A Revegetation Guide for Northern Savannas

Australian Government
Department of Sustainability, Environment, Water, Population and Communities

Greening Australia

Landcare Australia

A REVEGETATION GUIDE FOR NORTHERN SAVANNAS

Who this guide is for?

The landscapes of northern Australia are dominated by tropical savanna vegetation that varies from sparsely treed grasslands to denser eucalypt woodlands (Photo 1) and open forests. The driving force of the tropical north is the strongly contrasting monsoonal wet and dry seasons. Water is a critical component. Embedded within northern savannas are numerous small, but intrinsically important, patches of other vegetation such as monsoon vine forests and riverine or riparian forest. Wetlands of various sizes are also dispersed between northern savanna vegetation.

Although largely intact, the northern savannas face many threats. Invasive plants and animals, changing fire regimes, and agricultural, industrial and urban expansion all threaten to impact on the natural values that are essential for a healthy landscape. The increase in land clearing and degradation of natural areas means the need for effective natural restoration is growing.

This 'how to' guide to revegetation and regeneration of northern savannas is primarily focused on the 'Top End' savanna region of the NT. This information also has relevance to areas of tropical (wet-dry) northern Queensland and Western Australia. This guide describes eight key steps that need to be followed to help ensure a successful revegetation project.

Photo 1. – A typical savanna woodland near Darwin with an open eucalypt canopy, a mid story of young trees with palms, and a grassy groundcover.

STEP 1.

Assess site conditions

It is essential to gather as much information as possible on the site's history and current condition. Try and answer all of the following questions.

Has the landscape been altered by grazing, fire or clearing?

The impacts of land uses that degrade natural areas include inappropriate fire (too often or too hot), overgrazing by cattle and ferals, or loss of tree cover from past clearing. Often you need to look at what's missing. Compare your site with similar vegetation in good condition like a nearby nature reserve (a reference site). Are certain plant species missing on your site, or are native plant densities too low or too high compared to your reference site?

Is there evidence of weeds within or surrounding the site?

Invasive weeds have a detrimental impact on revegetation or regeneration projects of any size. When assessing site condition it is important to take note of any weeds. Check out the Further Reading section below for suggested resources to help you identify weeds in your area. You might also need the help of a local plant expert to make sure you are identifying plants that are weeds rather than natives.

Depending on the time of year (e.g. wet season), soil conditions and recent activity within the site, weeds may or may not be visible. If the area has been recently burnt, then weeds are likely to be hard to spot. Make sure to check surrounding areas for weeds. Even if weeds are not yet established within your site their invasive nature means they could quickly move in. Weed prevention is much easier and cheaper than treatment.

Weed seed is easily spread by movement of people, animals and machinery into and out of the site. Every time you visit your site, make sure you are not contributing to the problem by checking all shoes, clothes, machinery and vehicles for weed seed before entering and exiting the site.

Mission and Gamba grass are some of the most aggressive and invasive weeds of the northern savannas (Photo 2ab). These pose serious threats to any revegetation project as they will smother and out compete native seedlings. Identify and develop ways to deal with weeds early on in your project. This will save you time, money and effort in the long run.

Photo 2a.

Photo 2b.

Photo 2(a-b). Grassy weeds must be controlled before and after planting with natives. Common weeds include (a) gamba grass *Andropogon gayanus* and (b) mission grass *Pennisetum polystachion*

Any signs of feral animals?

Feral animals such as pigs and buffalo may be evident by the presence of wallows, soil disturbance, or loss of ground cover. Also keep your eyes out for tracks and droppings. Uncontrolled ferals can quickly destroy revegetation. They may eat or trample young plants, disturb soil, cause erosion or present a hazard to people. If you have identified that ferals are a problem it may be necessary to fence your site or put other protective measures in place.

Is there any waste or dumped material?

Any hazardous wastes dumped on your site need to be found and carefully removed. Dumped wastes are always a possibility particularly if you site is on the outskirts of a town or settlement. Contact youR local council if you're unsure.

Organic matter such as logs, branches and mounded soil may be present. These can often be incorporated into the revegetation of the site. For example logs and fallen branches can serve as habitat for reptiles and small mammals, or help reduce erosion. Depending on your specific needs, mounded soil can be spread and levelled, or used to construct erosion control earthworks. However, be mindful that disturbing and moving soil can increase the risk of erosion caused by intense tropical storms that typify the northern savannas.

Is there evidence of soil compaction?

Areas subject to vehicle or foot traffic, including access tracks and driveways, may become compacted over time. Compaction occurs in the subsurface soil layers from 10-40 cm deep. If the soil is heavily compacted it will be difficult for water to permeate or for new plants to take root. Click here to see ways of identifying soil compaction.

Are there signs of erosion, or areas in which erosion could potentially become a problem?

Erosion is common on degraded sites due to the lack of vegetative cover that assists in holding the soil together. If erosion is a problem within your site, it is critical that this is addressed early on in the project.

Examine the slope and soil surfaces of your site to understand how rainfall settles and flows across the site. This will help you to evaluate the need for erosion control measures. Signs of erosion may include:

- Rills and small gullies – erosion often starts when rainfall

cuts away small (a few mm) channels in the soil that can continue to scour and grow larger (meters) over time (Photo 3).

Photo 3. Reducing the risk of soil erosion is a major challenge due to intense rain storms that occur during the wet season. Rills have already formed on this steep bank.

- Sheet erosion is characterised by exposed tree roots or areas of bare soil caused when topsoil is washed away by the surface flow of rainfall.
- Undercutting is a naturally occurring process in rivers and streams, but this can be exacerbated when fringing vegetation is disturbed. Undercutting can cause bank instability, cave-ins and water pollution from large sediment loads.

Ways to remedying these problems are addressed in Site Preparation further on in the guide.

The potential for wet season flooding (inundation) may also affect your project. Depending on your species selection, some plants may struggle to survive if the soil remains waterlogged for too long. Also, flash flooding, or rapid movement of water through the site, may force newly planted seedlings out of the ground or wash away broadcast seed.

STEP 2.

Set clear site objectives

Answer the following questions to help set objectives for your revegetation. Clear site objectives are needed to help decide what species to plant, then how the site will be managed in the long term (Step 7). Clear objectives are also needed so you know what to monitor for measuring successes and failures (Step 8).

How will the site be used in the short and long term?

It is assumed that an objective is to improve the diversity and cover of native vegetation on your site. This can have many benefits including improving habitat for wildlife, reducing erosion or increasing pasture productivity for cattle. It is important to decide who will most benefit from revegetation of the site. Consider if your site will be used by the public, if it will be managed long term by the same landowner, or if it will contribute to a recognised nature reserve, or be used primarily for productive purposes like cattle grazing. Uses and beneficiaries of the revegetation should influence the amount of resources you put into the project and the method of restoration you choose to employ.

What do you wish to achieve by regenerating or revegetating the land?

Some examples include:

- Controlling erosion - perhaps your main goal is to manage or prevent soil erosion in and around the disturbed area. Grasses and fast growing pioneer species such as acacias are ideal in such situations.
- Restoring biodiversity and connectivity - do you want more birds on your land, or to help the local bandicoot population? By revegetating or regenerating the land you are creating habitat for native fauna and providing greater connectivity in the landscape.
- Improving aesthetic quality - maybe there is a greater need for shade or screening. By utilising native species you will contribute to greater diversity and beauty in your area.
- Providing food for livestock - the use of native grasses in large or small scale livestock operations is a more ecologically responsible practice than the use of introduced pasture species.

What is the best way to achieve your objectives?

Historically, much of the vegetation restoration that takes place in the northern savannas has been focused on stimulating natural regeneration. This is the re-establishment of naturally emerging plants, grasses and ground cover through weed control, erosion mitigation, controlling grazing and fire management. However, in areas in which the native vegetation has been cleared, subjected to other land uses, or become severely degraded, replanting or direct seeding of native species may be required.

What suits your particular situation the best; planting seedlings, direct seeding, allowing for natural regeneration or perhaps a

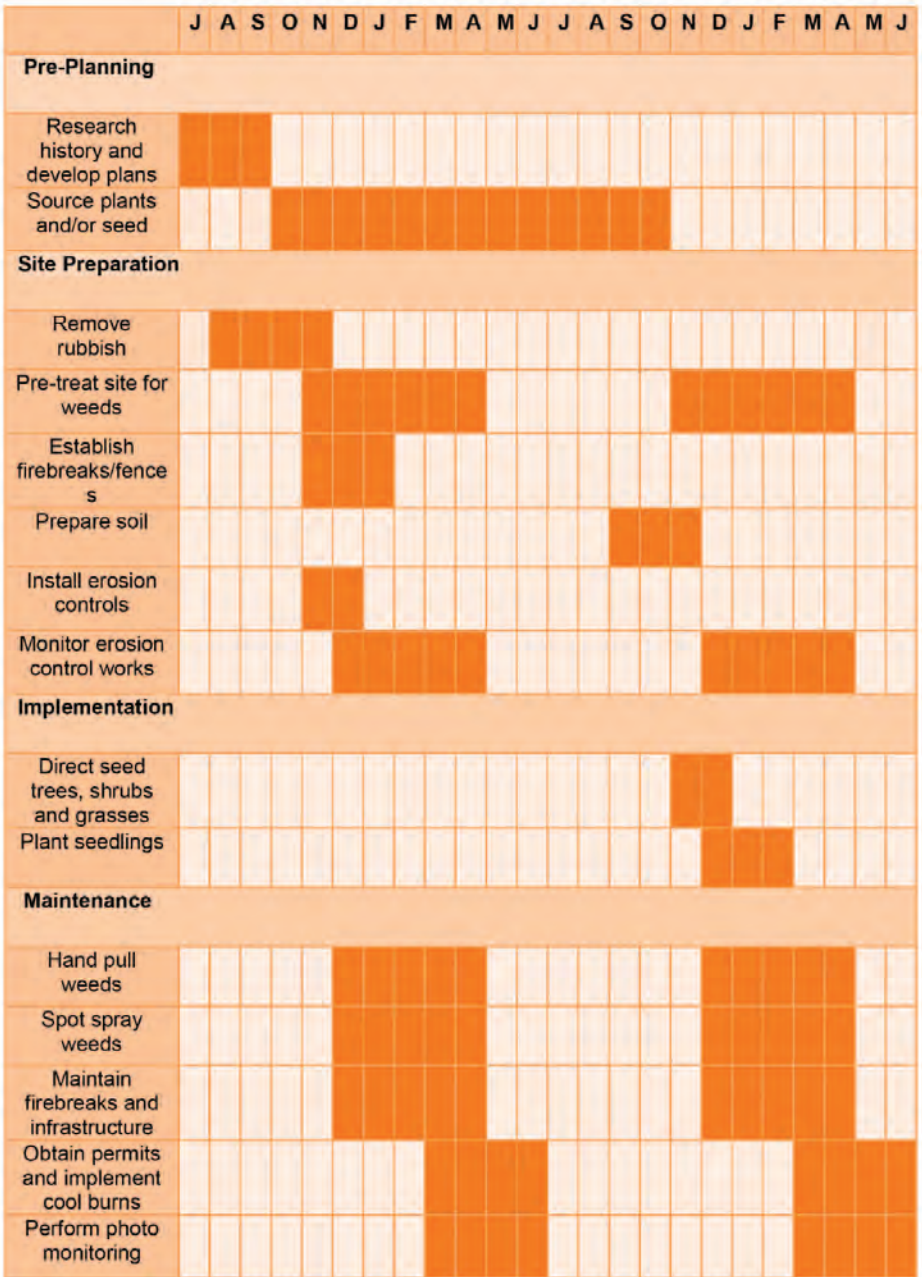
combination? A quick assessment of objectives, available resources and site conditions will help you determine which methods may work for your particular site. Section 6 of this guide provides guidance on stimulating natural regeneration, directly sowing seeds, and planting seedlings raised in a nursery.

STEP 3.

Site preparation

Prior to the commencement of any revegetation activities it is essential that proper and thorough site preparation is planned and carried out. Comprehensive site preparation improves the chances of success and makes maintenance easier. Site preparation needs to begin at least one year in advance of planting or direct seeding to ensure that the area is ready for planting or sowing early in the wet season.

When planning your project bear in mind that you can use a combination of methods to achieve your restoration goals. Perhaps you choose to plant tree and shrub species and then direct seed native grasses after planting. Whatever you decide, it is important that activities take place at the appropriate times. The table included is relevant to projects in northern Australia and provides guidance for the timing for restoration activities.



Erosion and sediment control

It is important to retain as much vegetation cover and cause as little soil disturbance as possible. This can be difficult if there is a need for weed control or soil preparation works that will disturb the soil. Ensure that soil is not left bare for long periods during the wet season.

To remedy erosion and control sediment you can:

- Locate silt fences, hay bales or coir logs so that runoff cannot wash down slope into waterways (Photo 4a).
- Strategically divert or slow water flow by creating woah boys or contour banks.
- Fill in gullies or rill lines.
- Install jute mesh (Photo 4b); matting or geotextile and stabilise areas with rocks or rock gabions.

Photo 4a.

Photo 4b.

Photo 4 (a-b). In small areas at risk of erosion, control structures such as (a) coir logs can be placed in a drainage line or (b) jute mesh laid across the soil surface before planting seedlings

Weed control

One of the most important aspects of any project will be weed control. Aim to begin treating your site for weeds at least 12 months prior to planting or sowing to eradicate any existing weeds and reduce the soil seed-bank. This will make the monitoring and maintenance phases of your project much easier. Herbicide application is an effective control method. See Further Reading for useful links to technical information on the use of herbicides.

If you choose not to use chemicals you will need to commit to a strict physical and manual control regime, removing weeds prior to seed set and causing as little soil disturbance as possible.
When assessing site condition, you will have identified any weed species that are present. This is the time to develop a weed management plan to effectively deal with them. Remember to include weed quarantine to prevent spreading weeds into other areas. Include the entire property in your weed management plan, not just the restoration site and keep a record of weed management activities for future reference.

A property weed plan template has been formulated by the NT Government's Weeds Branch and will serve as a useful tool when dealing with weeds in your area. Click here for further information.

Soil preparation

Preparing your soil bed before planting or sowing seed will help to create conditions favourable to plant growth. By ripping the soil you will be creating niches to catch water and seed, aerating the soil and allowing for better water penetration. Bear in mind that soil preparation should go hand in hand with weed control and erosion mitigation. Use the timeline provided above as a guide for soil preparation activities. Some common soil problems and their treatment options are outlined in Diagram 1.

Fire breaks

The Bushfires Act 2009 is the legislation governing bushfire management in the NT and states that property firebreaks must be at least '4 m wide and graded, or slashed to a maximum height of 50 mm with all slashed material removed'. Depending on its location you may want to install firebreaks around the site itself. Align firebreaks parallel to contour and ridge lines and avoid watercourses or, if necessary, cross at right angles to minimise erosion.

Feral animals

If there is a threat that animals such as feral cattle, horses, pigs or donkeys may enter your site consider fencing off the area. This will ensure that investments of time, money and effort are not trampled along with your seedlings.

Diagram 1.

Problem	Treatment	How it works
Compaction	Ripping to a depth of no more than 400 mm.	Ripping the soil will improve water infiltration and allow for better root penetration.
Water logging	Adding compost or gypsum to soil after ripping.	Improves aeration and drainage.
Dry and nutrient deficient soil	Mulching or introducing top soil	Assists with water infiltration, retention and encourages soil fauna.

STEP 4.

Choose species to suit local conditions

Soil

Knowing the soil type of the site is important to ensure that you choose species that will thrive. Many of the resources you will find on native plant identification will give an indication of the soil type that plant species or communities are particularly suited to. Soils in northern Australia are notoriously poor; they are ancient and often shallow and infertile. Some common terms about soil types in the northern savannas include:

- Lateritic soils - A generally rusty-red coloured soil, rich in iron oxides, formed through weathering of the underlying parent rock. These are the most infertile soils (low in nutrients) in our northern savannas due to long periods of leaching.
- Black soil plains - Also known as cracking clays they are generally associated with flood plains of major river systems of northern Australia and the grasslands of the Mitchell and Barkley regions. These soils are generally nutrient rich but only some plants can cope with their cracking nature.
- Alluvial flats - Soils dominated by silt and sand deposited by water movement, generally nutrient rich and found around floodplain and riverine areas.

Click here for further information.

One of the easiest soil characteristics to determine is its texture. Most savanna soils can be classified as sandy, loamy or clay soils. Sandy soils are well draining but don't hold a lot of minerals or nutrients. Loam, while good at retaining moisture and nutrients, is relatively well drained and doesn't stay waterlogged. Clay soils are some of the most fertile; they retain moisture, but can become waterlogged during wet periods and tend to dry out completely forming cracks and fissures. There are a number of resources available to help you to determine the soil type. Click here to see a guide to soil texture and compaction and other soil processes.

Remember, most native plants are adapted to a certain broad soil type and texture. Trees that grow well on a lateritic soil are likely to do poorly or die on a cracking clay soil. The nearest patch of bush may not show you what species to plant if that bush is growing on an 'island' of lateritic soil and your site is on alluvial soil. Like for like - match plants to soil and drainage (Text Box 1).

Plant species list

The species selection for your revegetation site will depend on the objectives for your site, soil type, surrounding plant communities, current site conditions and availability of seed and seedlings. Species selection is a bit easier in the northern savannas because there are still large areas of intact vegetation. It is likely that if you are carrying out restoration activities on a plot of degraded land there will be an area of relatively intact bushland nearby. This will give an indication of what vegetation types exist in your area if the two sites have similar soil and drainage. Make a list of as many of the native plants and grasses that are growing in nearby healthy bushland on the same soil type and drainage as that of your site. Include native grasses, either by planting plugs or direct seeding. Grasses are important as they play a vital role in the ecosystem including dense ground cover that reduces the risk of erosion.

There are vegetation databases available for public use that will give you an indication of species that occur in youre area, an excellent online resource is the NT NRM Infonet created by Territory Natural Resource Management.

Text Box 1.

Provenance – where seed should come from

Provenance should be considered in the following manner when collecting seed for revegetation:

Get the taxonomy right first

- Make sure you are dealing with the same species, sub-species, variety or cultivar
- Get the physical and genetic quality right
- Collect from over 100 plants when possible apart

Only collect from large populations or pool multiple collections from smaller populations

Store seed under best conditions from collection right through to use

Match the site condition
- Soil (texture and origin)
- Altitude
- Aspect
- Slope position
- Latitude (use bioregions as the boundary)

Click here for further information.

There are some native species that are better suited for use in a revegetation site than others. These are generally the hardy pioneer species. In a dry woodland setting Acacia and Eucalyptus species are commonly used. A diversity of plant species is needed to provide a diversity of wildlife habitats, from large trees to small grasses, and lots of plant layers in between (Photo 1).

Photo 1. – A typical savanna woodland near Darwin with an open eucalypt canopy, a mid story of young trees with palms, and a grassy groundcover.

The table below lists some of the 'proven performers' commonly used in different revegetation situations. The species appropriate to your site will vary depending on bioregion and vegetation community – not all of these species may be appropriate for your site or occur in your local area.

Open Woodland on well drained soil	
Acacia difficilis	Fast growing and competitive- pioneer species. Prefers sandy soils.
Acacia dimidiata	Common in the Darwin region.
Acacia gonocarpa	Fast growing and useful for weed suppression and screening. Distributed throughout the Kimberley and Top End.
Acacia holosericea	Strongly competitive pioneer species. Very useful for disturbed sites but should be used with restraint.
Buchanania obovata	Hardy woodland species.
Cocholospermum fraseri	Tolerates poor, shallow soils. Common throughout northern Australia.
Eucalyptus miniata	A dominant savanna species from the Kimberley to QLD. Fire resistant once established.
Eucalyptus tetrodonta	Usually in association with *E miniata*. Can reproduce from root suckers.
Planchonia careya	Common in the mid stratum from the Kimberley to QLD.
Syzygium eucalyptoides ssp *bleeseri*	Fire tolerant once established
Syzygium suborbiculare	Fire tolerant. Adapts well to well drained soils.
Grasses – mixed habitats	
Heteropogon contortus	Commonly used for soil stabilisation, fast to establish perennial species. Can be competitive and may pose a fire hazard.
Alloteropsis semialata	Important food source for seed eating birds. Early seeder. Common in open woodland.
Aristida inaequiglumis	Found in a wode variety of habitats on rocky and red loamy soils and sandy plains
Ectrosia schultzii	Attractive and low growing. Useful for firebreaks and access tracks
Ectrosia leporina	Useful species for firebreaks. Low growing with attractive seed head.
Heteropogon triticeus	A good species for wetter areas occuring on brown and red clay loams, sandy loams and gravelly soils.
Sorghum intrans	Annual speargrass. Important species across the Top End
Sorghum plumosum	Grows well on sandy red soils, heavy loams and creek lines
Pseudopogonatherum contortum	Common in sandy and silty soils in open woodland, depressions and swampy areas.
Seasonally inundated or waterlogged soils including drainage lines and bank stabilisation	
Acacia auriculiformis	Very fast to establish. Very useful in revegetation but may outcompete other seedlings.
Alphitonia excels (Photo 5)	Fast growing, tolerates waterlogging
Carallia brachiata	Good for bank stabilisation. More suited to permanent water source but should perform well in seasonally inundated areas with high watertable
Lophostemon lactifluus	Hardy once established. Prefers wetter areas
Nauclea orientalis	Fast to establish, performs well if roots have permanent water (high water table)
Melaleuca spp.	Various species perform well under different conditions. Hardy once established and will tolerate both waterlogging and seasonal drought.
Pandanus spiralis	Good for bank stablisation and erosion control. Tolerates waterlogging

If you need help in identifying plants you can collect samples, remembering to keep samples intact and include leaves, flowers and fruit or seed pods, and pressing it between sheets of newspaper. There are a number of plant identification keys that you can use, or pressed samples can be taken to the Herbarium or a local expert who can help you to identify them. Try to record scientific names of plants where possible as common names can vary from place to place and person to person. See the Further Reading section below for publications relating to identifying native plants.

Local seed is usually best

When planning your revegetation project it is important to plan well ahead of time on how and where you will source your seed or seedlings. It is important to consider the origin of your plant material, also known as provenance (where your seed came from). The origin of your plant material can play an integral role in the overall health and vitality of your project.

Seed collecting

You can take the time to collect your own seed for the project, either to use in direct seeding or in growing seedlings for planting. There is a lot to consider when collecting seed including applying for the permits that are often needed to collect native seed, the location of species and correct times to collect, seed viability, treatments and correct storage. There are numerous professionals in northern Australia who collect seed to supply both commercially and to the retail market (Box 2).

Text Box 2.

Getting the most from your seed

When ordering seed from a commercial seed supplier, ask these important questions:

- What is the viability (%) of the seed?
- Where has the seed come from (its provenance)?
- What is the age of the seed and how has it been stored?
- When comparing seed prices, remember that 1 kg of 90% viable seed is worth much more than 1 kg of seed with just 10% viability.
- Old seed may be OK, if it has been stored well. The moisture content of seed is key. Each percentage point decrease in seed moisture content between 15% and 5% **doubles** the life of the seed.

STEP 5.

Select quality seedlings

You may like to grow your own seedlings for your project. This can be done by collecting your own seed or purchasing seed to plant-out. There are, however, a number of excellent native plant nurseries where you can purchase a wide range of local native species to suit your needs.

Information on collecting your own seed and growing seedlings can be found in *The Bush Book*. Contact details for suppliers of native seeds, seedlings and mature plant stock in northern Australia are listed in the Further Reading section.

When choosing plants or seed to use in your project you should be mindful of the health of the plant material you are introducing to the site. Make sure plants are strong and healthy, have been sun hardened and do not have any pests or diseases that may be transferred to other nearby vegetation (Photo 6). The soil in the pot should be free of weeds and pathogens to prevent introducing new weed species or diseases to your site. A healthy seedling should be able to hold its own and not need staking. Seed stock should be free from mould and insects.

Photo 6. -Seedlings grown in pots should have healthy foliage and well developed roots, but not be root bound.

STEP 6

Planting, sowing and encouraging regrowth

Natural regeneration

Much of the northern savannas remains largely intact but is being increasingly impacted by land clearing, inappropriate fire regimes, invasive weed and animal species and overgrazing by stock. In an area immediately surrounded by intact native bushland it is possible to control some of these elements and allow the vegetation to naturally regenerate.

In order to let an area regenerate naturally, the right long term management is needed. Weed control on and off site will

greatly increase opportunities for naturally emerging native seedlings to become established. If your objective is to re-establish native trees and shrubs consider slashing native grasses after they seed to decrease competition with tree and shrub seedlings. However don't poison out native grasses because they help with weed suppression as well as protect soil from erosion. A highly visible stake placed next to young, emerging plants will help you to avoid them when weeding or brush cutting. There is no need to tie stakes to plants as seedlings should be strong enough to support themselves. Control of cattle grazing and reducing the risks of a hot late season fire is also needed to assist natural regeneration.

Planting native seedlings

Getting down and dirty planting trees is a fun and rewarding way to revegetate your land. Not only does it offer the 'instant impact' of seeing trees in the ground straight away, it affords an opportunity for everyone to get involved. Planting seedlings will give you greater control over the distribution of species within your site because you can quickly adapt to any changes in topography. For example, plant more appropriate species for swampy or waterlogged areas, then switch to hardy dryland species that thrive on rocky and well drained areas nearby.

Blessed with northern Australia's regular wet season and the reliable rainfall that it brings, planting seedlings or sowing seed is best done around the start of the wet, but after the onset of the first significant rains. This will of course vary from year to year so adapt to the weather conditions when possible. Importantly, plants need a few months of rainfall and damp soil to establish deep roots before facing the long and harsh dry season.

When carrying out a small to moderate scale revegetation project (usually no more than around 2,000 seedlings) the following practices give your plants the best chance of survival.

When hand planting using shovels, mattocks or crowbars (depending on the harshness of the soil), make sure each hole is at least twice the depth and twice the diameter of the seedling's pot with roughened edges. This will give roots a chance to expand and allow water penetration to the roots of plants. When planting in compacted soils, where ripping of the soil has not been undertaken, holes should be dug as deep and as wide as possible to give the plants plenty of room to take root (see Figure 1 below).

Figure 1.

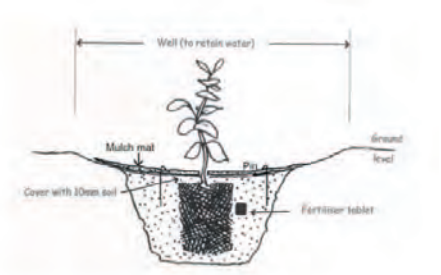


Figure1. Seedlings should be planted just below the general soil surface in order for a 'well' to be formed to capture additional rainfall. It is also important to cover each seedling with at least 2 cm of local topsoil to prevent the seedling from drying out.

If your holes are dug with machinery such as an auger, make sure you manually rough up the edges of the holes before planting. If the sides are smooth, the roots may not be able to break into the surrounding soil.

There is also special equipment for planting such as the Pottiputki, which is a hollow tube with a beaked end. The beak is pushed into the soil, small seedlings are then dropped into the tube and a trigger release opens the end leaving the seedling in place. Click here for further information.
The use of these requires thorough soil preparation, such as ripping, to ensure the ground is soft enough for the beak to be easily inserted. This equipment is generally used over larger areas.

Depending on your species selection and site objectives, a general guide for seedlings is to plant at 1 meter spacing. This allows room for the roots and canopy to reach their full potential. Through natural attrition some of your seedlings may not survive. Deal with this by overplanting, or planning for infill plantings once the first seedlings are established.

Most nurseries take back the pots to be cleaned and reused, so don't leave them at your planting site.

Direct seeding

There are a few important things to consider when choosing to sow seeds directly on the ground.

- Site suitability - Areas of harsh, rocky outcrops or area prone to flooding or waterlogging may be unsuitable.
- Seed availability - It is important to plan well in advance to get the species that you require. A lot more seed is needed for direct seeding compared to the handful of seed needed for propagating seedlings in the nursery. Grasses are abundant and easy to harvest for seed, so are a good choice for direct

seeding onto those highly degraded areas where natural regeneration is slow or non existent.

- Seed treatments - Certain species need particular environmental conditions before germinating (e.g. heat or scarification). Conditions may need to be artificially replicated to enhance or encourage germination. Greening Australia NT's *The Bush Book* has more detailed information pertaining to seed treatments.

Trees and shrubs - A general rule of thumb for native tree and shrub species is to allow 5 kg of seed per hectare of land. This equates to about 50 gm of seed for every 100 m2 (e.g. a 10x10 m square). On smaller scale projects, such as those addressed here, hand broadcasting is likely to be the most reasonable method of seed distribution (Photo 7). Seed should be added to a bulking medium such as sand and mixed thoroughly prior to sowing. You may like to roughly divide your area into 10x10 m plots and allocate 1 bucket containing the appropriate amount of seed (mixed with its bulking medium) per plot. Distribute seed by hand trying to achieve an even coverage. You can increase the seed quantity for areas that you feel need greater coverage, such as erosion prone areas. It is likely that many emergent seedlings will be outcompeted, but they will offer initial erosion mitigation.

Photo 7. Direct seeding native grasses by hand can help stabilise a modified bank. Hand sowing is only practical for small sites such as this one.

There are specialised direct seeding machines that will make broadcasting seed over vast areas and are much more time efficient. Methods will depend on specific machinery. Greening Australia NT's *The Bush Book* contains information on some of the machinery available for direct seeding.

STEP 7.

Maintenance post-planting

Performing maintenance on your restoration site is crucial to the long term success of the project. A maintenance program should incorporate site monitoring, weed control, firebreak maintenance, and implemented for as long as possible.

It is important to ensure that whoever is carrying out weed control within a revegetation site is able to distinguish between native plants and grasses and weed species at all growth stages. If the scale of the project allows it, weeding by hand is the best method. Seedlings should be at least 8 cm tall before a non-residual herbicide such as glyphosate mixed as per label recommendations is used within the site. You should take great care to avoid drift or overspray.

If you notice your seedlings drooping, wilting or browning you may need to water them during dry spells and through the first dry season. However, some plants may show similar signs of stress if the soil is too wet or waterlogged for too long. If this is the case then soil or surface drainage may be needed – hence the importance of the initial site assessment and preparation steps.

STEP 8.

Monitor to learn and improve

Monitoring should record what is done at each step of any revegetation project (Figure 2).

Monitoring just outcomes like spot lighting for nocturnal wildlife makes no sense if few plantings survive after the first dry season (Results). Monitoring of Actions (inputs) is needed to know what species were planted, at what density, and with what sorts of site preparation. If this Action data is not collected and archived,

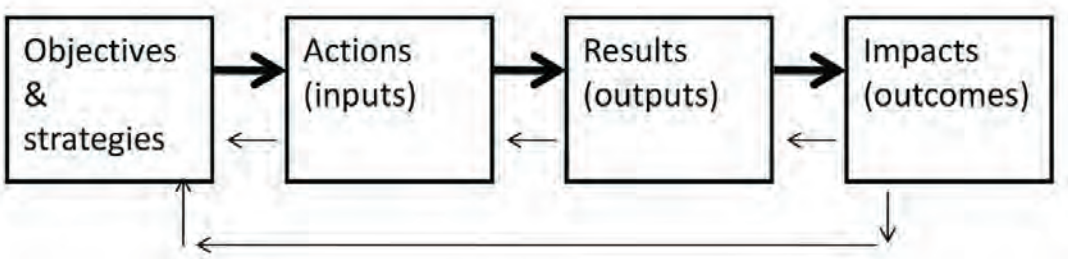


Figure 2. A framework that identifies the multiple points at which monitoring is needed to improve revegetation practices and identify outcomes. The thick arrows indicate the consequences of implementation and the thin arrows indicate key interpretation and learning feedback loops (from Freudenberger 2012).

then it's hard to determine what lived versus what died (Results). Monitoring Objectives and strategies is needed so ten years later Outcomes can be assessed against Objectives. It makes no sense to unfairly judge the habitat quality of a site if the original objective was simply to establish a visual barrier with some rapidly growing native trees and shrubs.

Horses for courses.

There are no universally applicable methods for monitoring outcomes, because that depends on site objectives. There are standard methods for monitoring birds if your site objective is to provide bird habitat, similarly there are methods to assess the reduction in erosion and sediment rates if these are your site objectives. Objectives should define monitoring. However, the Table below provides a guide to the 'generic' kinds of monitoring data that need to be collected for any type of planting. Key monitoring data for revegetation sites (adapted from CSIRO/ABARES research). Click here to find and manage a free database (VegTrack).

Photo monitoring

Long term photos taken from a fixed location are a universally useful tool for monitoring, but should be complemented by good record keeping as well as occasional flora and fauna surveys. Before, during and after photos are an excellent way to keep an eye on changes within the site and are inspiring to look back on later when the hard work is done (Photo 8ab). Setting up a photo point monitoring system should include:

- Decide on an effective place for your photo monitoring point. This may be an existing structure such as a fencepost, or you can erect your own using a star picket or something similar that won't get destroyed by termites or fire.
- Mark the location using a GPS, plus make a detailed map of where each photo point is located in relation to fixed features like a gate, track, rocky out crop and other landmarks. Include the GPS coordinates on your paper 'mud map'.
- Record the direction or compass bearing for the photo so you can replicate it each time.
- If you have more than one photo monitoring point, ensure you number them and label the photos accordingly. Take a photo of the maker label before each landscape photo, or include a clip board and paper (or small white board) with large text indicating the photo location and date in the photo. Save the digital photos in a computer directory labelled with the site name and year. Make sure you have a backup of the computer folder stored elsewhere (e.g. DVD or CD).
- Try to take photos around the same time each year. It is good to take a wet season and a dry season photo in order to record differences between the seasons.
- Before and after photos of any maintenance activities will show the impact of your hard work.

Remember to carry out photo monitoring regularly. It is also beneficial to keep records of any wildlife seen within your site. Carrying out vegetation surveys after a few years to help determine the success of ongoing management activities and the quality of the habitat you are recreating.

Photo 8a.

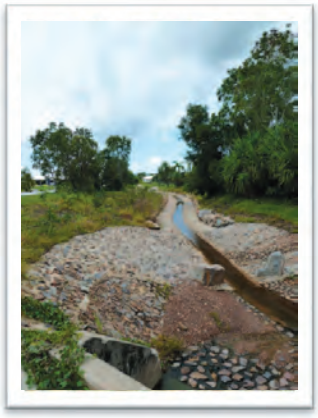


Photo 8b.

Photos 8 (a-b). BEFORE (a) and AFTER (b) a planting are a useful complement to good record keeping needed for learning from past projects so revegetation practices can be continuously improved.

Data type	Details	Definitions
Site Data		
1. Data record	Unique identifier for the site	The site is the area of the revegetation work for that season
2. Date	Day/Month/Year	Date of primary observation
3. Data source	• Name of observer • Contact details	Data collector's name and contact details including agency or business name
4. Site location	• Nearest Town & State • GPS coordinates for a site access point • Tenure of Site • Owner of land	Google Earth can be used to determine the coordinates (Lat/Long) of an access point like a gate if a GPS is not available.
5. Site area	• Hectares	Google Earth can be used to measure the area of a site
6. Existing land cover	• Describe the pre-planting vegetation cover or type of land use	Include dominant plant species covering the site pre-revegetation
Establishment Data		
7. Revegetation objective(s)	Improvements in: • shade & shelter • wildlife habitat • seed production • riparian health or water quality • soil stability • carbon sequestration • etc.	If more than one objective, specify primary and secondary objectives
8. Funding source and resources invested	• Agency or person supply funding • Dollars spent per site (grant and in-kind) • Hours of labour • Materials (fencing, herbicide, total kg of seed or total number of seedlings)	Include multiple funding sources. Dollars spent includes site preparation, planting and maintenance to date.
9. Site preparation	• Dates • Weed control technique (e.g. glyphosate at X ml/ha) • Soil preparation (e.g. rip and mound, or scalp with direct seeder)	Describe the dates and methods used to prepare the site for planting and/or direct sowing of seeds
10. Species planted or sown	• Species name (Latin binomial) • Seed provenance (source location)	Specify species of seed or seedlings used and where the seed was collected from (when known)
11. Planting or sowing rate	• Kg of seed/ha/species directly sown • Nursery seedlings planted/ha/species	List the planting or seeding rate for each species
12. Revegetation methods	• Direct seeding • Nursery seedlings • Tree guards • Mulches • Watering • Stimulate natural regeneration (e.g. fire or ripping) • etc	Describe what was done to establish more native plants on the site
Monitoring and Maintenance		
13. Monitoring frequency	• None • Occasional-opportunistic • Regular (planned)	If regular, list how often per year
14. Monitoring method(s) for revegetation	• Casual look around • Plots and formal surveys • What measured	Describe the method(s) used to monitor the status or health of the planting
15. Revegetation monitoring results	• Date • Names (Latin binomial) of surviving species • % of species planted that have survived • Density of surviving species (number/ha) • % of seedlings planted still surviving • General health or vigour of the reveg • Species of weed • Cover of weeds (e.g. low, medium, high)	Describes and quantify the success rate (results) of the revegetation at this site
16. Site Management	• Date • Observed threats to the revegetation • Management activity • Effectiveness	Lists management activities on the site post revegetation (e.g. weed and pest control) and describe how well they worked
17. Methods to measure outcomes	• None • Bird surveys • Habitat Hectares • Carbon sequestration • Salinity • etc	Describe methods used to measure or estimate the outcomes of the planting. Outcomes are the consequences or environmental ***impacts*** of the revegetation.
18. Results of outcomes monitoring	• Date • Survey or observational data	What found and what it means
19. Other observations/notes	• Date • Text or data	Other observations conducted at the site

Further Reading

Publications available through Greening Australia, (Darwin Ph: (08) 8947 3793)

The Bush Book: A manual for managing vegetation across northern Australia builds on the information supplied in this guide and is a practical resource for land owners and managers throughout northern Australia.

Native Plants for Top End Gardens is a beautifully photographed publication containing comprehensive information on many Top End native tree, shrub, palm and grass species.

Grasses of the Northern Territory Savannas: A field guide will help to identify a number of the native grasses that may be present in your area. It also contains some of the common weed grasses.

Aboriginal Landcare Education Program Learning Guides are a set of 14 comprehensive guides aimed at teaching Certificate II level students, but applicable to other levels and useful for both structured and informal training.

Species identification and selection

Australian National Botanic Gardens (2012) *Growing Native Plants on the Web*

Native Plants of Northern Australia by John Brock contains descriptions of over 450 species of native plants and is a useful resource for identifying native plant species in the Top End.

Flora of the Darwin Region Volumes 1 and 2 are available online.

The Northern Territory Herbarium provides plant identification services to the public free of charge for private purposes. Phone (08) 8999 4516 or herbarium email for more information.

Florabank website is a source of information on native seed collection and propagation.

Soils

Soil Conservation Handbook for Parks and Reserves in the Northern Territory is a Government document published in 1993 that contains a wealth of information on soil conservation and erosion control.

You can find information specific to Top End soils.

For technical details on soil types, condition and identifying and dealing with soil compaction.

Weeds

Weeds of Northern Australia a field guide is a recently released publication with up to date information pertaining to invasive weed species. With detailed descriptions and information on 150 species this is an essential resource for all north Australian land managers. Available from the Environment Centre NT Ph: (08) 8981 1984 or by email.

Northern Territory Government's Weeds Branch has a lot of online information about weeds in the Northern Territory.

Click here for weed information relevant to other regions of northern Australia.

Native seed and plant suppliers for northern Australia

Greening Australia Northern Territory
125 Thorak Rd, Berrimah.
Ph: (08) 8947 3793
Email:darwin.nursery@nt.greeningaustralia.org.au

Greening Australia Native Plant Nursery, Katherine
19 Second St, Katherine NT
Ph: (08) 8972 2943

Top End Native Plant Society
Ph: (08) 8983 2131
Email:topendnativeplantsociety@hotmail.com

Top End Seeds - seed collection and supply: Ph: (08) 8985 6885
Email: seeds@topendseeds.com.au

Greening Australia Dry Tropics Nursery

Pimilco, Townsville North Queensland
Ph: (08) 4755 2981
Email:drytropicsnursery@greeningaustralia.org.au

Nindethana Seed Service - suppliers of Australian native seed
Ph: (08) 9844 3533
Fax: (08) 9844 3573
Email: seed@nindethana.net.au
Web: www.nindethana.net.au

Further Assistance

For further assistance or advice we suggest you try contacting:

Greening Australia: Ph 1300 886 589 or find us on our web page.

Your Regional NRM (catchment) Organisation

Acknowledgments

Funds for the preparation and publication of this guide were provide by the Australian Government through the Biodiversity Fund. The guide was compiled by Catherine Orme with assistance from Dr Greg Leach. Editorial services were provided by Dr David Freudenberger and Dr Jason Cummings. Graphic design was provided by Landcare Australia Ltd.

Disclaimer

The views and opinions expressed in this publication are those of the authors and do not necessarily reflect those of the Australian Government or the Minister for Sustainability, Environment, Water, Population and Communities.

Australian Government
Department of Sustainability, Environment, Water, Population and Communities

Greening Australia

Landcare Australia