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Management of River and Creek Bank Plantings in Sub-tropical Coastal Riparian Rainforest

by
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Department of Natural Resources

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Kilkivan Landcare Group
Wide Bay Burnet Environment Council
Members of Crystal Waters Permaculture Village

Participating Primary Producers:
John Anderson, Gympie
Herb Berton, Maryborough
Alex and Andy Rudd, Conondale
Richard Stark, Kenilworth
Keith Anderson, Kenilworth
Pat Dwyer, Chinamen's Creek
Olsen Family, Chinamen's Creek

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Contents

This booklet focuses on planting techniques for revegetation of river and creek banks in sub-tropical areas.

Actively eroding areas occur on steep banks increasing the difficulty of re-establishment.

Special management techniques are required to grow plants on river and creek banks.

Remnant sites often require the same attention as new plantings.

INTRODUCTION

The re-establishment of indigenous vegetation is an effective solution to the problems of bank instability along our rivers and creeks.

The re-establishment of rainforest plants along rivers of the sub-tropical east coast of Australia can be expensive and time consuming. Planning and forethought are needed to reduce costs. A number of factors, such as flooding, poor nutrition, active erosion, siltation, weeds and frosts, can render the re-establishment of vegetation extremely difficult. Special management techniques may be required to grow plants in these areas, whereas on more sheltered sites plant establishment can be relatively easily achieved.

This booklet has been designed to help the user to plan and manage riparian vegetation re-establishment projects. It covers species selection, with special attention to limitations that govern species selection, and describes techniques for managing the establishment of riparian vegetation.

The protection and enhancement of the remnant strips of riparian rainforest vegetation that are found along many of the rivers in this area is an important tactic in the restoration of a healthy riparian rainforest.

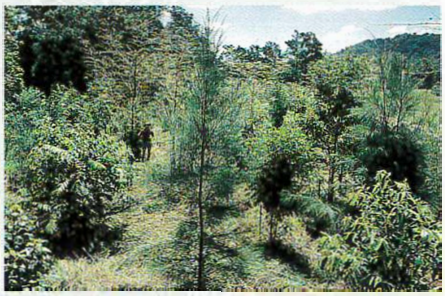
EXAMINING THE SITE

It is important to examine the site at least six months prior to planting. A planning framework can then be drawn up and certain measures, such as the removal of problem weeds and the sowing and establishment of cover crops, can be implemented prior to planting. The planning framework should include:

- an assessment of the broader river processes *ie* bank erosion, bed lowering, and in-stream sedimentation well above and below the site.
- identification of the need for physical structures to control actively eroding areas.
- a condition assessment of the vegetation in the riparian zone - Appendix A provides a framework for this assessment.
- plant species selection.
- a planting strategy.
- a weed control strategy.

Professional river managers (*ie* staff in State Government Departments such as the Department of Natural Resources (DNR)) should be consulted where significant vegetation re-establishment projects are to be undertaken.

It is best to prepare sites up to six months before planting to facilitate easy on-going maintenance and limit erosion at the plant sites. This allows time for the removal of problem weeds and enables cover crops to be sown and established before planting.



On some severely degraded sites engineering solutions may be required in conjunction with revegetation works.

Species selection for a particular site is influenced by;

- *the limitations to plant growth at that site*
- *the growth rates of plants at that site*
- *the condition of the site*
- *the abilities and resources of the manager.*

SELECTING PLANT SPECIES FOR REHABILITATION

The most effective method of selecting suitable species for rehabilitation projects is to find out what is already growing on the site. Carrying out a plant survey of the nearest relatively undisturbed sites can give a good idea of which species are able to rehabilitate degraded areas. Normally areas that have regenerated naturally will have potential re-establishment species growing on them.

From an ecological point of view it is preferable to re-establish plants indigenous to the site, however, some conditions may limit the ability of the once naturally occurring species to grow on the site. Other native species may need to be grown to facilitate the planting of the original species at a later date. Conditions at some degraded sites may have changed so considerably that re-establishment of the original species may not be economically possible. On some severely degraded sites engineering solutions may be required in conjunction with revegetation works.

Species selection for a particular site is influenced by; the limitations to plant growth at that site, the condition of the site, the abilities and resources of the manager, and the growth rates of plants at that site.

LIMITATIONS TO PLANT GROWTH

Climatic factors: *Sun intolerance*

Many rainforest plants need a shady site, therefore on exposed sites sun tolerant pioneer plants will need to be planted to provide shade. Wattles (*Acacia* sp.) have in the past been used as pioneer plants but experience on some sites indicates that these are vigorous, grow much faster than, and inhibit growth of, the more desirable rainforest species. However mature, naturally established stands of wattles on the Mary river have provided limited shelter for naturally regenerated rainforest plants. Subsequent floods have damaged these wattle stands allowing for liberation of the under-seedlings. This liberation could be assisted by treating the wattles with herbicides. River she oak (*Casuarina cunninghamiana)* is also a fast grower but again can dominate the whole site reducing the ability of rainforest plants to regenerate. Consideration could be given to thinning of such sites, although the effectiveness of this treatment is undemonstrated. Another similar untested option would be to use paperbark (*Melaleucas)* and bottlebrushes (*Callistemon)* as 'pioneer' or 'companion' plants and perhaps later thin some out to provide space for the rainforest plants.

Remnant rainforest strips provide sheltered sites for enrichment planting of other rainforest plants and can be good sites for re-establishing rainforest species.

Species selection is influenced by the vertical height and steepness of the river bank and the position of the plant on the bank.

Wind intolerance

Many rainforest plants need shelter from drying winds. The tops of banks are particularly open to wind and generally much drier. This is a difficult environment for the establishment of any plants, let alone rainforest plants. Planting the areas adjoining these bank tops with Farm Forestry timber plots will provide a windbreak which may be selectively harvested when mature. By this time the riparian rainforest will be able to tolerate the loss of shelter until a new Farm Forestry plot is grown.

Frost sensitivity

Frost can limit the establishment of many plants. Plants growing in sheltered areas *eg.* near the base of streambank cliffs or large trees, or where a light canopy occurs, are usually protected from frost. Pioneer, companion or Farm Forestry options could be used to overcome this problem.

Moisture

Plants tend to have restricted growth during dry periods. Plantings during times of high moisture availability are more successful. Rainforest is difficult to establish on dry degraded sandy banks and selecting hardier rainforest plants and dry riparian forest species like bottlebrushes and paperbarks may be necessary.

Inundation

Inundation may have both negative and positive affects. The lower parts of a river bank may experience periodic flooding damaging plants or washing them away. Water may also be more available in this part of the bank due to percolation from below or seepage from above assisting plants in dry periods. Flooding, however, may cause silt to be deposited on the leaves, weighing down the plant or burying it, or simply twisting the plant at its base and killing it (observed on *Eucalyptus tereticornis*).

As plants may have evolved in clean water conditions the silt loads of floods today may reduce the ability of some species to survive after floods or to regenerate naturally. It is therefore desirable for plants to be cleaned up and retrieved from silt and debris after floods because a silt covering on the plant reduces photosynthesis and can cause rotting in the leaf apex and roots of plants.

Young plants are also washed away more frequently on the lower bank. These areas require more attention to planting depth, and frequent replanting may be required.

Physical factors: *Bank Profile and Height*

Plant selection is influenced by the vertical height and steepness of the river bank and the position of the plant on the bank. On steep banks the top side of the bank may be drier and be open to the wind, which reduces plant growth compared to the same species planted in a shaded, protected area at the base of the bank. The lower area is protected from the elements and is wetter due to percolation of water from above and below but may be adversely affected by floods. Upper banks should be planted with fast growing, drought hardy, non-shelter loving species, middle and lower banks may require supple flood-tolerant, fast growing species whose roots anchor them quickly. Supple or whippy plants bend and are less inclined to be uprooted by floods.

Where limitations to plant growth are severe the choice of species is critical.

On stable, protected sites greater attention can be paid to recreating the original rainforest habitat.

On remnant sites plantings are sheltered but may suffer competition from larger, established trees.

Species selection entails selecting those species that are either tolerant of the site and climatic limitations, or predispose the site to the planting of other desirable species.

Severely limited sites

Where limitations to plant growth are severe the choice of species is critical. On severely limited sites, such as mainstream areas with actively eroding steep banks, where flood currents are strong and fast, few rainforest species are suitable for quick stabilisation of the site. Consideration must be given to the riverine processes to determine the impact these processes have had on the site and whether trees alone will do the job. These severely limited sites may need to be made stable, using engineering works to create conditions suitable for subsequent establishment of riparian species which are fast growing, have good vigour, are drought tolerant, have a mass of fibrous roots and bend with the floods. Equal numbers of bottlebrush (*Callistemons)*, paperbark (*Melaleucas)*, and she oak (*Casuarinas)*, mixed with some vigorous growing rainforest plants such as the figs (*Ficus)* are suited to these sites. The fruit of figs encourages birds and they will bring in seeds of other species. In later years thinning of the establishment species to enable replanting some of the original riparian rainforest species could take place. Where frosts are severe difficulties will arise with the establishment of rainforest plants like the fig.

Stable protected sites

On stable, protected sites, (sheltered areas with only minimal bank changes), which are often found in the upper reaches or tributaries of rivers and not impacted by river processes, species selection is much easier. Both slow and fast growing plants are suitable, and drought and the odd flood do not have such significant effects. On stable, protected sites greater attention can be paid to recreating the original rainforest habitat. The main limiting factor even on these protected sites is frost although, if the site is well protected and good growing conditions are present, plants can recover from frost. However considerable losses can still occur, height growth may be restricted and prolonged maintenance of the site can result in high establishment costs.

Sites with remnant riparian vegetation

On banks where vegetation decline has been the issue and remnant riparian vegetation still remains, enrichment planting may be required. Where there is reasonable integrity of surface conditions, limited erosion activity, and good shelter from frost and wind, rainforest plants can be established. A longer period of establishment is required due to slower growing plants and competition from the canopy trees. While this may involve more work, greater long term stability is achieved if the forest structure can be re-established. These sites provide important habitat for wildlife and fauna conservation.

SPECIES SELECTION

Species selection entails selecting those species that are either tolerant of the site and climatic limitations, or predispose the site to the planting of other desirable species. Having looked at the site, and established the factors that limit plant growth, an acceptable planting configuration can be determined. Table 1 gives a good review of the species that can be grown in different situations.

TABLE 1 – SPECIES SUITABLE FOR PLANTING ON RIPARIAN SITES

Species	Common Name	Suitable Sites	Forest Type	Position on Bank	Erosion Tolerance	Requires Protection	Growth Rate	Frost Tolerance
Species suited to highly eroding frost areas.								
Callistemon viminalis	Weeping Bottlebrush	U, M, L	RF, D	1–3	3	N	F	Y
Casuarina cunninghamiana	River Sheoak	U, M, L	RF, D	1–3	3	N	F	Y
Casuarina glauca	Swamp Sheoak	L	D	1–2	3	N	F	Y
Eucalyptus tereteticornis	Forest Red Gum	U, M, L	D	1–3	3	N	VF	Y
Eucalyptus tessellaris	Moreton Bay Ash	U, M, L	D	3	2	N	M	Y
Grevillea robusta	Silky Oak	U, M, L	RF	2–3	3	N	VF	Y/N
Hibiscus tiliaceous	Cotton Tree	L	T	1	3	N	F	Y/N
Lomandra hystrix	Tall Mat Rush	U, M, L	RF	1–3	3	Y	M	Y
Lomandra longifolia	Mat Rush	U, M, L	RF	1–3	3	N	M	Y
Melaleuca bracteata	Black Tea Tree	U, M, L	D	1–3	3	N	F	Y/N
Melaleuca linarifolia	Snow in Summer	M, L	D	1–3	3	N	VF	Y/N
Melia azedarach	White Cedar	U, M, L	RF	1–3	3	N	VF	Y
Waterhousea floribunda	Weeping Lilly Pilly	U, M	RF	1	3	N	F	N
Rainforest species suited to erosion control.								
Acacia aulacocarpa	Hickory Wattle	U, M, L	RF, D	1–3	3	N	F	Y/N
Acacia maidenii	Maidens Wattle	U, M, L	RF, D	1–3	3	N	F	Y/N
Acacia melanoxylon	Blackwood	U, M, L	RF, D	1–3	3	N	F	Y/N
Aliphitonia excelsa	Red Ash	U, M, L	RF, D	3	2	N	M	N
Clerodendrum floribundum	Lolly Bush	U, M	T, RF	2–3	2	N	M	N
Commersonia bartramia	Brown Kurrajong	U, M	R, F	2–3	2	N	M	N
Elaeocarpus grandis	Silver Quandong	U	R, F	1–3	2	N	VF	N
Glochidion ferdinandi	Cheese Tree	U, M, L	RF	1–3	2	N	F	N
Glochidion sumatranum	Umbrella Cheese Tree	U, M	RF	1–3	2	N	F	N
Guioa semiglauca	Guioa	U, M, L	RF	2–3	2	N	M	N
Jagera pseudorhus	Foambark Tree	U, M, L	RF	2–3	3	N	M	N
Syzygium australe	Brush Cherry	U, M, L	RF	1–3	2	N	M	N
Species suited to less degraded rises.								
Alectryon tomentosum	Hairy Alectryon	U, M, L	R F	2–3	2	YY	S	N
Argyrodendron trifoliatum	White Booyong	U, M	RF	2–3	1	Y	S	N
Arytera divaricate	Coogera	U, M, L	RF	2–3	1	YY	M	N
Bridelia leichardtii	Scrub Ironbark	U, M	RF	2	1	YY	S	N
Castanospermum australe	Black Bean	U, M	RF	2–3	2	Y	M	N
Castanospora alphandii	Brown Tamarind	L	RF	2–3	1	YY	S	N
Cleistanthus cunninghamii	Cleistanthus	U, M	RF	1–2	1	YY	S	N
Cryptocarya glaucescens	Jackwood	U, M	RF	2–3	1	Y	S	N
Cryptocarya hypopodia	Rib Fruited Pepperberry	L	RF	2–3	1	YY	S	N

Species	Common Name	Suitable Sites	Forest Type	Position on Bank	Erosion Tolerance	Requires Protection	Growth Rate	Frost Tolerance
Species suited to less degraded rises.								
Cryptocarya leavigata	Red Fruited Laurel	U, M	RF	1–3	1	YY	S	N
Cryptocarya obovata	Pepperberry Tree	U, M	RF	2–3	2	Y	S	N
Cryptocarya triplinervis	Three Veined Cryptocarya	U, M	RF, D	1–3	2	YY	M	N
Cupaniopsis anacardiodes	Green Leaved Tuckeroo	U, M, L	RF, D	1–3	2	N	M	N
Diospyras australis	Black Plum	L	RF	2–3	1	Y	S	N
Diospyras fasciculosa	Grey Ebony	L, M	RF	2–3	1	Y	S	N
Diploglottis australis	Native Tamarind	U, M	RF	2–3	1	Y	S	N
Dysoxylum muelleri	Red Bean	U	RF	2	1	Y	S	N
Elaeocarpus obovatus	Hard Quandong	U, M	RF	2–3	1	Y	M	N
Melicope elleryana (Euodia)	Pink Euodia	U	RF	2–3	1	Y	M	N
Mucana gigantica (v)	Burney Bean	U, M	RF	1–3	2	Y	M	N
Neolitsea dealbata	White Bolly Gum	U, M	RF	2	2	YY	M	N
Omalanthus populifolius	Bleeding Heart	U	RF	2	2	N	M	N
Pararchidendron pruinosum	Snow in Summer	U, M, L	RF	2–3	2	Y	M	N
Planchonella australis	Black Apple	L	RF	3	1	Y	S	N
Planchonella chartacea	Thin Leaved Coondoo	L	RF	2	1	Y	S	N
Planchonella pohlamniana	Yellow Boxwood	L	RF	2–3	1	Y	S	N
Polycias elegans	Celery Wood	U	RF	1–2	2	Y	M	N
Rhodamnia rubescens	Scrub Turpentine	U	RF	2–3	1	Y	S	N
Rhodomyrtus psidioides	Native Guava	U, M	RF, D	2–3	1	Y	S	N
Rhodosphaera rhodanthema	Deep Yellow Wood	U	RF	2–3	2	N	F	N
Sloanea australis	Maidens Blush	U	RF	1–3	1	Y	M	N
Sterculia quadrifida	Red Fruited Kurrajong	U	RF	2–3	1	Y	S	N
Streblus brunonianus	Whale Bone Tree	U, M, L	RF	1–3	3	Y	M	N
Syzygium francisii	Giant Water Gum	M, L	RF	2–3	1	Y	S	N
Toona australis	Red Cedar	U, M, L	RF	2–3	2	N	F	N
Trema tomentosa	Poison Peach	U, M, L	RF, D	1–3	2	N	M	N

Notes:

Suitable Site: U – upper reaches; M – middle reaches; L – lower reaches

Forest type: RF – rainforest; D – dry forest; T – tidal

Suitable growing position on river bank: 1 – toe; 2 – mid bank; 3 – top

Amount of erosion which species will tolerate: 1 – no erosion; 2 – some erosion; 3 – severe erosion

Species will require protection from sun and wind: N – no; Y – yes; YY – protection very important

Growth rate of species: S – slow; M – medium; F – fast; VF – very fast

Is the species frost tolerant: N – no; Y – yes; Y/N some individual plants might withstand frost (depends on genetic stock); NA – not applicable

Vine species: *v*

Good plant spacing

In a natural riparian rainforest plant density may exceed 30,000 plants per hectare. Bottle brush (callistemon) and paperbark (melaleuca) forests may have more than 10,000 plants per hectare in sub-coastal areas.

High planting densities allow for losses and provide a quick cover over the bank for protection against floods.

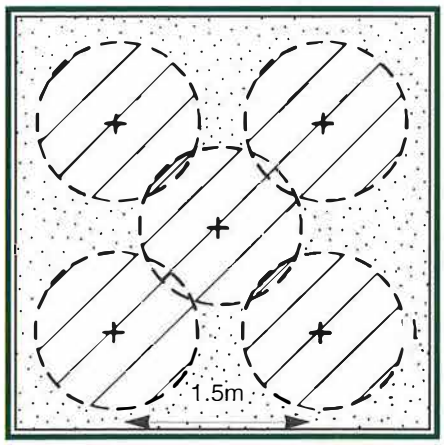
PLANTING STRATEGY

PLANT SPACING

Spacing for trees can range from 1.5 to 5m depending on the need and the site. The wider the spacing the more vegetative matter and thicker the stem at early age. However, low plant densities may limit the ability of the plants to stabilise the bank and floods may cause losses to a high percentage of the plants. Generally rainforest plants benefit from close spacing. Eucalypts are planted at wider spacings. Lomandras and sedges can be planted in clumps and rows in very dense spacing arrangements.

On badly eroded, or bare soil, sites there is a need to get good cover quickly and high initial plant populations are beneficial. Close spacings of up to 1.5 - 2m are recommended (or denser if economics permit) (Figure 1),

Figure 1 – Single Planting

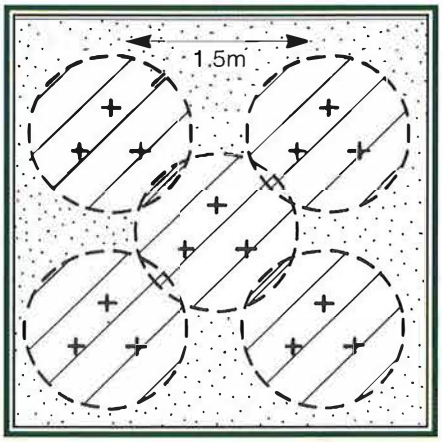


Single planting in a 1.5m diameter weed-free zone - 1.5 to 2m from the next weed free zone.

although dense spacings can pose problems from over-spray onto plants during maintenance. Regular spraying will reduce this problem as control will occur when weeds are small. When spacings are close together weed control over the whole planting area will occur.

A second option is to create 1.5m diameter weed free zones at 2m spacings. The seedling can then be planted with 2–3 companion tree seedlings at 50cm spacing within each planting site (Figure 2). The idea is to have high plant populations to allow for losses and to encourage a quick cover over the bank for protection against floods and frost. The trees need to be protected during spraying with spray boots (ie. half a plastic rubbish bin on a hand-held stick).

Figure 2 – Companion Planting



1.5m diameter weed free zones at 2m spacings with 2-3 companion plantings at 500mm spacings within the weed free zone.

Companion plantings may result in slower growth due to the competition effect between the plants. This technique has been successful on some sites though, and reasonable growth of up to 2m in height in a single year has occurred.

River banks are possibly the most difficult places to grow trees because of the severe limitations to plant growth from floods, drought, wind, erosion and frost.

Planting on river banks is not a once-off affair and requires continuous replanting after climatic events to assure that a reasonable final plant density is achieved. Projects should be planned over a three year period.

Some of these plants are thinned in later years to provide space for the slower growing rainforest plants and to remove competition pressure.

Even where pioneer plants are used to aid establishment of rainforest sun-sensitive plants and alleviate the effects of frost, denser initial spacings are preferred. Trees can later be thinned out if the remaining densities are too high.

It may not be practical to plant up to 10000 plants per hectare and 2000 - 3000 might be a more realistic number. This is of course influenced by available funds, and the possibility that 50% of the plants could be lost in floods and on-going tree plantings may be required.

TIME OF PLANTING

River banks are possibly the most difficult places to grow trees because of the severe limitations to plant growth from floods, drought, wind, erosion and frost. An ideal planting time would ensure that plants are anchored and healthy before floods and frosts. All riparian plants suffer in one way or another from frosts, particularly if the plants are young.

Pre-winter planting is not advised, although, in frost free areas or where frost tolerant plants are used, pre-winter planting is possible. Spring is possibly the best time to plant, although spring planting is severely limited by dry weather and irrigation is necessary. Planting in the summer, after Christmas, has also been successful, although large numbers of plants have been lost in the summer floods.

It is advisable to stagger planting's over the course of the year to try to establish plants in reasonable growing conditions well before floods. This will reduce the effects of natural disasters on a single large planting.

SITE PREPARATION

INITIAL WEED CONTROL

Woody weed control

Weeds are plants growing in the wrong place. In the context of sub-tropical coastal rivers, weeds refers mainly to a range of exotic trees, shrub, vine and grass species. Weeds severely restrict the growth and vigour of plants by competing for moisture, nutrients and light. Some weeds, such as severe infestations of cats claw, can weigh plants down breaking branches and stems.

Control of weeds is a major component of any vegetation re-establishment project. Some sites may have severe weed growth with shrub, tree, vine and tall grass weeds.

Tall tree or shrub weeds can either be killed on site or cut down. Killing trees or shrubs on site is cost-effective, but falling limbs can create hazards for people maintaining the planted trees.

Table 2 lists some weeds that occur in riparian zones.

Weeds are plants growing in the wrong place.

Control of weeds is a major component of any vegetation re-establishment project.

TABLE 2 – COMMON WEEDS OF RIPARIAN ZONES	
Woody Species	
Celtis sinensis,	Chinese celtis
Cinnamomum camphora,	Camphor laurel
Duranta erecta,	Blue sky flower
Eugenia uniflora,	Brazilian berry
Lantana camara,	Lantana
Luceana hucocephala,	Leucaena
Psidium guajava,	Guava
Rinicus communis,	Castor oil plant
Schinus terebinthifolia,	Broadleaf peppertree
Solanum mauritianum,	Wild tobacco tree
Vines Species	
Anredera cordifolia,	Madeira vine, Lamb's tail
Aristolochia elegans,	Dutchmans pipe
Asparagus plumosus,	Asparagus
Cardiospermum halicacabum,	Balloon vine
Cryptostegia grandiflora,	Rubber vine
Macfadyena unguis cati,	Cats claw
Macroptilium atropurpureum,	Siratro
Grasses	
Cynodon dactylon,	Couchgrass
Digitaria decumbens	Pangola
Panicum maximum var trichoglume,	Green panic
Pennisetum clandestinum,	Kikuyu
Sorghum halepense,	Johnson grass

Consult local experts for methods of controlling these weeds.

Fire

Fire is an efficient method of removing the bulk of difficult material and can reveal dangerous eroded banks which may need attention. If the fire is a cool burn little damage occurs to existing forest, although care must be taken to avoid damage to rainforest species. Burning in late winter with a slow fire will provide a safe working area and predispose the site to relatively easy chemical weed control, cover cropping and planting. The burnt areas will make it easier to control growth from germinating tree/shrub weed seedlings. Sometimes, when competition is removed, a severe growth of nut grass can erupt. If fire significantly reduces the plant cover on the surface soil, a cover crop should be sown on the site and sprayed or cleared rings prepared when the crop is 30 cm high.

Preparing a spray ring

CREATING A WEED-FREE ZONE FOR THE PLANT TO LIVE IN.

When planting, a weed-free zone should be prepared for the plant to live in. Shrub and tree weeds up to 3m away can impact on the growth of the seedling. Plants require a competition free circle of at least 1.5m in diameter to assure the plant grows at a maximum rate. As plants grow larger, this zone should extend to 2m. Competition free circles or 'spray rings' are created using herbicide sprays. Glyphosphate is a common chemical used to kill green material, residual herbicides like Simaszine are used on bare soil (however, these inhibit cover crops). One method of grass control is to completely overspray the whole site with herbicide, however this can create an erosion threat and cover crops may be needed. The less competition the trees get, the faster they will grow and the sooner the site will be stable; the more weed competition, the greater the chance of failure.

A competition free zone of at least 1.5m is prepared for the seedling to live in.

Seedlings need to be specially grown so that they have a good root mass and vigorous growth.

Planting depths on river banks should be much deeper than usual as erosion at the base of the plant can result in plants being washed away.

Planting depths of up to 10 centimetres above the potting mix level are recommended.

On some sites tall grasses, *eg* Johnson grass, fall over into the weed-free zone and protect the bare ground from erosion. Although some benefits arise from tall grasses, they can make the site difficult to access and therefore difficult to manage.

Regrowth trees of suitable species for vegetation re-establishment are susceptible to competition from weeds and should be treated in the same way as planted trees.

The manager will need to make the decision as to how large the weed-free zone should be, and for how long it should be maintained without jeopardising plant growth and causing erosion.

TILLAGE

Once initial weed control has been carried out, the site needs to be prepared for planting. On level sites cultivation with ploughs is a damaging method of site tillage, extensive cultivation on creek and river bank sites can expose soil to the full force of flood flows, resulting in serious soil erosion. Minimum disturbance at the planting site will reduce erosion hazard. The establishment of plant residue from ground covers will also reduce the potential erosion hazard.

Mattocks are an effective method of tillage, however, using a hand-held motorised soil auger or, if topography permits, a tractor digger provides more effective tillage. The use of an auger type digger is the preferred option because it keeps disturbance at the planting site to a minimum. Recently water injection has been used for digging holes.

Seedlings need to be specially grown so that they have a good root mass and vigorous growth. Bags or pots ten centimetres wide and twenty centimetres deep are appropriate for growing seedlings. When holes are dug with hand-held motorised soil augers this pot size will fit neatly into the hole.

Using a cover crop

Not using a cover crop

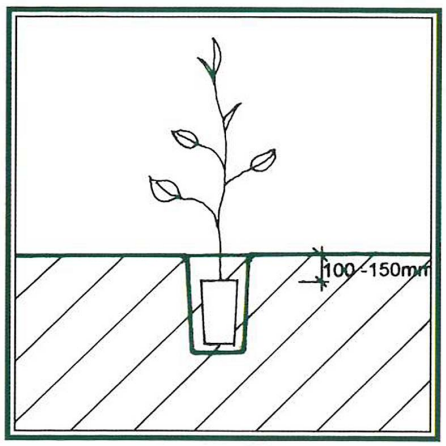
Care must be taken not to introduce or encourage a grass that will turn into a weed problem down-stream and threaten natural regeneration.

Cover crops will reduce the soil erosion hazard but this must be weighed against their competition effect.

Planting sites need to be kept weed free for 2 to 4 years.

Planting depths on river banks should be much deeper than usual as erosion at the base of the plant can result in plants being washed away. This also helps the roots to access any soil moisture. Planting depths of up to 10 centimetres above the potting mix level are recommended (Figure 3).

Figure 3 – Depth of Planting



Be careful as some rainforest plants may not tolerate the soil around the stem, local knowledge is needed to know which ones. Plants will need to be watered immediately after trees are put in the ground. This helps the soil sink around the roots and provides moisture to help the plant cope with the shock of planting.

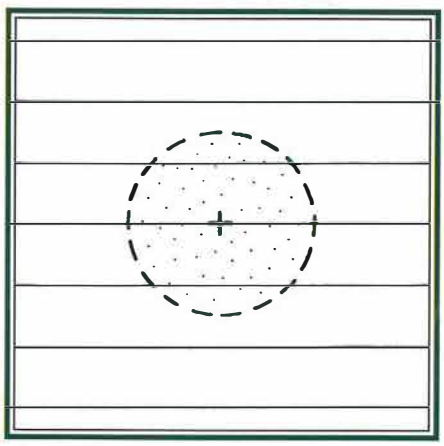
COVER CROPS

Any method of site preparation that completely exposes soil to the erosive power of flood waters needs modification with cover crops such as oats or millet. Care must be taken not to introduce or encourage a grass that will turn into a weed problem downstream and threaten natural regeneration.

Cover crops should be sown only when growing conditions are good and the cover crop must be sprayed with a herbicide to kill the crop within a few weeks or it will inhibit plant growth. The resulting plant residue will reduce the erosion threat from floods. Irrigation can enhance the initial growth of cover crops, reducing the time they compete with the plant.

In some situations however, irrigation can increase the incidence of weeds which require extra effort to control.

Figure 4 – Cover Crop



Once the cover crop has established a spray ring is created using a herbicide. The plant is planted in the centre of this competition free area.

MAINTAINING THE PLANTING SITE

On rehabilitation sites where no living plant cover exists a fast and healthy establishment phase of the plant can often be achieved, as there will be reduced competition during the plant establishment phase. This has to be weighed against the potential of losing soil around the plants, exposing roots, if floods occur.

Planting sites need to be kept weed free from 2 to 4 years. If any method of site preparation or control results in bare areas erosion may result. Should bare areas occur, due to either erosion or siltation, they

Should bare areas occur, due to either erosion or siltation, they should be sown with cover crops.

The trees need to be protected during spraying with spray boots (ie. half a plastic rubbish bin on a hand-held stick).

Maintaining interspacing

Managing the interspaces between the trees involves control and prevention of potential weed problems.

Fencing

All types of fencing need maintenance.

Fences will provide protection from domestic grazing animals like cattle, goats and horses. However, specialised fence design is necessary to be effective against native grazing animals.

should be sown with cover crops to reduce the erosion threat or to retain silt on the site. Whether using cover crops or planting seedlings, you should aim to protect all areas at all times. Any new bare areas can be eroded severely during floods and will need to be touched up with cover crops. The trees need to be protected during spraying with spray boots.

A negative aspect of having too much ground cover is that it can reduce natural regeneration.

A considerable amount of work may be involved in cleaning up after floods and uncovering foliage to retrieve plants.

MANAGING THE INTERSPACES

Managing the interspaces (spaces between the plants) also involves control or prevention of potential weed problems. Controlling the amount of bulk throughout the site opens the site to air flow and can reduce disease and insect damage. Shrub or tree weeds (eg. leucaena and camphor laurel), severe grass weeds (eg. Johnson grass), and vineweeds (eg. cats claw) need to be contained. With the area fenced off and cattle excluded the potential for increased growth of these weeds is great. As the plants get older (about 1-5 m high), depending upon the species mix of the site, some very controlled grazing may assist with weed control until the plants have control of the sites themselves. For example, young weaners and quiet cattle may be permitted to graze the tree dominated sites for one day every six weeks. If your option is to introduce understorey plants as the tree canopy closes (about year 2-5), permanent exclusion of cattle is required.

MANAGING THE GENERAL AREA

Plants in riparian zones are very susceptible to fire damage. Regular creation or maintenance of fire breaks and slashing or grazing of areas around the site will reduce the threat of fire. On level sites slashing and mowing between the plants will assist with fire management. The area may also need periodic application of cover crops.

Re-establishment sites will require periodic maintenance in perpetuity to ensure invasive weeds do not gain a foothold.

OTHER ASSOCIATED MANAGEMENT TECHNIQUES

Fencing

Permanent fencing is essential to ensure that cattle do not damage established trees and reduce the ability of lomandras, small shrubs, herbs and grasses to protect the floor of an established forest. If the site is to be grazed fencing provides good control over what is happening to the site. All types of fencing need maintenance.

Where fences lie across the flow of a flood, posts with hinged bases may be used. These hinged bases allow the fence posts to fall over when the flow of the flood is extreme. Permanent electric fences are a good option as they are easy to erect and easy to repair after floods, although energisers can be damaged and need to be removed if floods are expected. Hot wires close to the ground can protect trees from small native animals. Grass needs to be kept down in these areas.

Tree guards

Tree guards not only provide protection from browsing animals but can also enhance growth (sometimes however plants can be weak and spindly). Guards however are usually damaged by floods. As guards are often expensive to install, rodent proof electric fencing may be a cheaper alternative if animals are a problem.

Grazing

Grazing may be critical in controlling the emergence of problem weeds. It needs to be considered in the overall management of the site.

In the establishment phase of the trees intermittent controlled grazing with calves, young weaners and quiet cattle may help control grass bulk and some woody weeds. These animals should be able to graze for a day every six weeks.

Once trees are established, grazing may be a necessary management tool but it should still be strictly controlled in a fenced area.

Fertilising

Fertilising will often enhance the performance of riverbank planting. Nutrients such as nitrogen, sulphur, zinc and boron are often deficient on river banks. Phosphorus is often adequate on banks. Fertiliser recommendations need to be based on soil tests.

Where necessary plants should be fertilised at planting and then at three to four month intervals. These are best timed to support growth in good growing periods or flushes. 150-250 gms per tree of a mixed fertiliser can be used three times a year (research may indicate higher levels). Areas low in nitrogen may need regular applications of nitrogen. Fertilisers such as Osmocote or Komplete Blue, NPK and some sugar cane applications with high Nitrogen and Sulphur have been used. Sometimes additional applications of Nitrogen mixed with other fertilisers may be required. Where adequate phosphorus is available, low phosphorus fertilisers are used.

Fertiliser can be broadcast which is cheap and fast, but it can be lost to the atmosphere or in floods (Figure 5). Burying fertiliser in dollops under the soil is another option, less fertiliser is lost but this is more time consuming and therefore expensive (Figure 6). Care needs to be taken not to burn the roots with fertiliser.

Figure 5 – Broadcast Fertiliser

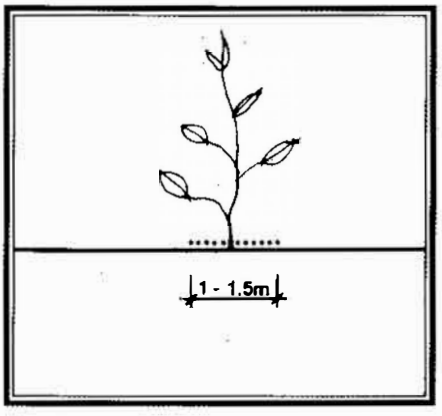
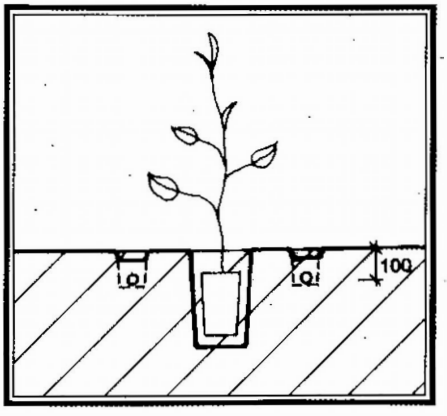


Figure 6 – Buried Fertiliser



Watering

Access to sufficient water in association with fertilising will assist with the establishment of planted seedlings and encourage the growth of ground covers. Plants must be watered within one hour of planting. Occasional watering or irrigation will help establishment and increase the growth of all vegetation. Care must be taken not to over-irrigate the banks and cause bank slippage

The soils along river banks are often free draining and planting sites can be water limited. Planting in dry periods should be avoided as river bank soils can have poor water holding capacity.

The performance of plants during drought has been shown to be poor even with irrigation. Dry periods inhibit the growth of plants and limit their ability to establish and develop roots to anchor the plants during floods.

Mulching

Providing a weed free zone around the seedling will significantly improve the plants' growth and survival. Some people prefer to use mulching for this purpose. Prior to mulching, weeds should be killed with herbicide or cleared by hand.

Adequate mulch may provide for moisture retention and soil structure improvement near the plant. The use of mulch on a riverine site presents some problems:

- It is difficult to keep in place on steep banks
- It is often pushed over the seedling during floods, burying and killing the seedling
- For large plantings applying mulch may be expensive and is time consuming
- To be effective a ring with a minimum diameter of 1.5m and minimum depth of 0.2m is required
- Dry compact mulch inhibits infiltration
- Misapplication of mulch onto the base of the plant causes stem rot
- Mulch limits the ability of residual herbicides to work effectively
- Reasonable quantities of water may be required to penetrate the mulch to provide adequate water for the plant

The alternatives to mulching include: weed mats which can be washed over the plants or washed away; chipping which is time consuming, can damage roots, and leaves bare areas for erosion to occur; or the use of knockdown and residual herbicides that are cost-effective and easy to apply, but require careful consideration and application when used near water courses.

Frost

It is difficult to avoid damage from severe frosts. Seedlings planted under the canopy of large pioneer trees have been less affected by frost, though growth has been reduced. Initial pioneer planting of frost tolerant plants may be necessary to provide frost protection for young rainforest plants. Unfortunately most

Insect Damage

pioneer species are also frost sensitive when young. Wrapping the plants in hessian or plastic bags or mulch may reduce frost damage but significantly increases costs. This can also create a litter problem.

Generally older trees are not affected by frost as badly as young plants. Plants should not be planted prior to winter as young plant mortalities are very high with pre-winter plantings. In frost prone areas it may be advisable to plant at the end of the frost period and water the plants up to the wet season. Some established seedlings may recover from frost, but frost can kill even well established plants or reduce the growth of the plants (as they need to reshoot after frost). The drier forest plants like bottlebrush (*Callistemons)* and paperbark (*Melaleuca)* could be used as pioneer plants to facilitate the planting of the more frost sensitive plants years later. These species have been known to be affected by frost when young, though a number of successful plantings have occurred after the summer rain and prior to winter.

Insect control

In an undisturbed riparian forest insects play an important role in the ecology of the forest, but in a new or remnant site, insects can do severe damage to plants and regular insect control may be required. Species like *Callistemon viminalis* (weeping bottlebrush), *Waterhousea floribunda* (weeping lily pillie, weeping satin ash), *Casuarina cunninghamiana* (river sheoak), *Melaleuca bracteata* (black tea tree), *Melaleuca linariifolia* (paper bark, snow in summer) and many rainforest plants can suffer severe insect attack which may reduce plant growth and populations by up to 75%. Insect control may improve the performance of plants while the natural control mechanisms are developing. Before using any insecticides (especially in riparian zones) the insect species, its impact and present stage life cycle must be identified. The intended insecticide must also be checked for its effectiveness, impact on the aquatic environment, and its registered uses. Table 3 gives a sample of the insect pests of riparian zones.

TABLE 3 – INSECT PESTS OF RIPARIAN PLANTS

TREE SPECIES		PEST	COMMENTS
Scientific Name	**Common Name**		
Acacia melanoxylon	Blackwood	Mealy bug. Sap sucker.	Massive deformity of tip and phyllodes. Deformed stem, white fungus-like waxy material which protects the mealy bug. Many brown, dead leaves, ants common (feeding on the honey dew), ants can move the mealy bug around. The species is also attacked by leaf tip larvae *ie* faecal pellets and thrips can be present. Some new shoots have aphids.
Alphitonia excelsa	Red Ash	Alphitonia beetle	Green, gregarious, leaf-eating beetle that can defoliate the whole plant.
Callistemon viminalis	Red Bottlebrush, Weeping Bottlebrush	Tip moth, larval stage; brown to yellowish caterpillar, to 1 cm.	Same symptoms as on *Melaleuca linariifolia* but possibly different species.
Casuarina cunninghamiana	River Sheoak River Oak	Wood moth, grubs silk producing.	Can also get pasture grubs eating roots.
Ficus coronata	Creek Sandpaper Fig	Fig beetle larvae. Black flat horny grub – slightly hairy. Fig beetle is brown 3-4mm long.	Skeletonises leaf to a fine spider web appearance.
Ficus fraseri	Shiny Sandpaper Fig	Green larva/grub (possibly family pyralidae – not identified to species).	Folds leaf
Ficus racemosa	Cluster Fig	Moth or butterfly, larval stage, greenish yellow caterpillar 1.5cm long silk producing.	Chews tips, curls and deforms the leaves. Caterpillar may be parasitised by wasps.
Grevillia robusta	Silky Oak	Mites	Bunchy top.
Mallotus philippensis	Red Kamala	Leaf miner, caterpillar.	Female lays eggs on leaf, caterpillars pierce outer layer and track through leaf leaving brown tracks all over.
Melaleuca bracteata	Black Tea Tree White Cloud Tree	Aphids – (associated with ants and lady beetle).	Aphids are sap suckers. Lady beetles eat them, and parasitic wasps lay eggs in them.
Melaleuca linariifolia	Paper Bark, Snow in Summer, Snowstorm.	Tip Moth 5mm long. Larval stage, caterpillar.	Lays egg in the tip, results in slight deformation and browning of tip. Caterpillar eats out inside of bud which curls up, a small black mark *ie*. fine pin hole (in which some wasps parasitise) is visible at entry point. Larva continues into stem – bud doesn't develop. Webs the tip together to pupate.
Melia azederach	White Cedar	White cedar moth. *(Leptocneria reducta)*	Defoliates leaves regularly
Parachidendron pruinosum	Snow Wood Tulip Siris	Similar to leaf eaters. Aphids.	Pull off decayed branches damaged by frost to prevent decay spreading into new wood. Damage tips of trees regularly.
Rhodosphaera rhodanthema	Deep Yellow Wood	Caterpillar.	Webs whole end of the buds.

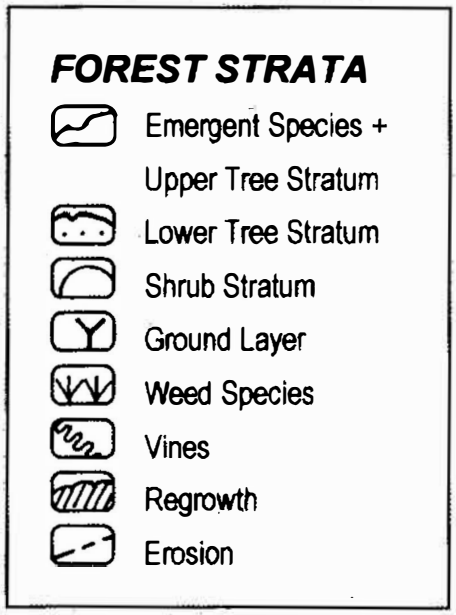
TABLE 3 – INSECT PESTS OF RIPARIAN PLANTS

TREE SPECIES		PEST	COMMENTS
Scientific Name	**Common Name**		
Syzygium australe	Bush Cherry, Scrub Cherry, Creek Cherry.	Lilly pilly pimple gall. Brown scale.	Oval brown shiny pits on one side of leaf, pimple on other to 4mm. Does severe damage to young seedlings.
Waterhousea floribunda	Weeping Lilly Pilly, Weeping Satin Ash	Lilly pilly pimple gall (psyllid, same family as lerps).	Immature stage, sits in pimple and sucks sap, adult is an aphid-like insect which flies away to lay eggs on another leaf.

It is not possible to specify here which registered chemicals should be used to control these pests. Your local produce merchant should be able to provide advice if shown an example of the pest or the damage.

APPENDIX A

CONDITION ASSESSMENT OF THE RIPARIAN FOREST



Healthy and sound riparian rainforests contribute to the stability of river banks. These forests are layered and each layer plays a role in maintaining ecological stability by ameliorating floods, filtering pollution, catching silt by reducing stream velocity and by preventing the erosion of river banks (Arthington *et al.*, 1992).

When considering plantings in riparian zones understanding the condition of the forest to be worked in is beneficial. Some forests may have adequate vegetation for natural regeneration while others may benefit from enrichment planting. Banks in a severe state of repair may require more expensive engineering works before a planting program is initiated. Professional river managers should be consulted before any project starts.

In an endeavour to understand the dynamics of change in remnants, five phases of condition of rainforest have been identified in south-east Queensland as shown in the figure on page 21.

Healthy Phase

Complete structural integrity with plant populations in excess of 30 000 and possibly more than 50 000 plants per hectare.

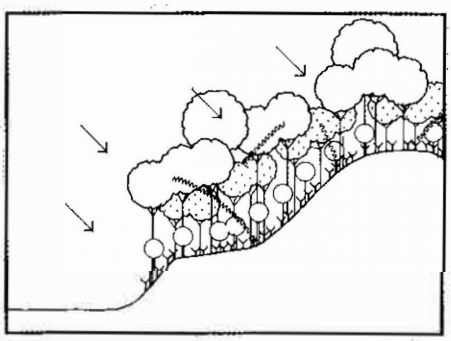
- Upper tree stratum: emergent trees that overshadow the canopy, tall and very tall trees providing deep roots for bank stability and shelter for the understorey. Included here are several species of vines.
- Lower tree stratum: tall shrubs and small trees contributing to water filtering and subsoil stability and providing a high degree of cover.
- Shrub stratum: small shrubs and large seedlings provide ground cover, stability and filtering.
- Ground layer: ferns, herbs, grasses and seedlings, all of which protect the floor of the forest from sheet erosion caused by water run-off.

Management

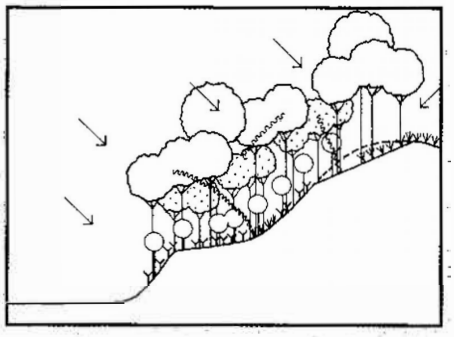
Inspection on the open perimeter of these remnants may reveal some impact on the plants by increased wind or sunlight. This is demonstrated by a reduction of substory plants and sun sensitive plants on the outside. Also woody weeds may be seen on the perimeter of the patch. Remedial work is required to remove any potential weed threat to the area and possibly the planting of wind breaks, buffer strips or wood lots to protect the remnant from decline due to the effects of wind and sun. These measures are required for all the phases below.

Surface Erosion Phase

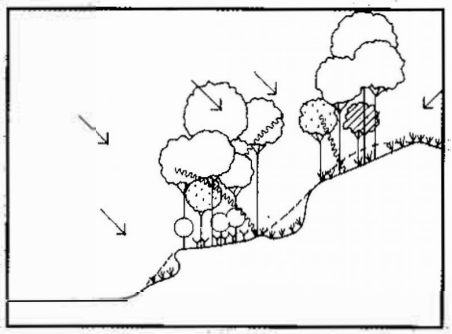
- Cattle damage trees and graze out the shrub stratum, seedlings of lower and upper stratum species and ground covers.
- Sheet erosion occurs on the forest floor after depletion of ground cover, caused by local water run-off from the steeper parts of the forest or from flood plain torrents.



Healthy Phase



Surface Erosion Phase



Flood Erosion Phase

- Greater light and wind penetration occurs from the top of the bank.
- There is a loss of organic matter and a reduction in collection of silt which once provided seed-beds for germination, especially for *Cryptocarya* and *Cleistanthus* species.
- Gradual infestation of creepers, vines, herbs and woody weeds.
- A reduction in plant numbers to 5000 plants per hectare, patchy in occurrence.
- Increase of trees falling into the river.

Management

The plot should be given an opportunity to regenerate. On some occasions this may be slow due to the competition effect of the forest and the lack of seed source of fast growing pioneers, the latter can be enrichment planted if necessary.

Shelter is required to protect the exposed perimeter areas of the remnant as for the healthy phase.

Remnants may require the exclusion of cattle to allow ground flora to grow, in order to reduce the incidence of sheet erosion.

Trees could be planted for cattle shelter adjoining the site.

Controlled grazing (no more than one day at a time) every few months may be required to help reduce the bulk of regrowth for fire damage prevention. Controlled grazing will reduce the damage on any new seedlings which can tolerate some grazing, poorly controlled grazing will send the site backwards.

Maintenance of plants; where seedlings have germinated maintain the plants the same way you would a new planting.

Chemical weed control will be required to control potential herbaceous, woody, or vine weeds.

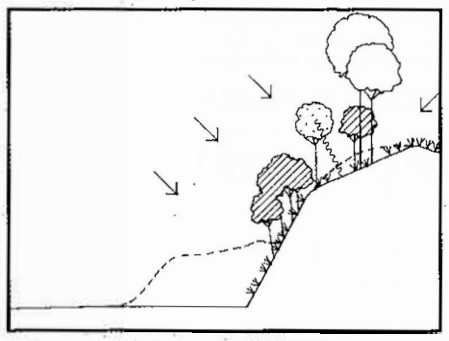
Flood Erosion Phase

The loss of canopy creates gaps in the forest strata which allow higher velocity flows of floodwater, creating a vicious circle of increasing degradation.

- There is an increase in sunlight and wind, limiting some species and dehydrating seedlings.
- There is a reduction in plant density to fewer than 2 000 trees and shrubs per hectare, very patchy in occurrence.
- Terraces develop as a result of soil loss, slipping or slumping.
- There is an increase in exotic tropical pasture grasses.
- The end result is the creation of a plant community composed of large- or rough leaved plants and vigorous growers in inaccessible positions and an increased infestation of weeds
- Increased numbers of trees fall into the river.

Management

All management mentioned above. Included in this may be the use of fast growing trees to fill in the gaps where floods can enter. Also where active terraces occur light engineering work may be required to contain the erosion. If the terraces are stable plantings with very fast growing trees may be beneficial.



Bank Failure Phase

Bank Failure Phase

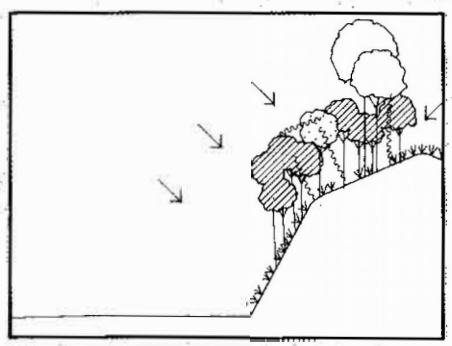
- There is a weakening of the toe of the bank.
- The occasional tree remains on the bank, sometimes causing erosion from scouring at the roots.
- Weeds are now dominant and pasture grasses severely inhibit the regeneration of native riparian species.
- Mass bank failure occurs.

Management

This phase requires all the management mentioned in this document

Return Phase

- This can occur at any of the phases above by natural regeneration if conditions permit.
- Establishment of fast-growing natives not necessarily indigenous to the site, *ie*. *Eucalyptus tereticornis*, Forest red gum, *Callistemon viminalis*, Weeping bottlebrush, and *Casuarina cunninghamiana*, River sheoak.
- There is a lack of species diversity and the construction of a completely new ecosystem, for example *Casuarina* forest.
- Woody weeds, vine weeds and tropical pasture weeds can become completely dominant.
- Trees may grow in the stream bed interrupting flow.



Return Phase

Management

If bank stability is the only requirement then the site needs to be managed for weed control and erosion control with added planting in any gaps. However, should the return of the indigenous riparian forest be required controlled thinning and enrichment planting with the selected species is necessary.

REFERENCE:

Arthington, A.H., Bunn, S.E. and Catterall, C.P. (1992)., *The Ecological Roles Of Riparian Vegetation*. "The role of buffer strips in the management of waterway pollution from diffuse urban and rural sources". Woodfull, J., Finlayson, B. and McMahon, T. (eds.). *in* (Proceedings of a Workshop held at International House, University of Melbourne, 9 October, 1992.) Land and Water Resources Research and Development Corporation, and Centre for Environmental Applied Hydrology, University of Melbourne. pp. 93-102

APPENDIX B

TREE GROWING ADVICE

Tree growing advice can be obtained from the following sources:

Information and Extension Services (Queensland Department of Natural Resources (DNR) Treecare Extension Office Centres).

Atherton	07 4091 1844
Ingham	07 4776 5655
Rockhampton	07 4931 9688
Bundaberg	07 4153 7805
Murgon	07 4168 1777
Gympie	07 5482 1522
Nambour	07 5430 0967
Brisbane	07 3227 7945
Dalby	07 7669 0842
Longreach	07 4658 4400

OTHER ORGANISATIONS WHO PROVIDE ADVICE ON TREE GROWING

Greening Australia	07 3844 0211
Men of the Trees	07 3300 6304
Wet Tropics Tree Planting Scheme	07 4041 2593
Trees for the Evelyn and Atherton Tablelands (TREAT)	07 4095 4706

Many Landcare groups have valuable experience with riparian tree plantings

APPENDIX C

DNR TREE FACTS

RIVER NOTES

Streambank Planting - Guidelines and Hints
Trees on Your Streambank, What's it worth.
How Healthy is your Watercourse? Assessing Streambank Vegetation.
Managing Stock In and Around Watercourses.
What Causes Streambed Erosion.

NB See Department of Natural Resources Queensland On-Line