A Revegetation Guide for Eucalypt Woodlands

Australian Government
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Greening Australia

Landcare Australia

A REVEGETATION GUIDE FOR EUCALYPT WOODLANDS

Who this guide is for

Temperate Eucalypt Woodlands are found throughout eastern and southern Australia including the lower elevation woodlands of Tasmania. They have been highly cleared for agriculture. Most remaining examples of woodland are found along roadsides or as small patches of farmland, often just a few remaining paddock trees. High quality woodland remnants support a remarkable diversity of plants and animals including many different species of wildflowers in the ground layer (Photo 1). Mallee Woodlands are dominated by eucalypt trees with multiple stems and a separate revegetation guide has been prepared for this woodland type that also occurs in southern Australia.

This introductory guide is for people wishing to learn, or be reminded about the basic principles and practices of planting trees, shrubs and grasses for revegetation of eucalypt woodlands in the temperate, rather than sub-tropical or tropical regions of Australia. This guide describes eight key steps that need to be followed to help ensure a successful revegetation project.

Photo 1. This is a high quality woodland with a stunning diversity of ground layer grasses and wildflowers, regenerating young trees and healthy mid-aged trees with a few older and decaying trees full of tree hollows.

STEP 1.

Assess site conditions

Revegetation is needed when there is little or no natural regeneration of native woodland plants occurring due to local constraints that limit the natural return of woodland trees and understorey plant species. Constraints include:

1. Recruitment
- Lack of seed
- Lack of suitable sites for seed germination (establishment niche)

2. Altered physical environment
- Temperature extremes - hotter and colder than within a natural woodland
- Wind exposure that can quickly dry out young plants
- Lack of fire or too frequent fire

3. Hostile soil conditions for native plants
- Soil compaction from cultivation, vehicles and livestock
- Soil erosion by wind and water
- Nutrient enrichment (high levels of Phosphorus and Nitrogen – good for weeds but not most native plants)
- Carbon depletion causing poor soil structure and
- Rainfall runoff rather than infiltrating into the soil
- Lack of soil microbes that greatly assist native plant survival and growth

4. Threats to woodland plant survival
- Weed competition from pasture grasses and weeds
- Insect pests
- Grazing by sheep, cattle and horses
- Browsing by native mammals

Examine your site to determine if you have any of these constraints (Photo 2). If you do, then active revegetation is needed, and you will need to reduce these constraints to succeed in establishing a diversity of woodland plants.

Photo 2. A degraded woodland suffering from erosion, over-grazing, a weedy ground layer, no regenerating young trees, just unhealthy older trees. Natural regeneration is unlikely so planting will be necessary in a site like this.

STEP 2.

Set clear objectives

There are many different reasons to plant locally native woodland species. These include:

- Wildlife habitat and dispersal corridors
- Shade and shelter for livestock
- Salinity management
- Harvesting firewood and timber
- Carbon sequestration
- Visual Amenity

Historically the objective of restoration has been to fully recreate the native vegetation believed to have occupied the site before it was degraded. This has been done by Alcoa in Western Australia for Jarrah forest where vegetation was removed for bauxite mining and in Victoria by Greening Australia where complex grasslands have been recreated. However, comprehensive restoration of hundreds of plants species is costly ($30-$70,000/ha). In contrast, revegetation usually only goes part way to re-establishing a diverse woodland indistinguishable from healthy native remnants. The greatest diversity of plants is found within the groundcover of high quality woodlands (grasses and wildflowers; Photo 1). A diverse woodland understory can be the most difficult to restore, whereas woodland revegetation tends to focus on trees and shrubs (if they are part of the desired mix).

In many cases, where the site is so altered that the physical and chemical environment no longer matches that occupied by the original native vegetation then a compromise may have to be accepted. You may have to use species that look like those that originally occupied the site but are much hardier – i.e. create a structural mimic of the original native woodland using species tolerant of the new conditions. In really tough sites, just getting a couple of species of trees and shrubs to thrive is a major accomplishment.

A decision on whether to try for full restoration, or a simpler revegetation should be based on a cost vs. benefit analysis, your objectives and the importance of the restoration in a landscape context.

Landscape context

Ideally revegetation or restoration should be conducted to buffer and connect existing patches of native vegetation, particularly patches that are protected by covenants, or are in reserves and have a demonstrated high natural value.

Wildlife, particularly birds, can be used to help for prioritise habitat improvements (Photo 3). Research on woodland birds and other wildlife has shown that native revegetation has the greatest benefit when planted:

- in block-shaped rather than narrow strips;
- in gullies or flat areas;
- next to other plantings or areas of woodland;
- and established around large old trees.

Photo 3. Woodland birds such as this Flame Robin are usually only found in quality patches of woodland and revegetation with plenty of understory features to provide feeding and roosting habitats. Many woodland birds need to move between patches to find enough resources, hence the value of planted corridors.

Revegetation can also be used to re-connect existing woodland patches by creating 'stepping stone' patches or 'corridor' plantings along ridge-lines and creeks (Photo 4). Improving landscape connectivity in this way should assist movement of wildlife in response to climate change.

Photo 4. Much of the temperate woodlands of southern Australia have been cleared for crops and pastures leaving just a few isolated paddock trees and fragmented strips along roadsides. Revegetation such as this, coordinated with neighbours, can be used to improve connectivity for a range of wildlife species that are not able to easily travel across open paddocks.

It is recommended that revegetation planners consult with the surrounding neighbours and local community to identify opportunities for linkages with adjacent revegetation work. This can achieve ecological benefits and some costs savings, but it is also a process that allows community concerns to be raised about possible increased fire hazards and pests.

STEP 3.

Choose species to suit local conditions

Choose woodland species that occur in similar soil-landscape environments. Where possible locally occurring plant species that match the relative abundance found in remant woodland nearby on similar soils and slopes. It is not realistic to restore all species that occur on a site because of limitations of seed collection, propagation, establishment and cost. Select a mix of species that provide layers of vegetation from tall trees (often eucalypts), medium sized trees (often acacias), large shrubs, small shrubs and large tussock grasses (Photo 5). Different layers of vegetation such as sort lived trees and shrubs provide food for pollinators, nesting sites for insectivorous birds and help resist the invasion of weeds. But most importantly choose local native plant species that will survive. Dead seedlings don't provide habitat nor fix carbon. Species suited to local conditions are the most likely to survive.

Seed for the chosen plants should come from healthy populations growing on similar sites within the same bioregion so they are adapted to the environment of the planting site. Rainfall, soil, altitude, aspect and slope position are important environmental factors in plant adaptation.

Photo 5. A high quality patch of remnant woodland or a planting such as this one needs to have lots of layers of vegetation, including older trees, young trees and shrubs as well as fallen timber to provide habitat (homes) for a diversity of wildlife.

An exception to this principle is where the environment has changed to the extent that some local species can no longer survive, for example from secondary salinity, altered soil structure, frost, increased aridity or water logging. In these instances, a 'nursery' planting may first be required to reduce wind exposure, water logging, salinity or other factors hostile to restoration of locally native species.

Securing a supply of seed has to be considered early in the planning for revegetation. Seed of the required species may only be able to be harvested for a short period in its natural habitat. Planning has to be in place for seed collection (e.g. locking up paddocks for grass seed harvesting) or seed purchase. Seed suppliers need plenty of advance notice to collect quality seed and process it appropriately. Like any crop, native seed quantity varies from year to year based on rainfall. A drought one year can greatly reduce seed supply in some eucalypt species three years later. Ordering native seed is not the same as buying a packet of veggie seeds from the shops!

Where the species is rare and seed is generally unavailable from seed suppliers, seed nurseries have to be established (Photo 6&7). A nursery area has to be set aside to grow rare plant species for seed collection. Once plants reach maturity seed is collected and stored for use in restoration. The seed of these species is often so valuable that it is better to plant seedlings rather than use seed of these species in the seed mix.

Photo 6. Securing sufficient seed may require developing Seed Production Areas (SPAs) which can start with a few seeds from each species propagated in foam boxes.

Photo 7. For large quantities of seed that is easy to harvest, consider developing a network of seed orchards or large 'Seed Production Areas' (SPAs).

Seed quantity

Estimating the quantity of seed needed for a revegetation project is complex because there are so many variables to consider including:

- planting method – direct seeding or seedlings grown in a nursery
- distance between planting rows (often 3-5 m)
- desired stem densities of trees, shrubs and ground cover
- seed viability which varies between species, seasons and whether germinated in the nursery or paddock
- size and longevity of species – short lived and small species are usually planted at higher densities than long lived and large trees.

Text Box 1 provides some rules of thumb for calculating seed quantities. Table 1 below provides a typical example of the quantity of seed and seedlings needed for a diverse planting. The type of species will naturally vary from place to place, but this total quantity of seed and seedlings is a useful guide.

As a general rule for wattle-rich seed mixes, use about 400 grams of viable seed per kilometre of sowing line in dry areas (400-600 mm rainfall) and 300 g/km for areas with rainfall more than 600 mm.

Direct Seeding (grams of seed in the mix/ha)		Tubestock (Number of seedlings per ha)	
Species	**g/ha**	**Species**	**No/ha**
Acacia salicina	65	*Eucalyptus albens*	40
Acacia stenophylla	40	*Eucalyptus melliodora*	40
Acacia dealbata	40	*Eucalyptus camaldulensis*	40
Acacia decora	70	*Callitris glaucophylla*	40
Eucalyptus albens	5	*Casuarina cunninghamiana*	40
Eucalyptus melliodora	5	*Mixed forbs and grasses*	600
Eucalyptus camaldulensis	5		
Dodonaea viscosa subsp. viscosa	20		
Lomandra longifolia	25		
Leptospermum brevipes	1		
Callistemon viminalis	1		
Callitris glaucophylla	20		
Casuarina cunninghamiana	5		
TOTAL	**302**		**800**

Table 1. Example of suitable quantities needed for a direct seeding species mix complemented by planting of seedlings for a hypothetical revegetation project in the Nandewar Bioregion of northern NSW.

Text Box 1.

Estimating seed and seedling quantities

Accurately calculating the amount of seed needed for a revegetation project takes considerable experience and knowledge of local planting conditions and plant species. If this local expertise is not available, the following equation and guidelines will provide a useful starting point.

Required seed (kg/ha) =

$$\frac{\text{Target plant density (plants/m}^2\text{) x (weight of 100 seeds, in grams) x 1000}}{\text{Germination percentage*(or nursery survival*) x establishment percentage}}$$

*Percentages must be listed as a percentage, not a decimal fraction

A working example for *Lomandra longifolia*:

$$\frac{\text{0.1 plant per m}^2\text{ x 21g (large seed) x 1000 (= 2100)}}{\text{50\% germination x 50\% establishment (=2500)}} = \text{0.84 kg/ha}$$

This is an example of a species with relatively moderate germinability and moderate survival of germinated seed. Germinability and survival data is scant or highly variable for most native species so the following rules of thumbs can are useful:

- For nursery seedlings (tubestock) assume seed germinability of 50% and 80% survival of seedlings in the nursery;
- Establishment percentage (in-field) for tubestock: 85%;
- To plant one hectare using tubestock typically requires less than 100 g of seed.
- Tubestock is often planted at 500-1000 stems per ha depending on the proportion of large trees in the seedling mix.
- Establishment percentage (in-field) for direct seeding: 5%;
- Direct seeding often requires 200 g of mixed seed/km which equates to 660 g of seed/ha at 3 m between rows.
- Quantities of seed will need to be higher for establishing ground cover grasses and wildflowers

STEP 4.

Select quality plant material

Only use healthy seedlings

The size and root structure of seedlings is critical to their survival after transplanting and to their long term survival. Poor root development in the nursery can result in early death, slow growth, instability in windy conditions and long-term self-strangulation.

Nursery containers should be chosen to produce healthy roots with lots of strong growing tips and low shoot to root ratio. Nursery systems should allow for maximum air pruning of roots. Modern nursery tubes are fluted (rather than smooth and round) so that roots are directed downwards. In addition, slots and holes in the sides of the tubes air-prune roots so root-binding does not occur (Photo 8). Seedlings should also be ordered or germinated with enough growing time to be able to meet specifications. In particular, root development should be sufficient so that potting media does not collapse on removal of the seedling from the container. A good quality seedling is 10-20 cm tall, is not root bound, and has been hardened in the glasshouse before delivery (Photo 9). Seedlings that are not hardened properly will be set back or killed when transplanted into hot or frosty conditions. Hardening involves nutrient starvation for at least one month (so leaves are tough and unpalatable), and exposure to low temperatures out side the glasshouse for at least one month to induce frost resistance.

Photo 8. Fluted nursery pots promote downward pointing roots, rather than spiraling roots that can develop in smooth and round tubes. Note also the air pruning of the roots at the bottom of the pot.

Photo 9. These well grown eucalypt seedlings are being hardened off to promote frost and drought resistance.

Seedlings should arrive on-site well watered, green but with a tinge of red. Seedlings with yellow foliage or only a few leaves at the end of the stem have been held too long in the nursery. Also beware of much fresh growth, these seedlings have received a recent flush of nutrients and may be too soft to withstand the shock of being transplanted into a windswept paddock. Most nurseries take back the pots to be cleaned and reused, so don't leave them at your planting site.

Genetics

It is vital to use the appropriate seed source for restoration plantings. A local native seed source has traditionally been the rule of thumb (Text Box 2). However there are circumstances where this may not be the best choice.

Exceptions

- Where the seed source of the local native provenance is not in the same landscape position, e.g. in a wet gully, while the restoration planting will be on a dry ridge. It is better to match for site (ecological position) than to automatically choose the closest local native seed source (Text Box).
- Where the local native seed source is an isolated tree or small population. Out-breeding trees like eucalypts will have poor quality seed if the tree is an isolated paddock tree, regardless of the health of the trees. Self pollinated seed is weak and seedlings will grow slowly and there will be high death rates amongst seedlings.

Text Box 2.

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)

Text Box 3.

Genetic pollution

There is a small risk that restoration plantings may introduce new genotypes to an important local population of a species. In some cases genetic mixing can cause sterile hybrids. A judgement has to be made as to the risk of diluting or changing the genetic make-up of recognised important population of a plant species. Although it may appear desirable to use seed from a provenance of hardy individuals of the species occupying a site 100 km away, this may compromise the objectives of protecting the genetic character of a particular population that is otherwise rare. However, if your site is a bare paddock many kilometres away from a rare or threatened species of interest, the risk of genetic pollution if likely to be low.

Collect seed from the nearest healthy intact population of the species containing at least 100 individuals in close proximity.

- Where there is expected to be a shift in the climate (through climate change) during the life of long lived species such as eucalypt trees. It may be necessary to include in the seed lot seed from lower altitude and drier sites than the local native provenance to take account of climate change.
- Poor quality seed will result in poor revegetation, so make sure it's healthy (Box 5). Once collected, conduct viability tests on your seeds so you know the sowing rates needed to germinate sufficient quantities of seed for your restoration plantings. Click here to see the Florabank web site for some simple techniques.

It is also important to collect seed from the right part of the tree. Seed from the upper outer branches of a tree is more likely to be out-crossed (not inbred) than lower branches.

When collecting seed, collect from trees separated by some distance (e.g. 100 m for eucalypts) because nearby trees will have a high degree of similarity in genetics (relatedness). When collecting seed don't destroy or over-collect from a single individual. Collect seed over only a proportion of the tree or shrub and don't butcher the plant by removing large numbers of branches.

If you are collecting your own seed, good record keeping is important. Record the GPS position of the collection site, date collected, number of plants collected from, and average distance between plants. This information is important for knowing where quality seed (e.g. good survivorship) came from for future collecting.

STEP 5.

Site preparation

Woodland plantings will only thrive if you've prepared the site well. The primary purpose of site preparation is to build adequate soil moisture before planting and control competition (weeds and browsing animals).

Access to moisture throughout the soil profile is essential to the survival and growth of newly germinated seeds or newly transplanted seedlings. Soil moisture must be built up in the 12-24 months prior to planting by removing plants that will use this moisture and by minimising soil disturbance that will increase evaporation. The usual method for achieving this is to use herbicides to maintain a weed free soil surface after initial soil preparation.

Weed control

Weeds compete with newly established plants for moisture. Many weeds are much more efficient at drawing moisture from the soil than new seedlings, so reduced growth or plant death usually results. Plants which struggle in the first few years of life never reach their full potential or growth rate. Weeds should be controlled in an area 1 m in diameter around new plants for at least 2 years to ensure the plants are vigorous enough to out-compete weeds.

Treat woodland plantings like a high value crop. Up to four applications of herbicide may be necessary to ensure a weed-free site at planting time:

1. Ideally two years before planting a broad spectrum herbicide to kill existing competitive plants and prevent seed set (avoid areas of native grass).
2. Follow-up application in late summer (summer rainfall areas) or autumn (winter rainfall areas).
3. Third spray applied 6-10 weeks after the second spray to control opportunistic weeds.
4. Final spray just before planting. If using residual chemicals here, follow the 25:25 rule – wait 25 days after application or wait for 25 mm of rain before planting (or seeding). The final spray may also include other chemical applications, such as insecticide for the control of red-legged earth mite or lucerne flea.

A fifth spray with a grass-specific herbicide will likely be necessary 6-12 months after planting to control developing grass competition with establishing shrubs and trees.

Vigorous perennial grass weeds like phalaris, Coolatai grass, African love grass and Chilean needle grass are likely to need repeated applications of glyphosphate to control them. Residual herbicides should not be used in any revegetation methods that rely on soil stores of native seed, as they kill germinating natives as well.

It may not be possible to meet these exacting standards outlined above, but the nearer your operation comes to meeting these

standards and timing outlined above for weed control the better your woodland plantings will survive and grow.
Make sure your equipment is appropriate to the size of the job. Backpack sprayers are suitable for spraying small areas or individual weeds, while a spray unit with a tank mounted on a ute or quad bike will be necessary for larger areas. For very large areas, a boom spray will be more efficient. Consider a weed control contractor for large jobs.

Browse control

Regardless of the quality of weed control a woodland planting will fail if heavily browsed (eaten). Seedlings are particularly attractive to browsing animals and easily killed by them. Your assessment of site conditions (Step 1) should have identified what browsing animals pose a threat (e.g. livestock, rabbits and hares, or natives like wallabies).

In most situations fencing off the area to be restored is essential. An ordinary stock fence will be sufficient in areas where it is only stock that have to be excluded or the numbers of native browsing animals are low (i.e. away from health native forest remnants). However where plantings will be established to buffer and connect healthy woodland remnants, animal proof fencing will be needed (e.g. hinge-lock wallaby fencing and/or rabbit proof netting). Fencing is a major cost to a revegetation project, but remember plantings are a high value 'crop'.

On the margins of woodland plantings that abut a healthy woodland remnant and where mammal browsing control is problematic seedlings can be placed inside a netting sock that prevents animals reaching the foliage (this looks like a small onion bag). The whole seedling, root and all, is placed inside the sock and the plant is planted surrounded by the sock. The mesh is loose so roots can grow through the mesh and expand without restriction. However the mesh can entangle the shoot affecting normal growth. The mesh breaks down over time.

There is a wallaby repellent (WR1), consisting of egg white and carborundum powder, which can be applied to the leaves of plants. The carborundum powder damages the teeth of browsers and discourages browsing. However practically, this can only be applied in a glasshouse so when planted any new leaves are susceptible to browsing.

Nursery seedlings (tubestock)

Ground preparation techniques are used to soften the soil and increase water infiltration, root area and soil aeration. Ground preparation will vary according to soil type, site history and establishment technique being used. Many plantings will fail if the recommended ground preparation is not followed.

Ripping on contours when subsoil is dry is suggested for compacted soils including cropping pans and to allow for easy use of manual planting tools. It is not recommended for deep sands or cracking clay soils. For broad-scale plantings mechanical cultivation is essential. It is not practical or cost-effective to individually dig 1,300 holes per ha for the seedlings used in restoration.

Mounding of non-sandy soils may be useful to maximize establishment and growth rates in waterlogged, heavy or saline soils. The state of the art in cultivation is the rip and mound technology used by the plantation forestry industry (Photo 10). It produces a favourable planting environment for trees by concentrating resources (soil, nutrients and water) near the roots of the seedling. It burries the weed layer and facilitates its breakdown, and softens the original soil surface to allow root penetration. The mounds, if placed along the contour, harvest water moving down slope (on the upper side of the mound) and direct it to the roots of growing trees (Photo 11).

Photo 10. This heavy duty machinery has been developed by the commercial plantation industry to improve tree seedling establishment in soils prone to water logging.

Photo 11. A site in Tasmania cultivated by the machinery shown in Photo 10. This site in the Midlands has now been successfully sown to a diversity of trees and shrubs.

Cultivation should be conducted along the contour. A simple contour guide can be constructed with a few bits from a hardware store (Photo 12). Rows are usually spaced at least 3 m apart to prevent over-crowding and to allow access in the future (e.g. for weed spraying).

Photo 12. Planting or seeding trees and shrubs on the contour minimises erosion and helps retain rainfall. This 'level-ometer' filled with water is a simple and inexpensive way to accurately drive along on the contour with a spray rig or direct seeder (Photo 15).

Generally, cultivation should be conducted at least six months before planting and three weeks after the first pass of weed control. Cultivation conducted after weed control results in soil that is more friable and will form a better mound.

Farm machinery can be adapted to perform the tasks outlined above. However in heavy soils or on steep ground a D7 bulldozer will be needed to pull a mounding plough. In boggy or clay soils a higher mound is preferred – principally governed by moisture available in the mound.

Soil treatments such as water crystals, gypsum, compost, coconut fibre can be added to improve the structure and water-holding capacity of the soil, but they add considerable cost to planting projects. A thin narrow strip of coarse sand has been used successfully as mulch for surface-sown seeds.

Acacias, just like other legumes such as Lucerne have a symbiosis with nitrogen fixing soil bacteria. However, bacteria specifically co-evolved with Acacias may be missing in long cultivated soil. Studies by CSIRO have shown superior germination, survival and growth in Acacias inoculated with specific strains of bacteria.

Insect pest control

Insects can entirely defoliate plants in the field. This is particularly a risk immediately after planting when seedlings are small and highly nutritious. In areas at risk (particularly near a healthy woodland remnant) a systemic insecticide tablet can be placed under the seedling or systemic insecticide can be injected into the soil around the root bowl before planting (usually in the nursery). Treating insect attack after planting is more difficult and more costly. Major problems arise with treating for insect attack when trees are more advanced and growing in the field because generally, any effective insecticide that kills the pest species will also kill desirable predator and/or pollinator species.

STEP 6

Planting and sowing

For broad-scale planting it is most practical to use forestry planting contractors to do the planting. A single professional planter can plant up to 3000 seedlings a day using a 'Pottiputki' which is a steel tube with a trigger release at the bottom (Photo 13). The Pottiputki is pushed into the ground, the bottom of the tube is opened and a plant passes down the tube into the ground so the root ball is below the mound surface. The ground is compacted using the feet and the planter moves onto the next placement. Normally seedlings are spaced at 2.5 – 3 m within rows giving 1000-1300 stems per hectare.

Photo 13. This tool (Pottiputki) can be used to hand plant many hundreds of seedlings a day. Pushing down on the tool creates a slot in the soil, then the seedling is dropped down the tube. This tool saves having to bend down to plant.

Plants are normally not protected individually with guards (unless individual treatment for browsing in considered necessary – see above). Protection relies on the perimeter fence. Traditionally, individual plants in small plantings have been protected using a planting bag, or milk carton supported by three posts and protected at the base using a weed mat. This method is considered too expensive to be considered for broad-scale plantings.

If the upper soil horizon is not moist at the time of planting, seedlings should be watered, but this can be impractical for large plantings, so wait for rain.

Table 2.

When to plant

Table 2 gives an overview of the best time to plant by region. In winter rainfall areas, planting should wait for the 'autumn break' – the onset of rains after the dry summer period. If you plant in winter, be careful with frost-sensitive species or when planting in frost hollows.

Techniques for direct seeding

Sowing seeds directly on-site has the potential to establish many more species than those propagated in a nursery. Direct seeding is often cheaper, but requires specialized support. A potential problem with direct seeding is that, in areas with low rain (less than 600 mm), and rain evenly spread across the year, there is often insufficient rain in a single fall to satisfy the germination requirements for all species in the seed mix. Large seeded species like Acacias tend to germinate first and dominate the site. This gives a woodland planting a skewed in species composition. In these cases consider using a combination of direct seeding and nursery seedlings.

Direct seeding tends to work best for trees and shrubs where annual rainfall is greater than 600 mm. In the Mediterranean climate of WA, direct seeding works in areas of low annual rainfall principally because there is a substantial peak of winter rainfall. Further work to improve direct seeding techniques, including pelletising seed (placing seeds in a ball of clay which includes a wetting agent, some fertiliser and insecticide), or sowing under a plastic film (temporary glass house effect; Photo 14) may improve outcomes for direct seeding.

Photo 14. Sufficient moisture and warm soil temperatures (e.g. 20C) are essential for seed germination. Trials are being conducted by Greening Australia and Birchip Cropping Group to examine how a fully degradable film manufactured by Integrated Plastics can improve seed germination by creating a temporary 'glasshouse' over lines of direct seeding.

A consistent feature of direct seeding is to scalp (cut) away up to 60 mm of topsoil. Native seeds are then generally surface sown on this scalp. Scalping is an effective technique to control weeds and remove excess nutrients that are concentrated in the first 60 mm of topsoil (Photo 15). Recent research in WA has shown a benefit from a small dose of fertiliser being included in the direct seeding mix (Goodall 2010; details below)

Photo 15. A traditional single row direct seeder in action. The large disk at the front scalps away a strip of topsoil to reduce weeds and remove excess nutrients. A mixture of seeds and a bulking agent (e.g. sand) are then gravity fed through a tube in front of the press wheel that ensures good seed to soil contact.

Direct seeding machinery

These machines come in a multitude of designs (Photo 15). However they all consist of three elements:

1. A scalping blade that removes the top soil to a depth of 30-60 mm
2. A seed box full of native plant seeds and filler (sawdust or sand) to help the seed flow evenly down a tube that delivers the seed to the middle of the scalped area, and
3. A press wheel that presses the seed onto the soil surface to prevent it being blown away and/or reduces the rate of harvesting by ants.

In some seeders the scalping blade is replaced by a mound forming discs and a blade that creates a “V” in the top of the mound (Mallen Niche seeder). Others spray a sticking agent or plastic over the seeds. A ‘Rolls Royce’ direct seeder is a modified turf making machine used for bowling greens (see grassland revegetation guide). It creates a diverse native grassland in a single pass, after the top soil has been removed from the whole paddock. This approach to re-establishing the grassy understory of woodlands could be applied to smaller areas within a large planting of just trees and shrubs (Table 1).

The basic direct seeders have only one seed box and can be towed behind a quad bike or ute. However more complex seeders are available with multiple seed boxes each delivering a different seed mix, so that in a single pass revegetation of complex structure can be created. These bigger machines are generally towed behind a tractor or four wheel drive ute.

Generally before direct seeding is conducted weed control is conducted over the whole site (see Step 3 above).

Low technology option

Direct seeding can be conducted using existing farm machinery. This involves four passes:

1. Weed control with knockdown herbicide
2. Cultivation by discing or harrowing
3. Sowing, by either:
   - Using a standard machine designed for sowing pasture grasses with some modification for the variety of size and weight of native seeds. However it is necessary to clean seed (remove chaff and awns) so that they do not block up the nozzles on the seeder; or
   - Using a fertilizer spreader that throws out the raw (uncleaned) harvested seed heads, leaves and chaff; or
   - Hand sowing.
4. A pass to cover or press seed onto the soil surface. This could be a pass with a roller, or a pass with a harrow to cover the seed and reduce chance of seed being harvested by birds or ants.

Seed preparation

Some seeds will require some form of treatment before seeding to increase the chances of germination. For example, hard-seeded species such as Acacia and other peas should be scarified or placed in boiling water then soaked overnight. Some species benefit from soaking in smoke-water overnight before sowing. Other species may need to have awns, wings or appendages removed in order to travel through the seeder. The book *Growing Australian Native Plants From Seed* by Murray Ralph is one of the best sources of pre-germination treatments. Click here to see the information that the Australian Native Plants Society also has on their website on seed preparation for sowing. In addition, CSIRO Australian Tree Seed Centre Operations Manual has comprehensive information on the germination and treatment of Acacias and other Australian tree species. Click here for further information.

The species that usually work best in direct seeding include wattles, peas, some eucalypts, casuarinas, grasses, daisies and ‘pioneer’

Text Box 1.

Scalping and turf seeding: the ‘Grassy Groundcover’ method

In Victoria, an innovative partnership between Greening Australia and the University of Melbourne has developed a successful technique for establishing complex grasslands and grassy woodlands from bare paddocks. The ‘Grassy Groundcover’ project was set up to revegetate locally rare native grasslands on the Volcanic Plains of Victoria. The project solved the seed supply problem by collecting small samples of seed of a wide range of species and growing them in foam boxes, for later seed harvest. This enabled the project to substantially increase the amount of seed available for restoration works. The weed control problem was solved by scalping off topsoil to remove weed seeds and the nutrients that favour weeds over natives. After scalping, a mixture of native species was sown from a single seed box using a modified turf seeder (Photo 16). The technique is slow, and takes many years to produce enough seed to do more than a hectare of sowing, but the results have been outstanding. For further details see: “Our Projects”

species (the first to come up after a disturbance in natural woodlands). Create a mix of species for your seeding objectives. Separate seed to suit the seeding equipment. For seeders capable of sowing at two depths, separate seed into buried and surface-sown species.
Seed may be vulnerable to predation by birds or removal by ants after sowing. Magnesium carbonate or other deterrents are regularly used to discourage ants. Red-legged earth mites, lucerne fleas and even snails often prey upon newly emerged seedlings. If mites are a known problem, implement a control program in advance. Ask your local Department of Primary Industries (or equivalent) agronomist for advice.

STEP 7.

Maintenance

After planting, the new seedlings are vulnerable to weeds, browsing, drought and insect pests. They will need to be closely monitored to ensure high survival and good growth. In dry periods supplementary watering may be needed.

All revegetation sites should be regularly inspected post-planting. Check for any problems such as browsing by livestock, damage from rabbits, red-legged earth mite infestation, or an over abundance of weeds.

If weeds are mainly grassy weeds, grass selective herbicides (e.g. Fusilade™) may be applied as an overspray using a boom if the newly emerged broad-leaf native seedlings are considered hard enough. Seek advice from a herbicide specialist if in doubt. A follow up spray is often necessary in the first year or two to control summer weeds which can compete with the new seedlings for the scarce moisture at this time of year. A shielded sprayer is useful for post-planting weed control (Photo 17). Weed control is usually not necessary once seedlings have established above the height of surrounding weeds. However, if the season is poor it may be advantageous to implement control work to maximise soil moisture levels.

Photo 17. A shielded sprayer is useful to control weeds between rows of plantings. Weed control is particularly important during the first two years post-planting as a dense cover of weeds will compete for sunlight, water and soil nutrients.

STEP 8.

Monitor to learn and improve

Follow a four-year planting cycle for maximum success, with 2 years of preparation before planting and two years of monitoring and maintenance afterwards. Most nurseries require six months' notice to supply trees and shrubs. For difficult-to-propagate species or species not usually grown (such as most ground-layer plants), nurseries are likely to require two years notice. Planting sites also need sufficient time to 'bank' moisture before planting.

After planting, the new seedlings are vulnerable to weeds, browsing and insect pests. They will need to be closely monitored to ensure high survival and good growth. In dry periods supplementary watering may be needed. Monitoring should record what is done at each step of any planting project (Figure 1).

Monitoring just outcomes like diversity of woodland birds makes no sense if few plantings lived (Results). Monitoring of Actions (inputs) is needed to know what plant species were sown and at what density with what sorts of site prepartation.

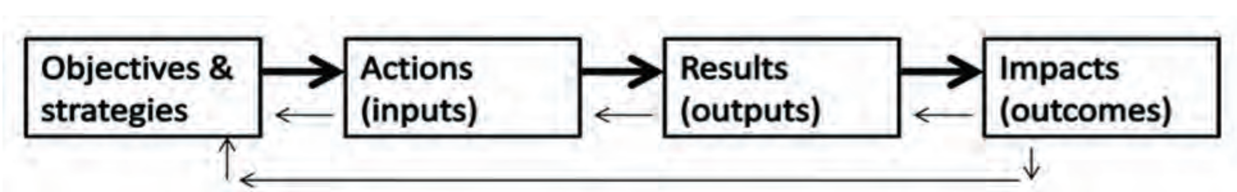

Figure 1. A framework that identifies the multiple points at which monitoring is needed to improve revegetation practices and identify outcomes. The thick arrows indicate the consequences of implementation and the thin arrows indicate key interpretation and learning feedback loops (from Freudenberger 2012).

If this Action data is not collected and archived, then it's hard to determined what lived vs what died (Results). Monitoring and 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 windbreak with some hardy 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 the site objective is to provide bird habitat, similarly there are methods to assess the reduction in salinity and erosion risks if these are 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. Remember, monitoring with photo points is an important complement to good written records (Photo 18abc).

Click here to download free key monitoring guide for revegetation sites (adapted from CSIRO/ ABARES research).

Photo 18 a

Photo 18 b.

Photo 18 c.

Photo 18 (a-c). Monitoring should include photo points from easy to relocate positions. This sequence captures the dramatic and rapid changes brought about by successful revegetation using a diversity of locally native species (a) 2002, (b) 2005 (c) 2010; note that this last photo has been shifted to the other side of the fence to get a better view of the changes.

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. glyphospate 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

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Rawlings, K., Freudenberger, D., Carr, D. (2010). A Guide to Managing Box Gum Grassy Woodlands. Canberra, ACT: Department of Environment, Water, Heritage and the Arts (156 pages).

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

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