A Revegetation Guide for Temperate Riparian Lands

Australian Government
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Greening Australia

Landcare Australia

A REVEGETATION GUIDE FOR TEMPERATE RIPARIAN LANDS

Who this guide is for?

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 along gullies, creeks and wetland areas in the temperate regions of Australia. This guide describes eight key steps that need to be followed to help ensure a successful riparian revegetation project.

The importance of riparian and wetland vegetation

Riparian land is defined as 'any land which adjoins, directly influences, or is influenced by a body of water'. The body of water could be a creek or stream (even if it flows only occasionally), a river, a lake, or a wetland. There is no rule of nature that defines the 'width' of riparian land, so it is important that riparian land is not thought of as just a narrow strip running alongside a stream. Riparian lands support a diversity and growth of plants that are adapted to the greater water availability and fertility found in these areas.

Riparian vegetation provides habitat for a wide range of wildlife from macro-invertebrates (e.g. aquatic insect larvae) through to fish, mammals and large birds. Shade provided by riparian trees and shrubs help reduce air and water temperatures. The vegetation on riparian land regulates in-stream primary production through shading, and energy and nutrient supply. Riparian vegetation provides essential aquatic habitat by way of large pieces of wood that fall into the stream and through root-protection of undercut banks. These root systems bind and reinforce soil and trap sediment (Photo 1).

Photo 1. The riparian vegetation along this stretch of the Clyde River (Tas) provides many ecosystem services including stream bank stabilisation, water filtration, carbon sequestration, and habitat for many species of wildlife, particularly during drought.

Grasses are perhaps the best soil stabilisers as they are quick to establish and their root systems stabilise large areas of soil while their foliage reduces water velocity. Riparian vegetation can help prevent water saturation that often leads to bank collapse, and can reduce water speed and subsequent bank scour and undercutting.

Wetlands need special mention as they function differently to creek frontages, even though by definition both are considered riparian areas. Wetlands are defined as places where water forms pools or flows that last long enough for plants and animals to base a significant part of their lifespan around an inundated existence. Some wetlands are permanent, forming bodies of water that rarely disappear. Others flow just beneath the surface, rising and falling with seasonal rainfall. Some last just a few months every year or so. Wetland plants and animals are adapted to the extremes of drying and flooding. Wetlands are important as habitat, for trapping nutrients and soil and retaining it within a landscape, and for maintaining surface and ground water quality (Photo 2).

Photo 2. Wetlands also provide many ecosystem services even if they dry up for months or even years. Wetlands can easily be damaged by uncontrolled grazing by livestock.

In agricultural settings, riparian areas protect adjacent farmland from erosion. The vegetation buffers crops and pastures from wind, and provides habitat for beneficial animals; especially pollinating insects and predators of pests. Shade and shelter from riparian vegetation can improve pasture productivity and livestock health. Riparian vegetation also stores large quantities of carbon, improves water filtration and reduces the risk of salinity. Quality riparian vegetation is one of the most important ways to improve and maintain catchment water quality.

STEP 1.

Assess site conditions

Before developing your revegetation plan, inspect your site carefully to understand its current condition (Text Box 1). Some useful questions to ask when assessing site condition include:

- How has the stream changed since European settlement; did it originally have trees or was it a wetland or grassland?
- Is there enough remnant vegetation left that is healthy enough to produce seed for natural regeneration?
- Are there areas of active erosion? Channel incision? Bank erosion?
- Are there any issues upstream and downstream that could affect revegetation outcomes such as invasive weeds?
- What is the adjacent land use and could it affect revegetation activities?
- Do livestock have uncontrolled grazing and drinking water access to the site?

Answering these questions will help identify what needs to be done to successfully revegetate your riparian lands. Revegetation is only needed when natural return of riparian plant species is unlikely. In some cases controlling grazing is all that is needed. But often there are a number of constraints which prevent natural recovery of riparian vegetation, these include:

1. Poor recruitment
- Lack of seed
- Lack of suitable sites for seed germination (e.g. too many weeds)

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

3. Hostile soil conditions for riparian plants
- Soil compaction from cultivation, vehicles and livestock
- Soil erosion by wind and water
- Nutrient enrichment (e.g. high levels of Phosphorus and Nitrogen – good for weeds but wless so for riparian plants)
- Carbon depletion causing poor soil structure
- Rainfall runs-off rather than infiltrating into the soil
- Lack of soil microbes that greatly assist native plant survival and growth

4. Threats to riparian plant survival
- Weed competition from pasture grasses and weeds
- Insect pests
- Grazing and traffic caused by sheep, cattle and horses (Photo 3)
- Browsing by native mammals

Text Box. 1

Rapid Appraisal of Riparian Condition

The Rapid Appraisal of Riparian Condition is one way of formally assessing changing site conditions. It assesses the ecological condition of riparian habitats using indicators that reflect functional aspects of the physical, community and landscape features of the riparian zone. The index is made up of five sub-indices, each with a number of indicators:

- Habitat continuity and extent (HABITAT),
- Vegetation cover and structural complexity (COVER),
- Dominance of natives *versus* exotics (NATIVES),
- Standing dead trees, hollows, fallen logs and leaf litter (DEBRIS) and,
- Indicative features (FEATURES).

The Rapid Appraisal of Riparian Condition has been used in south-eastern Australia to examine relationships between grazing intensity and riparian condition. Generally, poor riparian condition was associated with high levels of grazing intensity.

Testing of the Rapid Appraisal of Riparian Condition index confirms that it is a good indicator of the biodiversity and functioning of riparian zones and the methodology has been trialled on ephemeral and permanent creek systems around Bookham and Yass on the southern tablelands of New South Wales.

It is an easy to understand, simple and quick method of assessing the condition of a waterway and given how complex riparian ecosystem interactions are.

Click here for further information.

- Stream bank erosion including that caused by livestock access to in-stream water

Photo 3. Fencing is often the most important first step in repairing and protecting stream bank vegetation. This fence was positioned too far down the stream bank to provide adequate protection from livestock.

Any and all of these threats to riparian vegetation must be addressed to achieve successful and lasting revegetation.

Erosion assessment

Erosion deserves specific mention as it is a common problem that not only impedes the natural recruitment of riparian plants, but can also adversely affect revegetation. It is important to have an understanding of why erosion is occurring (Text Box 2). This will determine whether revegetation alone can solve the problem, or whether in-stream structures are required.

The type and position of vegetation needs to be matched to the nature of the problem. Soil type has a major influence on whether a site is likely to continue eroding.

- Rocky embankments are extremely cohesive and erosion of surface sediments is limited.
- Clay soils are reasonably cohesive and tend to erode slowly, although loose surface sediment is quickly lost (Photo 4).
- Non-cohesive sands, loams and dispersible clays are most prone to erosion and collapse (Photo 5).

Eroded areas

In terms of specifically addressing erosion using revegetation, there are some general rules of thumb:

• *Channel incision* occurs when the bed is eroded and deepens. This in turn increases the height of the banks to the point where the banks can no longer support themselves and they collapse, resulting in channel expansion. Vegetation on the channel or gully floor (although difficult to establish) is useful in stabilising the bed, but often some grade control structures are needed. Planting the toe of the bank and any in stream bars and sediment deposits will help to stabilise the channel. Shrubs and grasses in channel floors are preferable to trees, as they don't deflect water into the banks compounding the original problem.

• *Channel widening* may or may not be related to incision. If banks are eroding it may be because of bed incision, reduced channel capacity with no incision, unusual flow events and/or lack of ground cover. The key to addressing this issue is to establish vegetation as far **down the bank** as possible, as well as on top of the bank. Attention needs to be given to the 'toe' of eroding banks and this may require structural intervention in places. As with incision, in-channel vegetation in most cases should be restricted to shrubs, grasses and aquatic plants to prevent future deflection of water into banks from large trees.

• *Outer bank erosion* occurs when steep banks on the outside of a meander bend erode, and is commonly faced on larger streams. It is often very difficult to establish vegetation on such sites and in general, the higher the bank the less useful the vegetation on the top of the bank will be. Revegetation without other intervention on such sites is only likely to be effective where the height of the banks and the root depth of vegetation is similar.

Text Box. 2

Photo 4. Expert advice is needed to develop a plan to stabilise this crumbling river bank. The soil is reasonably cohesive, but the force of the river is large.

Photo 5. This ephemeral creek, has become incised through a highly dispersive ('spewy') yellow sub-soil, but is becoming stable due to light grazing pressure that is allowing for the natural regeneration of deep rooted grasses.

For non-cohesive soils, great care is needed in limiting soil disturbance during planting and rock or log structures may be needed. If in doubt consult with your catchment NRM organisation for advice on management of erosion in riparian zones.

Wetlands

Wetlands include damp-lands and sump-lands, ephemeral wetlands, fern gullies and springs, marshes, swamps, rivers and creeks, flood plains, billabongs, lakes, underground wetlands, salt marshes, estuaries, mangroves, farm dams and other artificial wetlands. Regardless of whether a wetland is being constructed or rehabilitated, an understanding of flooding and drying regimes is essential prior to any revegetation. Assess carefully how water should flow in and out of your wetland site. Flows and levels need to be worked out well before revegetation starts, including a range of depths that include wet and dry areas.

Moderately degraded wetlands often benefit simply from protection and being allowed to regenerate naturally providing there are enough natural elements to enable this. Constructed wetlands, or those in a very poor state may need soil works to improve hydrological flow patterns in conjunction with active revegetation. Local advice should be sought for any kind of wetland rehabilitation, particularly where the use of machinery is proposed.

Fallen timber

Large 'woody debris' is a term used to describe river snags including large limbs, branches and complete trees. Such fallen timber provides habitat for a range of species including fish and invertebrates as well as providing a food source of organic matter for other animals. De-snagging rivers leads to a loss of habitat, increased flow rate, and can result in channel erosion. Riparian vegetation is an important source of woody debris, and its removal or absence disrupts the ecology of the river.

STEP 2.

Set clear site objectives

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

- Wildlife habitat and dispersal corridors
- Shade and shelter for livestock
- Improved water quality
- Reduced erosion
- Salinity management
- Carbon sequestration
- Good looks! (aesthetics)

Historically, the objective of restoration has been to fully re-create the native vegetation believed to have occupied the site before it was degraded. However, comprehensive restoration of hundreds of plants species is costly. 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, a compromise may be needed. 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 vegetation 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 judgement, your objectives, and the importance of the riparian restoration in a landscape context.

First identify the best riparian vegetation you've got, whether it be along a reach, within a catchment or even a region. These areas provide a good starting point for a riparian revegetation project. If there is no reasonable riparian vegetation left, start in an area up stream that is the most stable and easiest to plant out. Don't start in the toughest and most eroded areas. Deal with these difficult areas once you've gained experience revegetating less degraded areas nearby.

Although full restoration may be impractical, most degraded systems can be revegetated well enough to improve water quality, livestock shelter, and wildlife habitat. Useful objectives can be as simple as: 'fencing both sides of the entire creek length and replace all willows with native trees by 2018'. Clear and specific objectives define success. They allow you to assess the course of action you need to take and measure progress towards achieving your goals. It is worthwhile producing a simple map showing areas of remnant vegetation, areas of erosion, existing fencing and proposed works needed to achieve your objective(s).

Landscape context

Ideally revegetation or restoration should be conducted to buffer and re-connect existing high quality riparian remnants. In addition, it is important to link riparian vegetation to terrestrial vegetation to provide habitat connectivity right across the whole landscape – work with your neighbours. Many species of wildlife regularly travel to dry woodlands to feed and return to riparian areas for water and shelter. In many landscapes, wildlife, particularly birds, can be used as indicator groups for prioritising connectivity between patches of riparian vegetation and nearby woodland patches.

STEP 3.

Choose species to suit local conditions

Choose riparian species that occur in similar soil-landscape environments. Where possible, locally occurring plant species that match the relative abundance of those found in nearby riparian remnants on similar soils and drainages should be used (Text Box 3). 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 (e.g. eucalypts), medium sized trees (e.g. acacias), large shrubs, small shrubs, large tussock grasses, rushes and sedges (Diagram 1). Different layers of vegetation planted in the right places provide food for pollinators, fix soil nitrogen, provide nesting sites for insectivorous birds, organic material for fish and macro-invertebrates and help resist the invasion of weeds. Most importantly choose native plant species that will survive.

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. For example some genetic introductions can result in sterile hyprids. A judgement has to be made as to the risk of diluting or changing the genetic make-up of a important population of a recognised plant species. Although it may appear desirable to use seed from a provenance of hardy individuals of the species occupying a site e.g. 100 km away, this may compromise the objectives of protecting the genetic character of a particular population that is otherwise rare.

Text Box. 4

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)

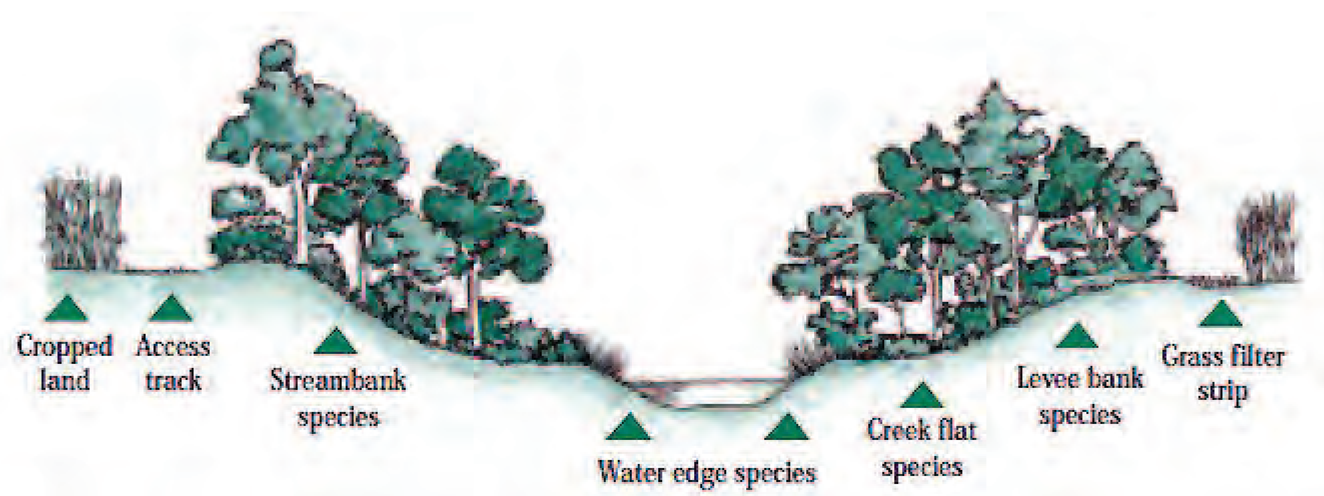

Diagram 1.

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 (Text Box 4). Rainfall, soil, altitude, drainage and flow regimes are all important environmental factors in riparian plant adaptation.

An exception to this principle is where the site environment has changed to the extent that some local species can no longer survive. Secondary salinity, altered soil structure, and changed water flows (e.g. less flooding) mean that some local species may no longer survive on your site. In these instances, a 'nursery' planting may first be required to reduce wind exposure, erosion, water logging, salinity or other factors hostile to restoration of local 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. Seed suppliers need plenty of advance notice (at least a year) 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 are rare and seed is generally unavailable from seed suppliers, seed nurseries or orchards may need to be established 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 a broad seed mix.

In most cases however, rare plants are not used unless remnant vegetation is being enhanced. For most riparian revegetation activities, a mix of common species is sufficient to restore a reasonable level of ecosystem function.

STEP 4.

Select quality plant material

Only use healthy seedlings. The size and root structure of seedlings is critical to their survival both after transplanting and long term. 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 not too much leaf and stem. 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 (Photo 6). In addition, slots and holes in the sides of the tubes air-prune roots so root-binding does not occur. Seedlings should also be ordered or germinated with enough growing time to meet quality specifications. In particular, root development should be sufficient so that potting media does not collapse on removal of the seedling from the container.

Photo 6. Fluted nursery pots promote downward pointing roots, rather than spiralling roots that can develop in smooth and round tubes. Note also the air pruning of the roots at the bottom of the pot.

A good quality seedling is 10-20 cm tall, is not root-bound, and has been 'hardened off' before delivery. 'Hardening off' involves nutrient starvation for at least one month (so leaves are tough and less palatable), and exposure to low temperatures outside the glasshouse for at least one month to induce frost resistant. Seedlings that are not hardened properly will be set back or killed when transplanted into hot or frosty conditions.

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 a lot of new fresh growth, as these seedlings have received a recent flush of nutrients and may be too soft to withstand the shock of being transplanted into a hostile environment. Most nurseries take back the pots to be cleaned and reused, so don't leave them at your planting site.

Quality seed

It is vital that seed is appropriately sourced for riparian plantings. Native seed sourced locally is a good rule of thumb, however there are circumstances where 'local is best' may not apply.

Exceptions

- Where the local seed from any given species is not from the same kind of riparian land at your site (e.g. seed from a steep stream bank rather than a broad flood plain). It is better to match for environmental site conditions rather than to automatically choose the closest local native seed source for any given plant species.
- Where the local native seed is sourced from an isolated tree or scattered population. Out-breeding trees like eucalypts will have poor quality seed if the tree is isolated in a paddock, regardless of its health. Self pollinated seed tends to be is weak, the seedlings will likely grow slowly, and there will be high death rates. Collect seed from the nearest healthy intact population of the species containing at least 100 individuals in close proximity.
- Local may not be best if 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 seed from lower altitude and drier sites). Or your riparian site may be much drier because it's down stream of a dam and now rarely gets flooded. In such cases, seed from drier sites is likely to be better than seed from well flooded sites above the dam.

Additional rules of thumb for seed collecting

- 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.
- 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).
- Don't destroy or over-collect from a single individual. Collect seed only from a proportion of the tree and don't remove large numbers of branches.
- Record the position of plants, ideally with a GPS reference, and keep a copy with the seed. If the seed is sown in a nursery, label the seedlings with the source location too. This information is important for knowing where quality seed (e.g. good survivorship) came from for future collecting.
- Once collected it is important to conduct viability tests on the seeds to know the sowing rates needed to germinate sufficient quantities of seed for your restoration plantings.
- Collect seed at the right time with the right equipment (Photo 7a,b).

Photo 7a.

Photo 7b.

Photo 7. (a-b) River red gum seed (*Eucalyptus camaldulensis*) that is ripe, but hasn't been shed yet. Make sure you have the right equipment like a pruning pole to harvest small quantities of seed from each of many trees.

STEP 5.

Site preparation

Plantings will only thrive if the site is prepared well. The primary purpose 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.

The first rule is to do no further harm or avoid the damage in the first place. It is easy to damage natural streams and wetlands. It is hard, slow and expensive to repair then back to a functional state. Appropriate riparian site preparation methods should be chosen to reduce the risk of creating erosion. Often, methods that disturb soil significantly are not appropriate close to waterways. Soil disturbance should be kept to an absolute minimum. Weed control must also be undertaken carefully, particularly where the use of chemicals near water is necessary.

Weed control

Weeds compete with newly established plants for moisture and sunlight. 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.

There is only one chemical registered for use along waterways – Glyphosate (RoundUp Biactive™) which has the surfactant removed to reduce impacts on aquatic life. This is a broad spectrum herbicide and appropriate for killing weed and grass competition prior to revegetation.

Weed control should be undertaken:

1. Ideally one year 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. Final spray just before planting.

Vigorous perennial grass weeds like phalaris (common along waterways), African love grass and Chilean needle grass are likely to need repeated applications of glyphosate to control them. Residual herbicides should not be used close to waterways.

Make sure your equipment is appropriate to the size of the job. Backpack sprayers are suitable for spraying small areas or individual weeds (Photo 8). 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.

Photo 8. A backpack sprayer is idea for small areas that need careful application of herbicide. Avoiding spray drift is particularly important in this instance of willow poisoning.

The area sprayed should be limited to the placement of the revegetation. That is, 1.5 m wide strips for linear plantings (direct seeding and tubestock) or 0.75 m circles for spot spraying (tubestock). This reduces chemical use (and cost) and will ensure that fewer bare areas are at risk of erosion and weed invasion.

Grazing control

Regardless of the quality of weed control, a riparian 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 native mammals like kangaroos and wallabies).

In most situations, fencing off the area to be revegetated is essential (Photo 9). An ordinary stock fence is generally sufficient in areas where it is only stock that have to be excluded or the numbers of native browsing animals are low. Alternative watering points for livestock must also be considered.

Photo 9. Fencing prior to revegetation is essential to restrict grazing and browsing animals. It may be less expensive to fence out a wider area to avoid lots of turns that require strainer posts and stays.

Guarding trees in association with fencing is also useful to minimise browsing to some degree. There are a variety of options ranging from cardboard milk cartons and bamboo stakes (generally sufficient for rabbits) through to tall GreenGuards™ with hardwood stakes which have proven (somewhat) successful in minimising grazing by wallabies and kangaroos. Both these guards break down naturally. Plastic guards are not recommended along waterways as they do not readily break down, and can strangle aquatic life. Ideally guards should be removed when plants reach a certain height, but this often doesn't happen in reality. For this reason, biodegradable guards are recommended. When undertaking direct seeding, guards are not an option.

Control of feral animals as part of a wider (neighbourhood) program should also form part of standard land management practices and ideally should be focussed in areas where revegetation is planned.

Soil preparation for tubestock (nursery seedlings)

Broadscale cultivation should generally be avoided in riparian land. Instead, spot cultivation is preferable. This can be in the form of a spinning excavator attachment, or an auger attachment operated from a small excavator or dingo digger.

A backhoe bucket can also be used to dig holes. Hand augers are also an option although require a lot of effort. This option is usually reserved for sites that can't support or be accessed by machinery. In the case of using an auger, there are options available (developed by CSIRO) with horizontal 'wings' that reduce the likelihood of 'glazing' occurring on the sides of the hole. If this option is not available, a crowbar will need to be used to break up the sides of the hole prior to planting, especially in heavy clay.

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, and are often not used for large scale revegetation projects. A thin narrow strip of coarse sand has been used successfully as mulch for surface-sown seeds. Inoculants of soil biota, such as Wattle-Grow can be added to both direct seeding and seedlings to increase the nitrogen-fixing ability of Acacias and some pea species. There is also research into a product called 'biochar' which is effectively charcoal added during site cultivation, and is expected to improve the moisture holding capacity of soil. It is still under trial with some promising initial results but remains very expensive if purchased in large amounts.

Insect control

Herbivorous 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, a systemic insecticide tablet can be placed under the seedling or systemic insecticide can be injected into the soil around root bowl before planting (usually in the nursery). Treating insect attack after planting is more difficult and 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. A decision needs to be made through the planning phase whether chemical insect control is warranted depending on the likelihood of this being a problem.

Another option for controlling insects is to plant lots of flowering understorey plants. These attract small insectivorous birds to the site which eat many hundreds of insects per day. As the ecosystem balance is restored, plants become subject to less insect attack.

STEP 6

Planting and sowing

There are several methods for riparian revegetation, with the main ones being tubestock planting and direct seeding. Tubestock (nursery seedlings) are usually the most appropriate method of revegetation along waterways and eroding areas, as access for direct seeders and other machinery can be difficult. A planting implement should be used to assist with seedling planting and minimise bending over (Photo 10ab).

Photo 10a.

Photo 10b.

10 (a-b). Planting seedlings with Hamilton Tree Planter implement. A 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.

Aquatic plants can be hand planted, although in areas where there is some natural vegetation remaining, these tend to regenerate by themselves. Long stem tubestock are also an option for establishing vegetation in areas prone to flooding, as they establish quickly and are more resistant to scouring and being buried with sediment (Text Box 5).

Text Box. 5

Planting Long Stem Tubestock

Long stem tubestock are particularly useful when plants are likely to be flooded or are in areas prone to erosion. Long stem tubestock are plants grown for up to 18 months to heights of up to 2 m using a specific nutrient storage regime (e.g. in the base of a channel). Long stems are planted at a depth of 0.5-1.5m using a water jet attached to a small pump. Two types of jets have been developed and include a standard jet for planting in fine soils, sand and loams, and a percussion jet for planting in gravel and cobbles. With the percussion method, the PVC is replaced with steel pipe and drainage bar and a dolly bar is used to hammer the jet to the required planting depth. Hand and mechanical augers have also been used with success for planting long stems.

Long stems take a long time to grow, and are expensive but may be the only option is some areas. As they are planted deep into the ground, the leaf nodes form into roots providing well established plants in a short time frame. They are able to withstand high water flows and being buried by soils (providing some part of the plant is visible). Long stems tend to be reserved for sites where tubestock establishment or direct seeding proves unsuccessful.

General tips for planting riparian areas:

- Appropriate vegetation needs to be established as far down the bank as possible. From the top to the toe of the bank. Generally shrubby, grassy and aquatic vegetation is more suitable for these areas as they are more effective at reducing water velocity and don't deflect water into erodible banks.
- A range of species should be used.
- There are several different microclimates along riparian zones (Diagram 1 above) that provide conditions suitable to specific vegetation.
- Excessive rainall run-off from the surrounding land should be addressed where possible, for example increase perennial pasture cover in adjacent paddocks.
- The largest buffer strip possible should be rehabilitated that reflects management objectives and site characteristics. Some people put an arbitrary figure on buffer widths, but in reality it is dependant on site specifics.

Wetlands

Aquatic plants including emergent and submergent plants can be grown from seed or from division of plants. When revegetating, it is advisable to start with a range of hardy "framework" species that can trap sediment and nutrients and set the scene for more delicate species. Planting should initially be undertaken in shallow areas, as they will spread themselves into their natural zone as they establish in response to light and water depth. Planting may also need to be undertaken in stages to allow plants to take advantage of natural cycles. Bare rooted seedlings are the most cost-effective way of obtaining aquatic plants. They are also not adversely affected by some of the challenges faced by dryland bare rooted plants. Cellstock and tubestock are also available and suitable for wetland revegetation.

Direct seeding

Sowing seeds directly on-site has the potential to establish many more species than those propagated in a nursery. Direct seeding is considerably cheaper, and if done properly can be very successful. However, direct seeding does not work as well in areas of high moisture with a high level of grass competition. For example, areas dominated by Phalaris. When using direct seeding to establish vegetation along riparian zones, it tends to be restricted to the banks adjacent to dry gullies. If direct seeding is chosen in pasture dominated riparian sites, particular attention needs to be given to weed control as part of site preparation.

The most common reasons for failure of direct seeds are poor weed control, sowing undertaken at the wrong time of year, lack of rainfall and being premature deemed a failure followed by grazing the site with domestic stock. Germinating plants are hard to see, so advice must be sought from the direct seeding operator before deciding if it has failed. Plants will continue to germinate for several years after direct seeding takes place. Directly sown seeds quite often will sit in the soil until conditions become conducive to germination. A 'failed' direct seeding site in year one may become a successful site in year two or three.

Direct seeding machinery

These machines come in a multitude of designs. However they all consist of three elements (Photo 11):

Photo 11. Direct seeding machine in action. Direct seeding can be a less expensive way of establishing a diversity of species, particularly in flat area with good access (e.g. Photo 12)

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 with or without 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.

The basic direct seeders have one or two seed boxes and can be towed behind a 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.

Seed preparation

Most hard coated seeds 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. The Australian Native Plants Society also has an informative 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.

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.

When to plant

Tubestock planting can generally take place all year round except during the hot summer months. Usually the planting season will start during autumn once the weather starts to cool and after rainfall or an 'autumn break' occurs. The planting season extends into spring before the onset of hot weather. However, the seasonality of flooding must also be considered. Spring planting should be avoided if there is a regular spring flood through your site.

Direct seeding is generally restricted to spring, when the soil is warm enough for seeds to germinate.

STEP 7.

Maintenance

Maintenance is vital and often overlooked as an integral part of revegetation. This is especially true of riparian areas which are subject to a range of pressures such as weeds, flooding, erosion and often a concentration of browsing animals.

A maintenance strategy should be implemented that incorporates grazing management, weed control, feral animal control and fire management.

Maintenance considerations in a nutshell:

- Regularly inspect the site – identify and record successful species for future reference.
- Check for pest animals e.g. insect attack or signs of browsing.
- Post planting weed control may be necessary if high weed competition.
- Check fence lines are secure from browsing animals.
- Replace lost plants if necessary. This is not usually needed if losses are less than 20% provided plants were spaced at 3-4 m apart.
- Thinning – generally only relevant to direct seeding and farm forestry sites.
- Check and straighten or replace tree guards as necessary.
- Remove tree guards from large plants.
- Water necessary during extended drought.

STEP 8.

Monitor to learn and improve

Monitoring should record what is done at each step of any planting project (Figure 1).

Monitoring outcomes like diversity of birds or aquatic macroinvertebrates makes no sense if few plantings survived (Results). Monitoring of Actions (inputs) is needed to know what plant species were sown and at what density with what sorts of site prepartation. If this Action data is not collected and archived, 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 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 methods. However, the Table below provides a guide to the 'generic' kinds of monitoring data that need to be collected for any type of planting. Monitoring requires good record keeping but should also be complemented with photos taken over time (Photo 12).

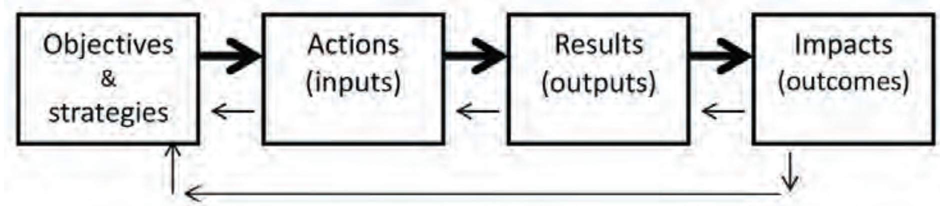

Figure 1. A framework that identifies the multiple points at which monitoring is needed to improve revegetation practices and identify outcomes. The thick arrows indicate the consequences of implementation and the thin arrows indicate key interpretation and learning feedback loops (from Freudenberger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

record keeping needed for monitoring input activities and the results or impact of activities such as revegetation. Photos help inspire and inform.

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

Table 1. Key monitoring data for revegetation sites (adapted from CSIRO/ABARES research). A free database (VegTrack) to manage this data can be downloaded at http://www.csiro.au/Outcomes/Environment/Biodiversity/VegTrack-Software-Download.aspx

Further Reading

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Further Assistance

For further assistance or advice we suggest you try contacting:

Greening Australia
ph 1300 886 589
or find us on
http://www.greeningaustralia.org.au/contact-us

Your Regional NRM (catchment) Organisation

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