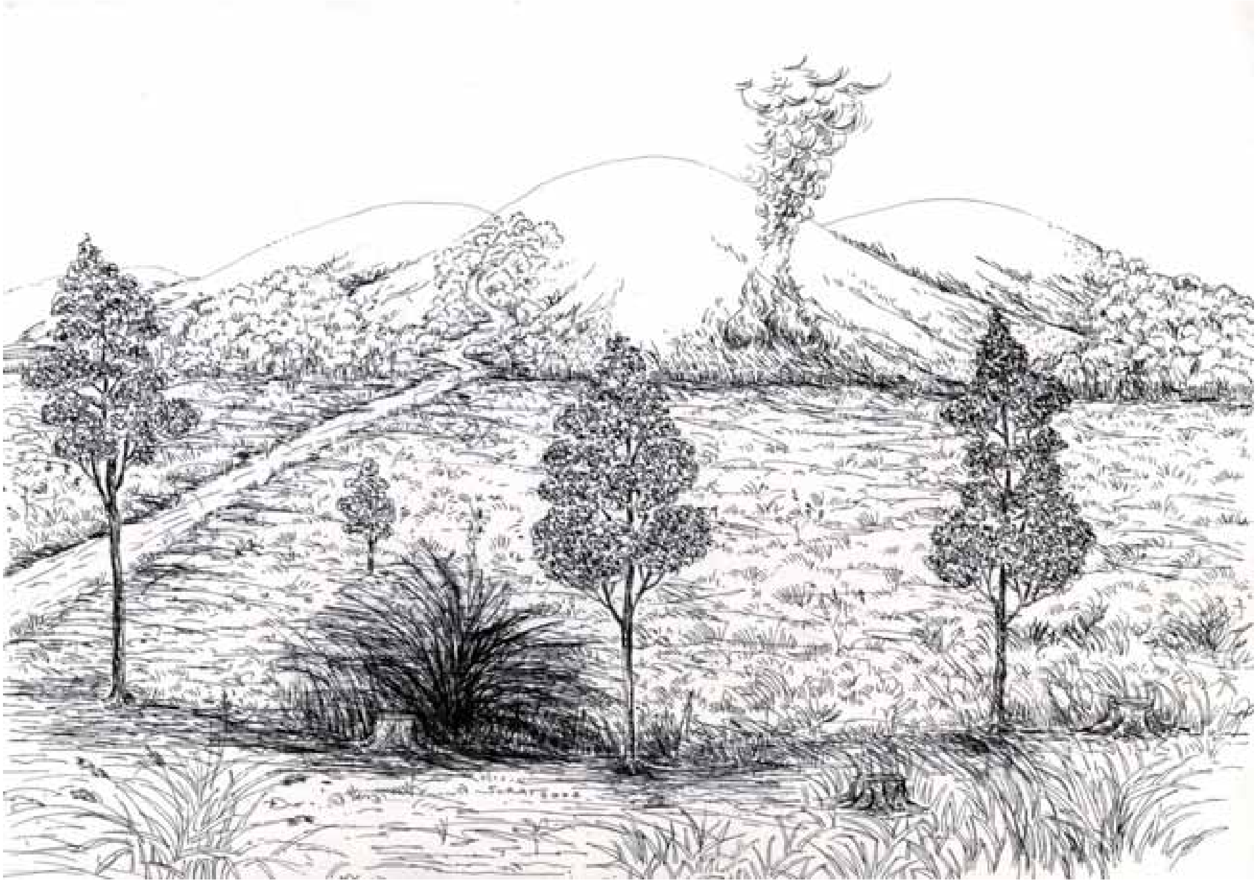
Because ANR relies on natural processes, it requires less labour input than tree planting and can therefore be a cheap way to restore forest ecosystems. However, ANR and tree planting should not be regarded as two exclusive alternatives to forest restoration. Forest restoration often involves a combination of both tree planting and ANR techniques. Under certain circumstances, ANR alone may be sufficient to restore forest ecosystems (see diagram in FORRU, 2006), but tree planting should always be implemented in combination with whatever ANR techniques are appropriate.

Where is ANR appropriate?

ANR is appropriate wherever the natural processes of forest regeneration are already underway to some extent, or where conditions clearly favour forest regeneration. For example, some seed trees should exist nearby and seed-dispersing animals should remain reasonably common in the vicinity. Sites, which already support a high density of tree saplings or sprouting tree stumps, are particularly suited to ANR. The density of naturally occurring tree seedlings, saplings or stumps (numbers of stems per hectare) probably provides the best prediction of whether ANR, on its own, will be sufficient to restore forest on any particular site. However, it is also important to consider the sizes of the seedlings, saplings and tree stumps observed. Tall saplings are more likely to survive than

Level 3 Degradation

Site factors		Landscape factors	
Vegetation	Herbaceous weeds dominate	Forest	Remnants remain as seed sources
Soil	Remains mostly fertile; erosion low	Seed dispersers	Mostly small species dispersing small seeds
Sources of regeneration	Mostly from incoming seed rain; a few saplings and live tree stumps may remain	Fire risk	High



Appropriate response for biodiversity conservation	ANR + planting 20-30 framework tree species; protect remaining forest remnants and prevent hunting of seed-dispersing animals.
Appropriate response for economic yield	Include economic species among framework trees planted. Ensure local people are well paid for tree planting and aftercare; analogue forestry; agro-forestry.

small ones. The probability of a sapling growing into a mature tree increases greatly once it overtops surrounding weeds. Since patterns of natural forest regeneration vary greatly from place to place, standards to determine whether ANR alone is sufficient for forest restoration must be developed locally, by combining field surveys with local knowledge.

What are the limitations of ANR?

ANR acts mostly on trees that are already established in deforested areas. Unfortunately, most of the tree species, capable of colonizing such areas are light-demanding pioneers, with seeds that are dispersed by wind or small birds. They represent only a small fraction of the tree species richness of climax forest. Therefore, whilst ANR might be sufficient to restore tree cover and to some extent forest structure, significant recovery of biodiversity may require additional measures. Where large seed-dispersing animal species have become extirpated, planting large-seeded climax forest tree species may be the only way to convert secondary forest, created by ANR, towards climax forest. In such circumstances, ANR may be combined with enrichment planting or framework forestry.

What is enrichment planting?

Enrichment planting simply means planting trees to i) increase the population density of existing tree species or ii) increase tree species richness by adding tree species to degraded forest. Traditionally it has been associated with adding commercially valuable tree species to a managed forest to increase economic yield. Framework forestry takes this concept one stage further in that it also seeks to ensure that planted trees add maximum ecological functionality to forest ecosystems undergoing restoration.

What is framework forestry?

The framework species method of forest restoration involves planting the minimum number of tree species required to re-instate the natural processes of forest regeneration and recover biodiversity. It combines the planting of 20-30 key tree species with various ANR techniques to enhance natural regeneration, creating a self-sustained forest ecosystem from a single planting event. Originally conceived in northern Queensland, to repair damaged tropical rainforest (Goosem and Tucker, 1995), the framework species method has been successfully modified to restore seasonally dry tropical forests to deforested sites in northern Thailand’s conservation areas (Elliott et al., 2003). Now, it is also being adapted for sites in China, Lao, Cambodia and Vietnam*.

What are framework tree species?

Framework trees are indigenous, non-domesticated, forest tree species, which, when planted on deforested sites, rapidly re-establish forest structure and ecological functioning, whilst attracting seed-dispersing willdife. Thus framework tree species promote dispersal of seeds from nearby forest and create conditions conducive to their germination, resulting in recruitment of tree species in planted plots.

* This book and “How to Plant a Forest” are available in the languages of all these countries. Contact details for each country are listed opposite the contents page.

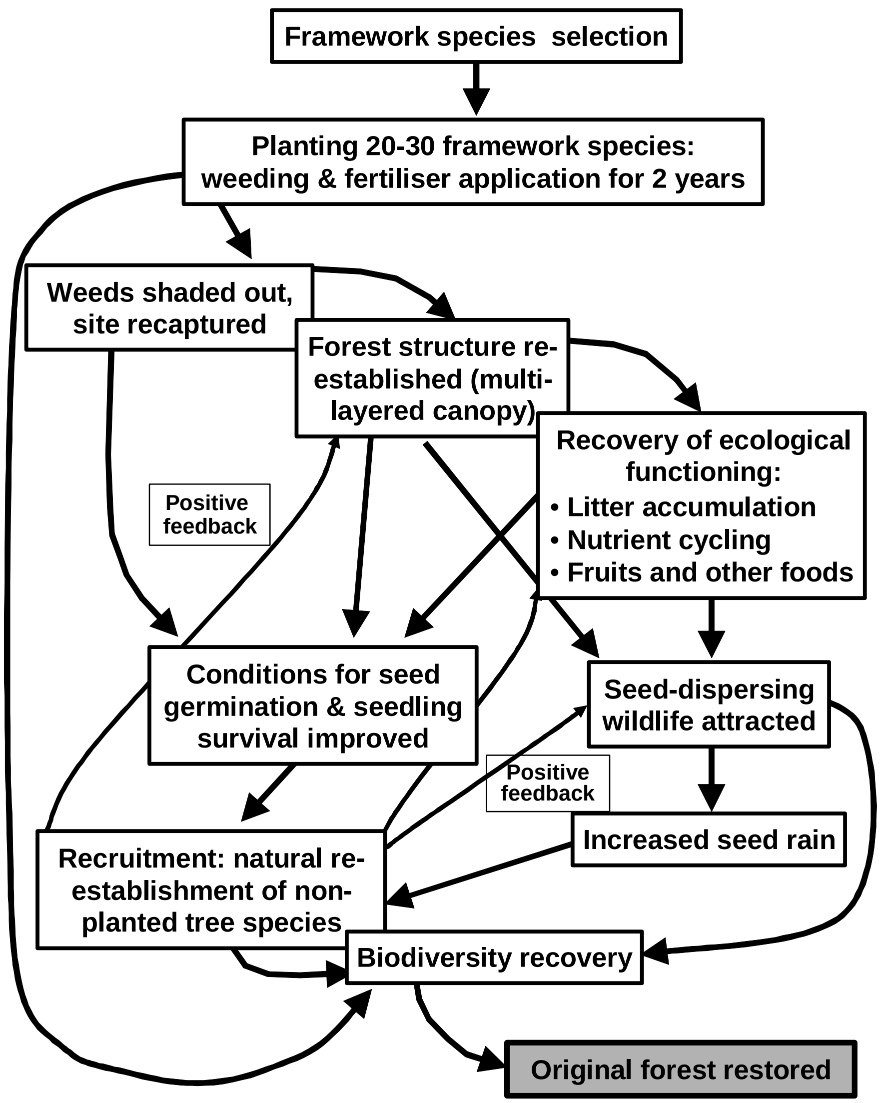
What are the characteristics of framework tree species?

The essential ecological characteristics of framework tree species are therefore:-

- High survival when planted out in deforested sites;
- Rapid growth;
- Dense, spreading crowns that shade out herbaceous weeds;
- Flowering and fruiting, or provision of other resources, at a young age, which attract seed-dispersing wildlife.

In addition, they must be easy to propagate and, ideally, their seeds should germinate rapidly and synchronously, with subsequent growth of vigorous saplings to a plantable size in less than 1 year.

In the seasonally dry tropics, where wild fires in the dry season are an annual hazard, an additional essential characteristic of framework species is resilience after burning. When fire prevention measures fail, the success of forest restoration plantings can depend on the ability of the planted trees to resprout from their rootstock after fire has burnt their shoot systems (i.e. coppicing).



Are framework trees pioneer or climax species?

Mixtures of framework tree species planted should include both pioneer and climax species. Goosem and Tucker (1995) recommend that at least 30% of trees planted should be pioneers. By planting both pioneer and climax trees in a single step, forest succession can be short-circuited. Many climax forest tree species perform well in the open, sunny conditions of deforested areas, but they fail to colonize such areas due to lack of seed dispersal or an inability to compete with vigorous weeds. Those with large, animal-dispersed seeds suffer from the decline of large mammals. By including some climax forest tree species amongst those planted, it is possible to overcome this limitation and accelerate recovery of climax forest.

Fast-growing, pioneer trees rapidly close canopy and shade out weeds, whilst slower growing climax species form an understorey beneath the pioneer tree crowns, adding structural diversity to the forest and increasing the variety of resources available to wildlife. Pioneer trees begin dying 15-20 years after planting. However, by this time, a rising understorey of climax forest trees is ready to replace them, along with a dense layer of naturally established trees, derived from seeds brought in by wildlife.

What kind of animal species must framework trees attract?

Trees that provide food or nesting sites can attract seed-dispersing animals for long periods, during which the animals may deposit seeds that begin the process of restoring the forest's original tree species composition. Therefore, planted framework trees act as "bait" for seed-dispersing animals. Dispersal of seeds between intact forest and planted plots is carried out by relatively few, common, fruit-eating, animal species that are equally at home in forest and in deforested areas. These include small to medium sized, birds, particularly bulbuls (*Pycnonotus* spp), fruit bats (e.g. *Cynopterus* spp) and some medium-sized mammals, including civets, Hog Badger (*Arctonyx collaris*), Common Wild Pig (*Sus scrofa*), Common Barking Deer (*Muntiacus muntjak*), etc. Tree species that are most likely to attract such animals produce small to medium-sized fruits or nectar-rich flowers (preferably within 3 years after planting). Increases in insects in planted plots attract insectivorous birds, and seed-dispersing birds (Toktang, 2005), as well as mammals, with mixed diets, but little is known about insects associated with framework tree species.

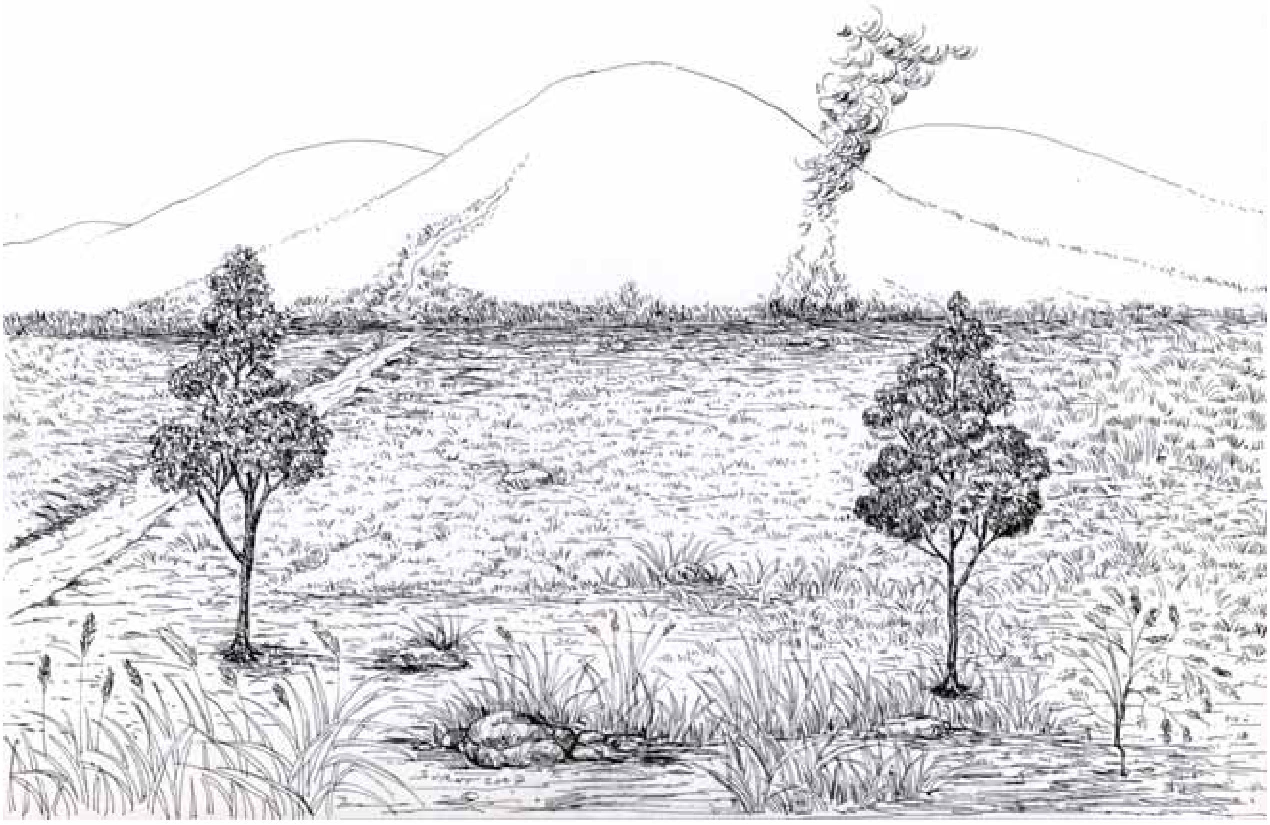
How does the framework species method work?

Planted framework tree species rapidly re-establish ecosystem structure and function, whilst animals attracted to them bring about biodiversity recovery by natural seed dispersal. The planted trees restore forest structure, by developing a dense, multilayered canopy, which shades out herbaceous weeds. They also restore ecosystem processes, such as nutrient cycles, and improve conditions for seed germination and seedling establishment of additional (non-planted) tree species (termed "recruits"), by shading out light-loving weeds and creating a cooler, more humid microclimate on the forest floor.

Biodiversity recovery is initiated when seed-dispersing birds, bats and other small mammals are attracted to the planted trees. The 20-

LEVEL 4 DEGRADATION

SITE FACTORS		LANDSCAPE FACTORS	
VEGETATION	HERBACEOUS WEEDS DOMINATE	FOREST	ABSENT WITHIN SEED DISPERSAL DISTANCES OF SITE
SOIL	EROSION RISK INCREASING	SEED DISPERSERS	MOSTLY GONE
SOURCES OF REGENERATION	FEW	FIRE RISK	HIGH



APPROPRIATE RESPONSE FOR BIODIVERSITY CONSERVATION	MAXIMUM DIVERSITY PLANTING
APPROPRIATE RESPONSE FOR ECONOMIC YIELD	AGRO-FORESTRY; MIXED SPECIES PLANTATIONS. CONVENTIONAL PLANTATIONS

30 planted tree species represent only a small fraction of the total number of tree species that grow in most tropical forests. Recovery of tree species richness, therefore, depends on natural seed dispersal. Once planted trees have created conditions conducive to tree seedling recruitment, they must produce resources (e.g. fruits or nectar-rich flowers), which attract seed-dispersing animals. These animals transport seeds of many additional tree species from nearby forest remnants into the planted sites. It is this subsequent generation of naturally established trees, which restores the tree species composition to that of the original forest.

What management is required?

Between 20 and 30 framework tree species are planted, spaced about 1.8 m apart (about 3,086 per hectare). Mulching and frequent weeding are essential for at least 2 years after planting, to prevent weeds from smothering the planted trees. Fertilizer application accelerates tree growth, resulting in rapid canopy closure, which shades out the weeds. In seasonally dry climates, fire prevention is also essential. Naturally established trees are nurtured and protected from fire in the same way. Preventing hunting is also necessary to conserve populations of seed-dispersing wildlife.

Does the framework species method have limitations?

For recovery of tree species richness, the framework species method depends on nearby, remnant, forest to provide i) a diverse seed source and ii) habitat for seed-dispersing animals. In fragmented, upland, evergreen forest sites in northern Thailand, medium-sized mammals such as civets may disperse seeds of some forest tree species up to 10 km. So the technique can potentially work well within a few kilometres of forest remnants. Scattered trees can also provide a seed source for recovery of some tree species.

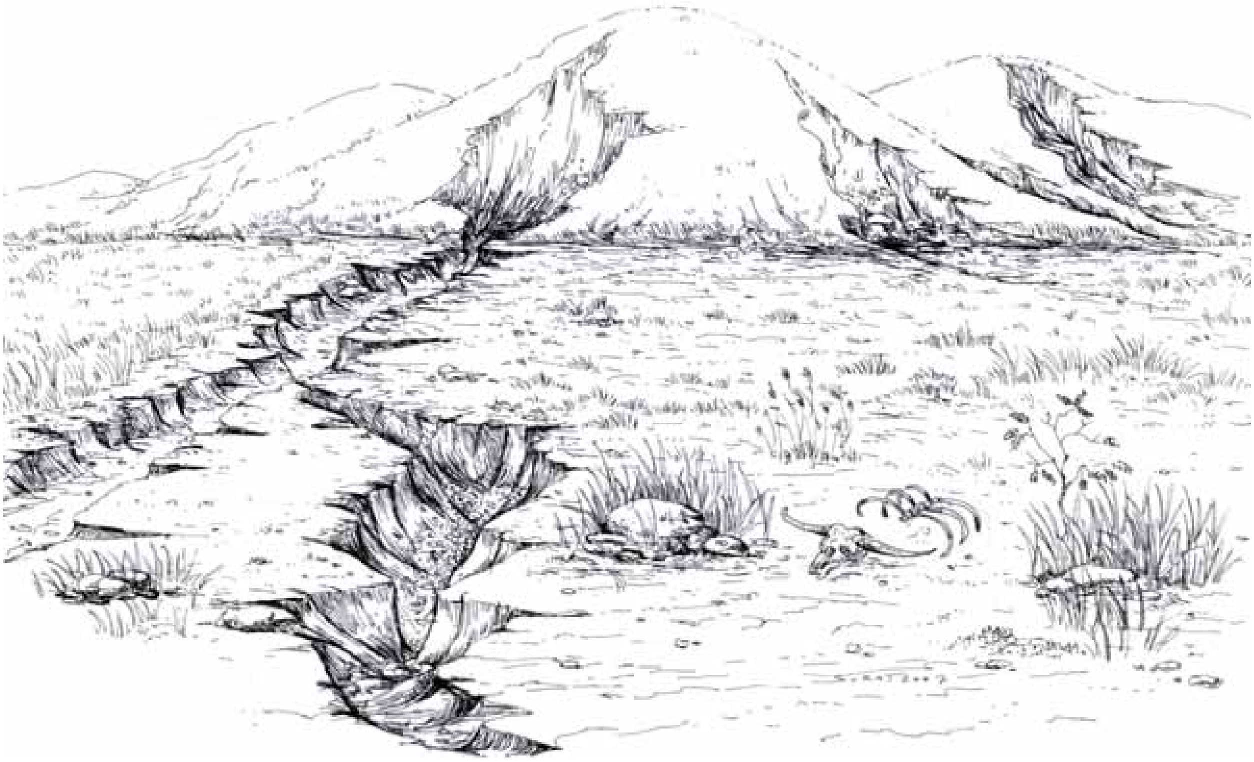
If seed sources or seed dispersers are absent from the landscape, recovery of tree species richness will not occur, unless nearly all tree species from the original forest are replanted – either as seeds or saplings raised in nurseries. This is the “maximum diversity” approach to forest restoration.

Maximum diversity plantings

Several methods have been developed to restore as much of the tree species richness of the original forest as possible, without relying on natural seed dispersal. These include the maximum diversity method of Goosem and Tucker (1995) and the Miyawaki method (Miyawaki, 1993). Both techniques involve rigorous site preparation, followed by planting a large number of tree species and intensive aftercare for several years. Planting a range of tree species instantly enhances tree species richness. As the trees grow, structural diversity of the forest is restored and diverse wildlife habitat is created, although if the site is a long way from remnant forest, overall biodiversity recovery will be limited. These methods are very costly, since the “free service” of natural seed dispersal is replaced by expensive tree planting. Seed collection and propagation of the very

Level 5 Degradation

Site Factors		Landscape Factors	
Vegetation	Sparse: herbaceous weeds	Forest	Absent within seed dispersal distances of site
Soil	Significant soil erosion	Seed dispersers	Mostly gone
Sources of regeneration	Very few	Fire risk	Very high



Appropriate response for biodiversity conservation	Improve soil conditions by planting "nurse trees" (e.g. pioneer legumes) – followed after a few years by thinning and maximum diversity plantings.
Appropriate response for economic yield	Ensure that nurse trees yield economic income to local people when they are thinned. Select tree species that also yield economic products; or establish conventional plantations of one or a few high value tree species capable of withstanding the degraded soil conditions.

wide range of tree species that com-prise a tropical forest is both technically difficult and costly. Also a lot of research is needed to achieve an effective plantation design.

Nurse Trees or Foster Ecosystems

Where degradation has progressed to the point of loss of top soil, extreme measures may be needed before any of the techniques described above can be applied. This usually involves planting hardy tree species, that can thrive in the harsh conditions of eroded sites. “Nurse” trees improve site conditions, by shading out weeds and producing leaf litter. This increases soil organic matter and moisture-holding capacity. Nurse trees are then gradually removed, as framework tree species are planted (where forest remnants survive in the landscape) or maximum diversity plantings implemented (where forest remnants are absent).

Nurse tree species are fast-growing pioneers, with dense broad crowns and high fire resilience. Legumes are ideal, since they add nitrogen to the soil via their leaf litter. Selected tree species should also yield an economic benefit to local people. Since nurse species do not remain in the final forest ecosystem, exotic species can be used, provided they are not invasive. A critical consideration in this type of forest restoration is how to harvest the nurse tree crop without damaging natural regeneration in the understorey

What about economic forestry?

The primary aim of this book is to stimulate research to develop forest restoration techniques for biodiversity recovery and environmental protection, but where human settlements are present, economic considerations may have a higher priority than biodiversity conservation. In such cases, more productive forms of forestry may be needed. However, even intensive forest systems can be made more beneficial to biodiversity, if they are managed sensitively.

Table 1.1 - Summary of main forest restoration approaches and their uses

	Characteristics	Suitable for...	Advantages	Disadvantages
ANR	Fire prevention, weeding, direct seeding, cattle removal etc. to maximize performance of surviving trees and to enhance tree species recruitment.	Sites, close to natural forest, with high densities of live tree stumps and naturally established tree seedlings and saplings; where further degradation can be prevented.	Low technical and financial inputs; can be implemented easily over large areas.	Results in a secondary forest with mostly pioneer species. Recolonization by climax forest tree species delayed.
Framework species method	ANR techniques applied to surviving woody vegetation PLUS planting 20-30 carefully selected indigenous forest tree species, which rapidly shade out weeds, close canopy and attract seed-dispersing animals.	Sites dominated by herbaceous weeds with few trees but with natural forest fragments and seed dispersing animals surviving in the landscape.	Rapid site re-capture and recovery of forest structure and function; biodiversity recovery through attraction of wildlife and natural seed dispersal.	Requires research and high technical and financial inputs to develop an efficient system. Biodiversity recovery may be slow where natural forest and/or key seed-dispersing birds and mammals are absent.
Maximum diversity plantings	Forest succession is short-circuited by planting most forest tree species in a single step.	Where natural seed dispersal is limited by lack of seed sources and/or seed dispersing animals.	Tree species diversity is instantly restored; rapid recovery of forest structure and function.	Very expensive. High technical inputs required. Obtaining seeds and growing so many tree species is logistically difficult.
Nurse crops or foster ecosystems	One or a few fast-growing tree species planted to ameliorate site conditions for subsequent planting of a greater diversity of tree species.	Where site degradation has resulted in deteriorated soil and microclimatic conditions that would reduce performance of most planted tree species.	Rapid site capture; prevention of further erosion and gradual improvement of site conditions.	Low biodiversity value initially; but an unavoidable step where site degradation is severe. Harvesting nurse crop yields economic income.

Plantations as catalysts

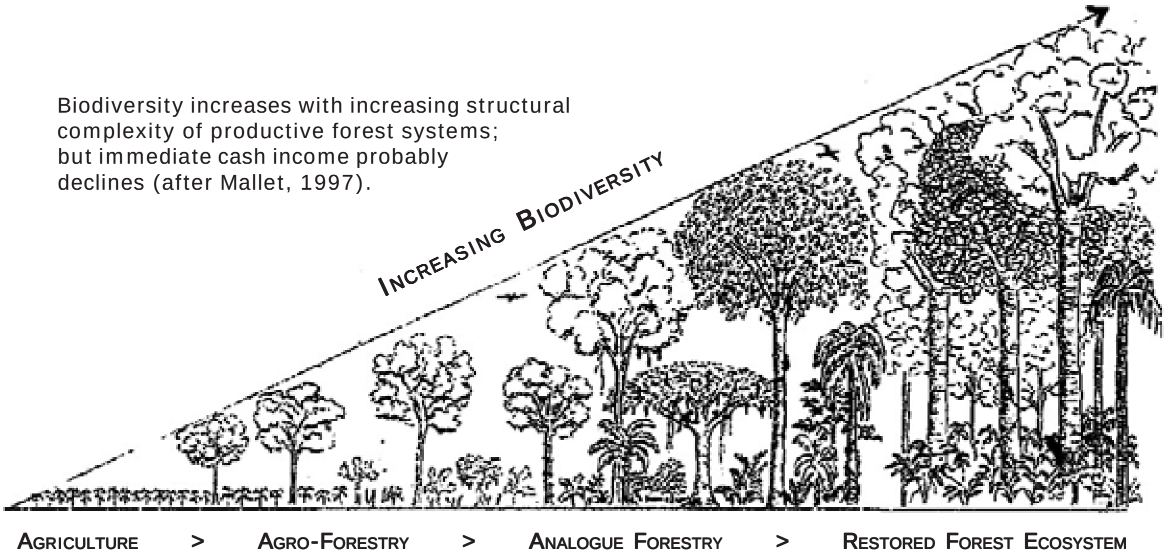
Even conventional commercial tree plantations of one or a few tree species can promote biodiversity recovery to some extent. Compared with degraded land, dominated by herbs, tree plantations can significantly accelerate forest succession by shading out weeds and attracting seed-dispersing animals (Parrotta, 2000). The extent that conventional plantations can do this is considerably less than that of framework species plantings, but obviously the economic yield of such plantations are higher.

Biodiversity recovery in plantations can be encouraged if silvicultural practices are carried out sensitively. Weeding, thinning and removal of the final cut must be done without damaging the natural regeneration that the plantation has helped to foster. There are many examples around the world where plantations of commercial species have been established and subsequently abandoned due to changes in economic conditions. If the species planted are short-lived pioneers, they can be harvested, or they eventually die naturally, making way for a floristically rich secondary forest (Parrotta, 2000). However, if new plantations are intensively managed, it is less likely that they can play an important role in forest restoration.

Accelerated pioneer-climax series (APCS)

Plantations can be made more “biodiversity friendly” by planting several species and taking ecological succession into consideration. This is the approach being developed in Vietnam with the accelerated pioneer-climax series (Van So, 2000). APCS follows the principles of natural succession by planting a small number of pioneer species, followed later by inter-row planting with climax species. This restores soil productivity and ecological balance. Pioneers are chosen for their high growth rates, and also the provision of wood products for farmers in the short term, so they are gradually removed as the system matures. Consequently they may include exotic as well as native species (Van So, 2000).

Biodiversity increases with increasing structural complexity of productive forest systems; but immediate cash income probably declines (after Mallet, 1997).



Agro-forestry

Agro-forestry increases and diversifies economic benefits from forestry by adding crops and/or livestock to the system. Since trees remain dominant, some habitat for wildlife is retained. Multi-purpose trees are usually planted, i.e. those that improve soil, produce fodder for domestic animals and/or fruit for human consumption. Selection of native forest tree species (rather than exotics) can increase the benefits of agro-forestry for biodiversity. However, wild birds and mammals are not well-tolerated in agro-forestry systems, since they are often regarded as pests, which threaten crop productivity.

Analogue forestry (AF)

Analogue forestry has similar aims as agro-forestry but retains the overall structure of mature tropical forest; substituting economic species for each of the plant life forms that contribute to forest structure. AF restores degraded forestlands with productive and biodiverse agro-forests that meet the extractive needs of local people (e.g. firewood, timber, foods, medicines etc.), whilst maintaining ecological integrity. Emergent or canopy trees are retained for shade and resin production. Shade tolerant crops, such as coffee and bamboo, form the shrub layer, whilst vines may be replaced by pepper and woody lianes by rattans. The ground layer may be replaced with culinary or medicinal herbs such as ginger.

AF recognizes that high biodiversity is essential for the stability and productivity of the system. Therefore, a significant proportion of the species present may have no direct human use, but they are planted or retained for their ecological value. One of the economic drawbacks of AF is the difficulty of marketing the great diversity of products produced in relatively small quantities.

Table 1.2 - Summary of forest reforestation methods with higher economic benefits

	Characteristics	Uses for Biodiversity	Advantages	Disadvantages
Plantations as catalysts	Conventional single-species plantations of high value tree species; exotic or indigenous.	Plantations may foster limited natural regeneration and biodiversity recovery in their understories, provided forest fragments and seed dispersers remain.	High economic income from high value commercial tree species.	Unpredictable changes in market conditions may affect profitability. Sensitive management of the plantation to foster biodiversity recovery may reduce profitability.
Accelerated pioneer-climax series	Plant rows of pioneers and later inter-rows of climax tree species.	More complex forest structure compared with conventional plantations; more likely to enhance biodiversity recovery.	Mimics natural forest regeneration whilst also providing an income. A greater variety of species helps to spread economic risks in changing market conditions.	Sensitive management of the plantation to foster biodiversity recovery may reduce profitability.
Agro-forestry	High density plantings of a few economic tree species mixed with crops and/or livestock production	Some advantages gained through greater variety of plant species planted.	A wide range of crops and tree products and the adaptability of the system reduce economic risks.	Complex maintenance procedures for the many economic species present add to costs and disturbs wildlife.
Analogue forestry	A tree dominated ecosystem, analogous in structure and ecological function to local forest ecosystems, but which also yields economic benefits.	Increased biodiversity is an underlying goal. Includes up to 20% of species planted for ecological value.	Farmers benefit through use of species that provide marketable products; restores biodiversity and encourages development of a more natural ecosystem.	Strong dependency on external inputs: research, training and funding. Marketing many products in small quantities problematic.

SECTION 3 - FOREST LANDSCAPE RESTORATION

What is Forest Landscape Restoration?

Within a landscape, several of the different kinds of forestry described above may be implemented, on different sites, to achieve a balance between biodiversity conservation, environmental services and economic productivity. This is the basis of “Forest Landscape Restoration” (FLR), which is being promoted by many international organizations. It aims to regain ecological integrity and enhance human well-being in deforested or degraded forest landscapes (Mansourian *et al.*, 2005).

To conserve biodiversity, FLR recognizes the need not only to protect and manage any remaining forest, but also to restore it. It balances human needs with those of wildlife, by restoring a range of forest functions to the landscape. Planting trees is an important component, but it is only one of many activities that contribute to FLR. Local communities play a critical role in shaping the landscape, and gain significant benefits from future forest resources, so their participation is critical.

Landscapes include geology, land form, vegetation, ecology, human influence, socio-economic characteristics, climate and history, which combine to provide an area with a unique local identity. Where local communities have used forest as a source of forest products, or cleared areas for agriculture, landscapes may consist of a mosaic of vegetation types, including agricultural land, plantations, community forest, remnant primary forest and regenerating secondary forest. A “degraded” landscape is one that is no longer able to maintain an adequate supply of forest products or ecological services for human well-being, ecosystem functioning and biodiversity conservation.

To conserve biodiversity, FLR recognizes the need to protect and manage remaining forest and restore forest to degraded areas. At the landscape level, conservation priorities must be balanced with those of local communities. Achieving such a balance can be a complex undertaking and can require many compromises.

What can FLR achieve?

By working closely with local communities, through consultation, training and information exchange, FLR can:

- Restore environmental functions by planting native trees, ANR or natural regeneration.
- Provide benefits to local communities, e.g. medicines and food, clean water and protection from flooding and landslips.
- Encourage people to engage positively in forest restoration, because of socio-economic and ecological benefits.
- Address the root causes of forest degradation, such as over harvesting or browsing.
- Improve the quality of forest fragments for wildlife.
- Balance land-use trade-offs at the landscape level, which are acceptable to all stakeholders.
- Reverse the threat of further deforestation.