

# Natural regeneration and rainforest restoration

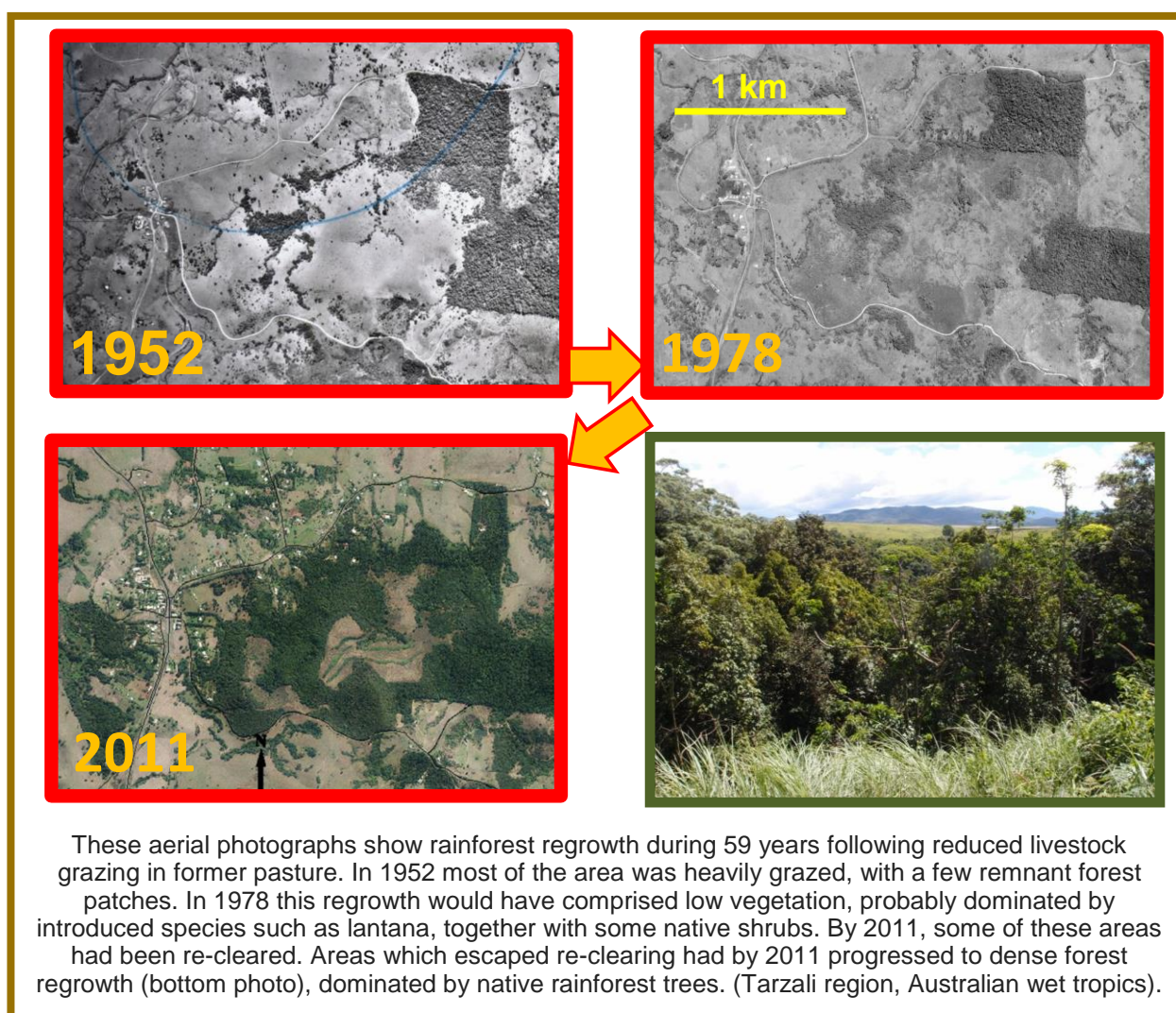
## - outcomes, pathways and management of regrowth

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About half of the world's tropical forests have suffered some form of clearing, mostly for conversion to agricultural land. This has generated significant carbon emissions, depleted important ecosystem services (such as flood mitigation) and threatened global biodiversity. Natural forest regeneration following retirement of agricultural land will help to reverse these declines.

This fact sheet discusses the nature of regrowth in rainforest landscapes, its pathways of development, associated uncertainties, and how it could be harnessed in conservation efforts.



<http://e-atlas.org.au/nerp-te/wt-griffith-cost-effective-rainforest-restoration-12-2>

# What is regrowth and why is it important?

Photo: Kylie Freebody



Rainforest regrowth patch about 30 years old, in retired pasture (Atherton Tablelands, Australia).

Reforestation of cleared land can occur through a variety of different pathways. These may be **active** – when people intervene to accelerate the establishment of trees, typically by planting them for timber or environmental reasons.

However, often they are **passive** – when trees establish through unassisted regrowth, also termed natural regeneration. Box 1 (below) explains these and other relevant terms.

Globally, the area of regrowth forest greatly exceeds the area of planted forest, and its extent is continuing to increase – associated with both the degradation of agricultural land and a shift in human population from rural to urban areas.

The current trend for increasing area of regrowth forest has in some regions reversed the net decline in forest landscape cover caused by extensive clearing in the 19th and 20th centuries. This raises the question: can reforestation rescue declining rainforest biodiversity?

The answer is: “partly”. Research has shown that regrowth forest can:

- provide habitat for some declining species;
- buffer or link forest remnants to help reverse species’ declines; and
- provide habitat that may help species survive climate change.

Regrowth also directly removes carbon from the atmosphere; protects watersheds from erosion; stabilises stream banks; improves soil quality; and undertakes many other important ecological functions. Many of these functions do not require the regrowth forests to have a similar species composition to that which occurred in the original forests.

However, there is also strong evidence that most regrowth areas lack some important features and species that characterise old-growth forest, and therefore cannot be a substitute for uncleared forest. But conservation biologists also agree that protecting the remaining old-growth and remnant forest will not on its own avert further declines in biodiversity and ecosystem services. Reforested areas are indeed needed - but in addition to, rather than instead of, remnant forest.

There is current debate about what limits or increases the environmental values of regrowth rainforests, and also about their potential for regeneration success. Some answers have recently begun to emerge through scientific research into both active and passive restoration.



Inside a well-developed 42 year old regrowth patch (Australian wet tropics).

Photo: Carla Catterall

## Relevant terms and definitions, as used in this fact sheet.

**Regeneration** is the process of tree recruitment, establishment and growth.

**Secondary succession** is the ecological sequence of vegetation development over time after severe disturbance or deforestation, and involves changes in both physical structure and species composition.

**Oldfield succession** is the vegetation development after a time of agricultural land use which has ceased.

**Pioneer species** are the tree species which are the first to establish during secondary succession.

**Arrested succession** occurs when some factor has prevented or stalled the development of vegetation.

**Reforestation** is the re-establishment of forest (of any sort) on land that was once forested but then cleared.

**Restoration** is the return of a self-sustaining indigenous ecosystem following human-induced disturbance.

**Passive** reforestation or restoration is **unassisted**, i.e. it occurs without intensive human intervention.

**Active** reforestation or restoration is **assisted**, i.e. it occurs with (and depends on) human intervention.

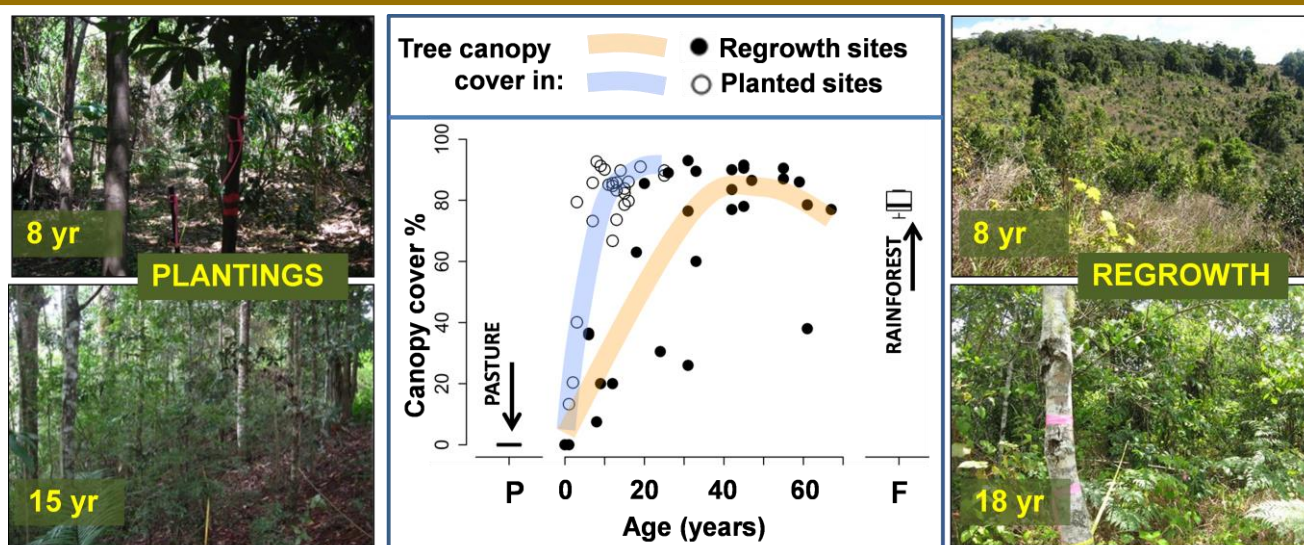
**Secondary forest** is forest that returns after severe disturbance or deforestation, either passively or by active restoration.

# Understanding how rainforest regrowth occurs

The process of vegetation development during both assisted and unassisted forest restoration is slow. It takes decades for large-diameter trees to grow, and may take centuries for them to form hollows, fall and decay. It would take a very long time to monitor the changes at any individual site. Fortunately, it is possible to gain some insights into this process by measuring vegetation characteristics within **chronosequences** of reforested sites that vary in age (i.e., differing numbers of years since their redevelopment commenced).

## Pathways of regrowth development

It is reasonable to expect that a well-designed tree-planting could accelerate the rate of forest recovery, and this is supported by research. For example, in the study shown below, sites replanted at high diversity and density took about 10 years to develop a tree canopy as dense as that seen in mature remnant rainforest, compared with 30-40 years on average for regrowth sites.



This graph shows the differences in % canopy cover among replanted and regrowth sites that vary in age (each point represents a different site). The blue line shows the average trajectory of development in replanted sites aged 1-25 years, and the orange line shows regrowth sites aged 1-67 years.

The ranges of canopy cover values typically seen in pasture and mature rainforest are also shown.

Regrowth sites had a more variable development rate: some had very high canopy cover within 20 years, while a few remained sparse and open even after 30-60 years. On average, their development was slower.

Canopy cover in the best-developed sites, whether replanted or regrowth, exceeded that in rainforest - probably because they lack the natural "light gaps" which form in mature forest when large trees fall.

All measured sites were on the Atherton Tablelands of the Australian wet tropics (the authors, unpublished data).

Photos: Kylie Freebody

Looking into the canopy: regrowth sites typically have lower canopy cover than similar-aged replanted sites



Canopy cover is one of the simplest rainforest characteristics.

Nevertheless, it is a useful indicator of early development because the tree canopy has important functions of providing habitat for fauna, shading the ground, and regulating local climate.

Many other characteristics of rainforest develop more gradually. And various factors can slow the progress of even the early stages of canopy regeneration, especially in regrowth sites.

## What factors limit rainforest regeneration?

Retired agricultural land may remain in a state of **arrested succession** for extended periods if forest trees are slow to establish. A sequence of factors determines whether this will occur (see diagram).

**Ecological barriers** involving both fauna and physical factors can limit the spontaneous development of rainforest regrowth at three stages.

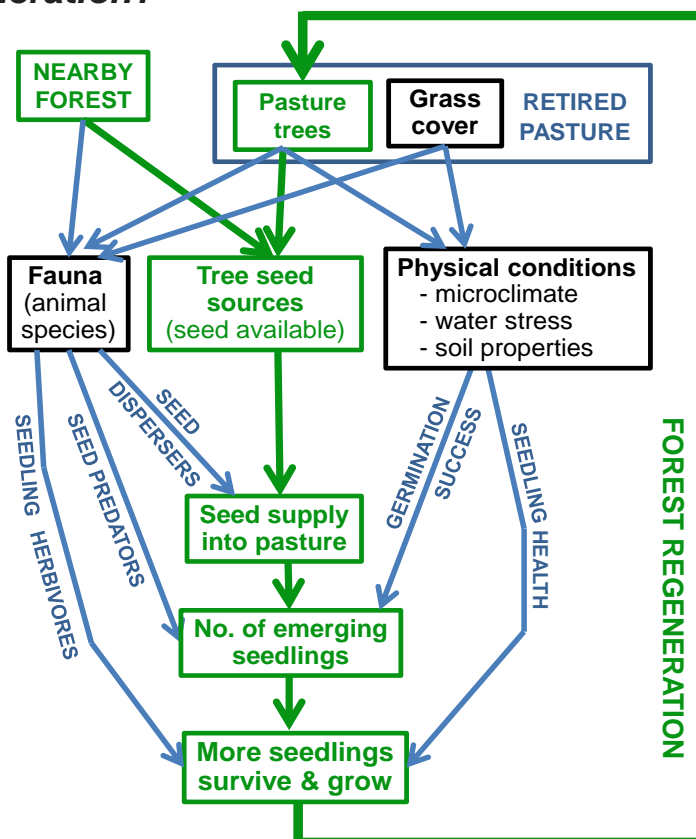


Photo: Carla Catterall



Fruit-eating birds such as this figbird move seeds around.

**1. Seed supply.** Most rainforest trees have short-lived seeds, and therefore agricultural soils rapidly lose their “bank” of stored seeds. Regrowth can only occur if new seeds are dispersed into an area. This dispersal depends mainly on the presence and movements of fruit-eating birds. Most rainforest trees encase their seeds in edible pulp to attract seed dispersers. Fruit-eating birds that fly across open spaces can transport forest seeds into regrowth areas. Unfortunately the most effective seed-dispersing bird species are typically reluctant to venture away from the edge of intact rainforest habitat, and are often absent if forest remnants are small. A few species will make such movements if suitable perches are available, but even these rarely perch in open grass.

**2. Seed survival and germination.** To produce viable seedlings, the transported forest seeds must survive and germinate. Animal predators can greatly reduce survival: the larvae of beetles and other insects consume seeds from within, and mammals such as rodents (native or introduced) destroy or digest whole seeds. Seeds’ germination can be inhibited by unsuitable local physical conditions, such as insufficient light, moisture, or disturbance.

**3. Seedling survival and growth.** Physical conditions and fauna also combine to limit the survival and growth of seedlings. They need a supply of light, water and nutrients to grow: in areas of former pasture, vigorous grasses (or other ground-covering plants) are often more effective at competing for these resources. Herbivorous mammals can destroy young seedlings in a single bite, and insect herbivores (such as beetles and caterpillars) can slow their growth.

Research is beginning to reveal worldwide similarities in how these barriers act. By gaining a better knowledge of the factors involved, we can understand why some sites develop faster than others, and make better decisions about what kinds of interventions could speed up forest regeneration.



Both native and introduced rodents eat rainforest seeds.

Photo: Terry Reis



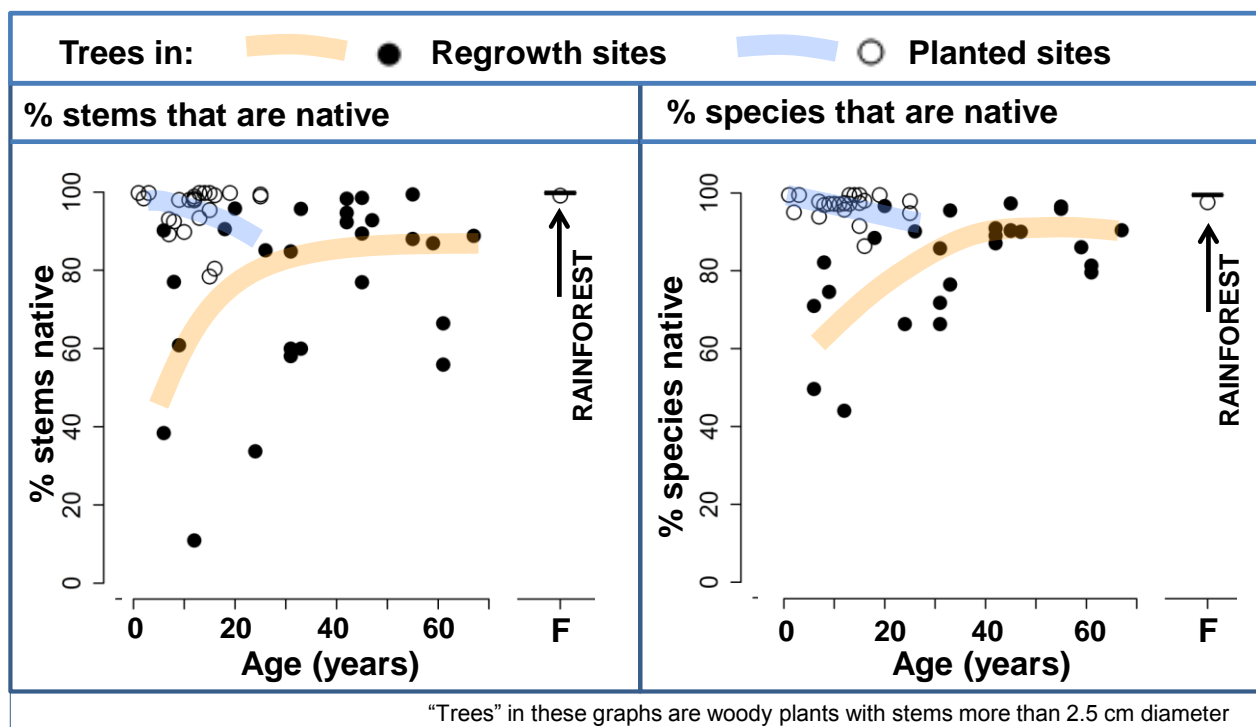
Herbivorous mammals, such as this pademelon, feed on seedlings.

Photo: www.thalabeach.com.au/

## Complex roles of introduced plants in regrowth

For reasons that are not well understood, in some tropical regions the first trees to establish and grow in areas of disused pasture are often invasive species. These **non-native pioneers** produce fleshy fruits which are spread by birds, and their seedlings appear able to compete well with pasture grasses and can grow rapidly. Once sufficiently grown they provide perches and food for fruit-eating birds which are then more likely to bring in the seeds of native rainforest plants.

Over time the native rainforest species accumulate and in some landscapes will often be the majority of canopy trees in passive regrowth after several decades (see graphs, below).



These graphs show how the proportions of native and non-native trees change over time in regrowth and replanted sites on the Atherton Tablelands of the Australian wet tropics. Blue lines show replanted sites aged 1-23 years, and orange lines show regrowth sites aged 1-67 years. Values in relatively undisturbed mature rainforest (typically almost 100% native species) are also shown.

In the youngest regrowth sites, native trees were only about 40% of stems and 60% of species in the first five years, and non-native trees dominated. But after several decades the natives increased to become the majority of trees - around 80% of stems and 90% of species after three decades.

Only native seedlings were planted in the actively restored sites, but over time the percent of trees that were native dropped; to around 90% of stems and 95% of species after two decades - this occurred because the seedlings of non-native species colonised these sites (the authors, unpublished data).



Inside this 67 year old regrowth patch, once-dense lantana has died off to a few stems (arrowed), probably because it needs more light than is now available in the shady understorey.

In most Australian rainforest landscapes common non-native species include lantana (*Lantana camara*), wild tobacco (*Solanum mauritianum*) and camphor laurel (*Cinnamomum camphora*). Over time, there is a complex balance between facilitation and inhibition by these woody weeds, which is poorly understood, and needs more research.

For example, the non-native plants may facilitate rainforest regeneration as described above, or in some situations may slow further forest development, if they form a dense canopy which could slow or suppress the growth of the rainforest seedlings beneath. Understanding and working with this balance is a major challenge in rainforest restoration.

## Intervening to stimulate, accelerate or redirect regrowth

Tree planting, if done in certain ways, can achieve a rapid development of forest cover by directly overcoming many of the barriers described above. However, this incurs considerable cost, which limits such plantings to small areas of land. In recent years, practitioners and researchers have begun to devise and test a more varied menu of possible lower-intensity approaches, aimed at harnessing or redirecting the process of forest regrowth rather than replacing it with planted trees.

Many of these interventions begin at either end of a spectrum of potential starting points:

**1. If very few established trees** are initially present, then interventions focus on removing the early barriers to regeneration described previously. There are two important types of action.

- **Increasing the seed supply** can be achieved either by direct seeding (sowing the seeds of suitable tree species) or by installing artificial perches for seed-dispersing birds. Early trials have shown that the success of both these approaches can be low, and varies greatly.
- **Suppressing herbaceous vegetation** such as pasture grasses can be achieved directly through methods such as cutting, pulling, herbicide or burning, or indirectly through low intensity grazing (although the latter method has been infrequently trialled).

The box below gives an example of some of these interventions. A recent scientific review has shown that combined approaches that simultaneously address different barriers (e.g., increasing the seed supply while also suppressing pasture grasses) are likely to be more effective than single-factor interventions. Additionally, there is a wide range of other emerging approaches, such as applied nucleation - planting small tree clumps to create forest islands capable of future expansion.

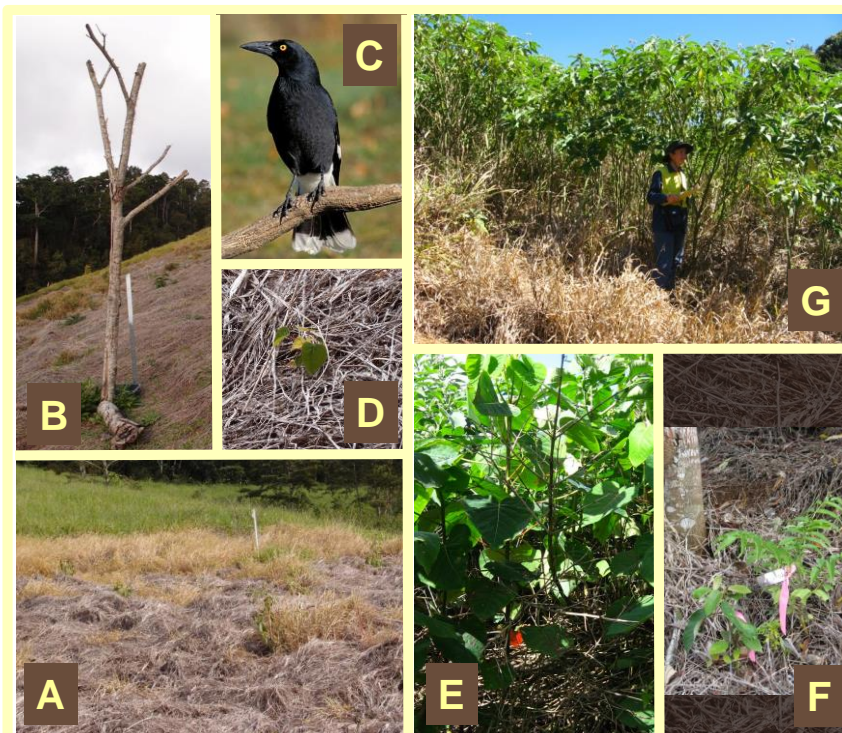
### CASE STUDY: KICKSTARTING FOREST REGENERATION IN RETIRED PASTURE

Here, barriers to forest regeneration were removed by suppressing grass with herbicide (A), and adding structures (B) to attract seed-dispersers (C).

Seedlings (D) emerged rapidly through dead grass – some reaching 2 m tall in a year (E). Relative to untreated pasture, native rainforest seedling densities 20 months after treatments began had increased by about:

X 50 for herbicide only,  
X 800 for herbicide beneath perches, and  
X 1500 for herbicide beneath pre-existing small trees (F); whether these were native or non-native.

Another striking outcome was the rapid emergence of a new tree canopy, formed by non-native wild tobacco (G).



Photos: Kylie Freebody, Carla Catterall, www.petermoulding.com/

**2. If established trees at moderate density** are present, then regeneration processes must already be under way, and methods of “**assisted natural regeneration**” (ANR) can be used. Worldwide, this has most commonly taken two forms.

- In tropical Asia, ANR is considered potentially useful if small saplings of rainforest trees are already established among pasture grasses at densities exceeding 700/ha, but without a closed canopy. Manual suppression of the grasses around these saplings is then used to shift the competitive balance, which helps the saplings grow large enough to shade the ground.
- In the Australian subtropics, ANR (as “bush regeneration”) is practised in areas where secondary forest has become established, but is dominated by non-native trees or shrubs (and sometimes vines), together with a seed or seedling bank of native rainforest trees. Herbicide applications are then used to kill the former and accelerate the growth of the latter.

# Strategic use of regrowth in conservation and restoration

Potential approaches to rainforest restoration on former agricultural land range in intensity from tree planting, through assisted regeneration techniques, to simply allowing vegetation to recover on its own over time. These approaches vary in their relative costs, speed, and likelihood of success in different situations. Also, funds are always limited.

Strategic approaches are needed to achieve the best outcome in both area and quality of restored vegetation, relative to available funding. Such approaches combine and consider information on an area's potential ecological importance, its likely speed of recovery if simply left alone, the likely costs and outcomes of alternative restoration actions, and the desired timeframe and resources available.

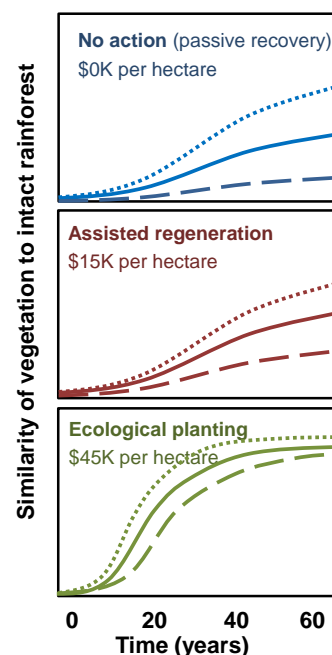
Current knowledge is not sufficient to enable confident evidence-based choices of which restoration method or portfolio of methods will be most cost effective for any particular restoration goal in differing circumstances. Many rainforest restoration projects have understandably continued to favour intensive tree-planting, in the absence of persuasive evidence for the efficacy of other approaches.

To overcome these information gaps we need a wider range of carefully designed restoration experiments, coupled with longer term quantitative assessments of both their costs and their outcomes over short and long time periods. In turn, these must also be compared with the long-term costs and outcomes of doing nothing other than ceasing agricultural land use.

In the long term, extensive forest recovery can occur without assistance, through natural regrowth over large areas if agricultural activities cease. However, the possibility of natural regrowth is not often considered in strategic restoration plans, perhaps because of the uncertainties in expected outcomes. Further investigations of the trajectories of regrowth over time and planning tools that allow proper treatment of uncertainty will both help to address this limitation.

The emerging knowledge in this field is also revealing how retention of existing remnant forest patches and individual trees is important not only for their own difficult-to-restore environmental values, but also because of the contributions which they make to the processes of forest regrowth in the surrounding landscape.

A hypothetical example of how three different approaches to reforestation (no action, assisted regeneration, intensive replanting) could be strategically compared.



Each graph shows the rate of vegetation development under three scenarios: optimistic (dotted lines), medium (solid lines), and pessimistic (dashed lines). The possible cost of each is also shown.

Depending on the speed, quality and total area of desired reforestation, together with the project budget, a manager may choose any of these specific approaches.

Other factors such as the amount of nearby forest are also likely to affect these development rates.

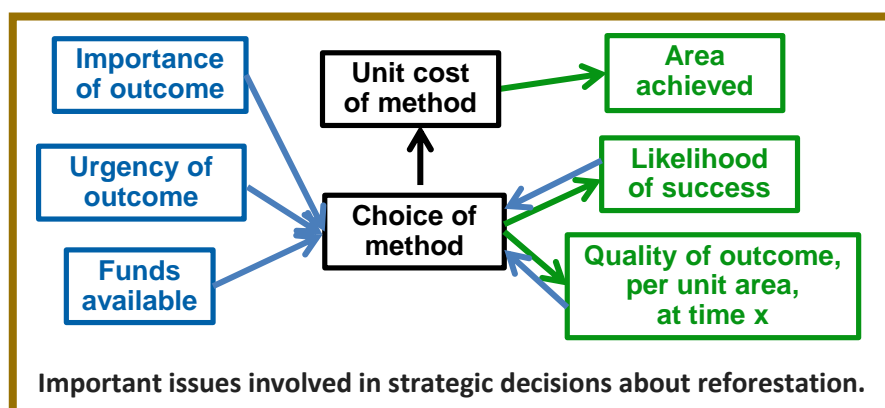


Photo: Kylie Freebody

## Further reading

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