Eucalypts for High-grade Timber in the Medium Rainfall Zone of WA

A Feasibility Study for a New Industry

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for the

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Front cover
13-year-old *Eucalyptus saligna* being grown for high-grade sawlogs at experimental site near Dinninup, Western Australia.

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Summary

This report summarises current knowledge on growing and processing eucalypt sawlogs for high-grade products. It draws principally on Western Australian data and experience collected by CALM and the Forest Products Commission over the past two decades. Its primary purpose is as a base document for the development of a new eucalypt sawlog industry in the 450 to 650 mm annual rainfall zone of south west of Western Australia. The report will be used initially by the consultant selected to produce an Industry Business Plan for the new industry.

The industry is to be based on cleared private land, delivering multiple benefits for farmers, for regional economic development and for the general community.

The goal for stage one is to establish a resource, centred on water recovery catchments and covering about 20,000 ha, with the capacity to produce 150,000 m^3 per year of high-grade eucalypt sawlogs as soon as possible. The plantings will assist in the protection and recovery of water resources threatened by salinity. The plantings will also be designed with farmers so their economic and environmental goals are met.

The goal for stage two is to increase the resource, in the rest of the 450 to 650 mm annual rainfall zone, to a level capable of producing 1,500,000 m^3 per year of high-grade eucalypt sawlogs by the year 2030.

Several factors are coming together to create a situation which is favourable for the development a new hardwood industry. They are:

- The supply of hardwood sawlogs from native forest in WA is declining rapidly while the demand for high-grade timber seems likely to increase.
- Agriculture needs commercial tree crops to help overcome serious economic and environmental problems.
- There is strong interest amongst farmers in growing eucalypts for high-grade timber.
- CALM's research shows that it is feasible to produce eucalypt sawlogs in 20 to 25 years and that the timber is of high-grade, suitable for flooring and furniture.
- The integration of commercial tree crops with farming is seen as an important tool for improving water quality in water recovery catchments, such as the Warren/Tone and Collie Catchments.

- The Water and Rivers Commission have NHT funding available to help fund a pilot program to plant eucalypts for sawlogs centred on water recovery catchments.

Market research indicates that the national and international demand for timber products from high-grade hardwood is likely to increase. Uses include flooring, panelling, mouldings, furniture and veneers.

Species trials in south west Western Australia over the past three decades indicate the most prospective species for a eucalypt sawlog project. The main species include *E. saligna, E. globulus, E. botyoides, E. cladocalyx* and *C. maculata*, the later two being preferred species for the drier end of the medium rainfall zone.

Silvicultural studies show that it is possible to produce 50 cm diameter sawlogs in 20 to 25 years in the medium rainfall zone. A wide-spaced approach is essential if these growth rates are to be achieved. Pruning of wide-spaced trees is essential if high-grade timber is to be produced. Parrot control is also crucial if suitably formed trees are to be produced.

Economic analyses show that the IRR for *E. saligna* and *E. globulus* at average yield, average cost and average stumpage is 9%. IRRs ranged from 2% for low yield, high cost and low stumpage up to 14% for high yield, low cost and high stumpage. IRR for *C. maculata* (the least productive species) ranged from 0% to 10% with an IRR of 5% for average yield, cost and stumpage.

Young fast-grown eucalypts do require different handling, milling and seasoning techniques compared with traditional practices. R&D findings indicate that suitable techniques to handle the high growth stresses of young logs can be developed.

Whilst findings from R&D into growing and processing eucalypts for high-grade products give sufficient confidence to commence a pilot planting program, there needs to be a comprehensive R&D program to support the initiative. The R&D program would need to cover the range of aspects from breeding to growing and from processing to marketing.

Background

This report summarises current knowledge on growing and processing eucalypt sawlogs for high-grade products. It draws principally on Western Australian data and experience collected by CALM and the Forest Products Commission over the past two decades. Its primary purpose is as a base document for the development of a new eucalypt sawlog industry in the 450 to 650 mm annual rainfall zone of south west of Western Australia. The report will be used initially by the consultant selected to produce an Industry Business Plan for the new industry.

The industry is to be based on cleared private land, delivering multiple benefits for farmers and for regional economic development.

The goal for stage one is to establish a resource, centred on water recovery catchments and covering about 20,000 ha, with the capacity to produce 150,000 m^3 per year of high-grade eucalypt sawlogs as soon as possible. The plantings will assist in the protection and recovery of water resources threatened by salinity. The plantings will also be designed with farmers so their economic and environmental goals are met.

The goal for stage two is to increase the resource, in the rest of the 450 to 650 mm annual rainfall zone, to a level capable of producing 1,500,000 m^3 per year of high-grade eucalypt sawlogs by the year 2030.

The scope of the study is the growing and processing of eucalypts for high-grade timber in the medium rainfall zone. Although the production of high-grade eucalypt timber will also occur on farmland in the high rainfall zone it is not the focus of this study. The challenge being taken up with this new project is to develop a new industry outside traditional timber production areas where multiple commercial and conservation benefits are being sought by landowners and the community.

In many respects the time is right for the development of a new eucalypt sawlog industry. Firstly the supply of hardwood sawlogs from native forests is declining rapidly because of changes in community expectations. A new resource needs to be found because the demand for high quality hardwood is likely to continue. Increasing the importation of hardwood sawlogs into WA is not likely to be a suitable option. Supplies from traditional sources, such as tropical rainforests, are declining substantially and a higher level of imports is not desirable from the point of view of Australia's balance of trade.

The second important setting is the state of agriculture in the medium rainfall zone. Farming in this zone has serious economic and environmental problems. Traditional agricultural commodities, such as wool and grain, are low in value. Salination of land and water and erosion of soil are major concerns for many farmers. Commercial tree crops are an important tool in developing more productive and sustainable farming methods.

The main water resource catchments for the State are located within the medium rainfall zone. The catchments of the Mundaring Weir, the Wellington Dam and the Warren, Tone and Kent Rivers have all been identified as important water supply areas, where water quality must be either protected or improved. The Water & Rivers Commission have the responsibility for improving water quality in these catchments. The catchment of the Wellington Dam (the Collie River) is a high priority catchment, because the water is likely to be required by Perth in the future. Farm forestry is seen as a vital tool in improving water quality.

The production of high-grade eucalypt timber appears to be a practical and viable proposition. CALM's research into eucalypts for sawlogs shows that it is feasible to produce sawlogs in 20 to 25 years, even in the medium rainfall zone, if trees are wide-spaced and high-pruned. Mill studies show that the timber is of high grade and suitable for flooring and furniture. It is possible to achieve a sufficient recovery of high value timber to provide a commercial rate of return.

There is also strong interest amongst farmers in growing eucalypts for timber. This is partly because farmers need additional tree cropping options to meet their site differences but also because they tend to like the idea of eucalypts for high-grade timber compared with some other tree crops. The option of growing eucalypts for sawlogs is viewed by many landowners as an attractive new choice in tree cropping.

The availability of some seed capital is the fourth factor that has created favourable conditions for the development of a new industry. The W&RC have NHT funding for a pilot-planting program centred on water recovery catchments. About 150 hectares is being established with farmers in the winter of 2001, under the pilot project. The species to be planted are *Eucalyptus globulus* and *E. saligna* (on the better soils at the wet end of the range) and *Corymbia maculata* and

E. cladocalyx (on a range of soil types and rainfalls). These plantings will help 'kick-start" a new industry.

From the Government's point of view a eucalypt sawlog project in the medium rainfall zone has the potential to help achieve the vision of new industries (based on wood from commercial tree crops) and more sustainable and productive agriculture (based on the integration of commercial tree crops with farming.

The Project is being jointly developed by four government agencies – the Forest Products Commission, the Department of Conservation and Land Management, the Water and Rivers Commission and the Department of Agriculture. A high priority is to develop a broad Industry Business Plan to guide this important new project for the State.

Products & markets

The most likely use of plantation timbers in the short to medium term is in appearance timber products including flooring, joinery, decorative mouldings and furniture. Some work has already been done in developing and marketing laminated timber products from plantation grown eucalypts, and this needs to continue. Laminating is crucial for utilising narrow pieces that come from small logs.

Although plantations will produce structural timber if managed for that purpose, in the short to medium term it is not expected that plantation eucalypts will compete with pine for structural uses, because they are inherently more expensive to process. It is also unlikely that plantation timber will compete with traditional native timbers for the production of decorative veneers. Other possible uses for plantation timber may include LVL production, but this would require significant investment, the selection and growth of suitable species and appropriate technology.

Panel products including medium density fibreboard, particleboard and flakeboard can be produced from suitable plantation grown eucalypt species, either entirely or as a supplementary fibre. Significant investment in plant and technology and markets for large volumes of product are required to produce panel products competitively. The issues affecting the use of eucalypts in panel products relate to world supply and demand balances and market preferences for the particular properties of panels made from the different species and species mixes.

Notwithstanding the need for regulation of chip quality and species mix, it is assumed that residues from the added value utilisation of plantation timbers could be sold as wood chip for use in pulp and paper manufacture. The selling of other than bluegum chip will require at minimum a coordinated wood flow by species to suit the buyer and even then, the price will depend on the supply of blue gum relative to demand.

Species

Many species of eucalypts have been planted on farmland across the rainfall range in the south west of Western Australia during the past three decades. Some species have been trialed for sawlog production. These plantings indicate the most promising species for sawlog production, in terms of tree form and growth rate. Examples of species with potential are listed in Table 1 below.

Table 1. Examples of species with sawlog potential in South West Western Australia. Information on stem form, site requirements and growth rates is presented.

Species	Stem form	Site requirement	Growth rates
600-700 mm rainfall			
E. globulus	Long straight bole in plantations.	Best development in moist valleys on good loams. Occurs naturally on dolerite and shallow humus soils over mudstone. On rather poor sands in coastal areas.	Fast growth in high rainfall areas and on fertile soils.
E. saligna	Straight stem good form	Moderately fertile soils, moist but not waterlogged (Parent rocks could be shale, sandstone, conglomerate or basalt).	As above
E. grandis	Straight stem, good form	On flats or lower slopes of deep, fertile valleys. Prefers moist, well-drained, deep, loamy soils of alluvial or volcanic origin.	As above
E. botryoides	Straight stem, good form	Grows well on poor sandy soils of coastal areas. Best growth on moderately fertile loams inland.	As above
E. viminalis	Straight stem, good form on better sites.	Prefers moist but well-drained alluvial or sandy podsolic soils with clay subsoils. Wide topographic range.	As above
Corymbia maculata	Clean straight bole. Good natural branch shed.	Grows on a wide range of soils, best on slightly moist but well drained and moderately heavy texture such as soils derived from shales. Commonly on sandstone sites, valley slopes and ridges if latter are not dry.	Moderate
450-600 mm rainfall			
E. cladocalyx	Good form on better sites, with stem 2/3 height. Only 1/3 to ½ on poor sites. Good natural branch shed.	Shallow (skeletal) or podsolic soils, frequently shallow. Less commonly on sodic brown soil or deep sands. Often on ironstone gravels.	Moderate
E. tricarpa	Reasonable form?	Fairly heavy alluvial soils, clay loams and better quality sandy loams.	Moderate
C. maculata		As above	Moderate
E. saligna		As above	Moderate
Salinity-tolerant			
E. occidentalis		Heavy textured soils, poorly drained. Some provenances tolerate salinity and heavy clay soils.	Moderate

Wood quality and properties

Wood properties can be modified by how the trees are grown. A brief description of the effects of various silvicultural practices is given.

Silvicultural approaches. There are two main silvicultural approaches, which can be used to produce high-grade eucalypt sawlogs:

1. **Dense plantations**
2. **Wide-spaced plantations.**

The dense plantation approach involves planting at conventional plantation densities (about 1250 trees/ha). Plantations would normally be thinned commercially (for pulpwood, for example) and crop trees left to grow on into sawlogs. Crop trees are generally not pruned.

The wide-spaced approach involves growing about 150 crop trees/ha. Stands are culled to the final stocking by about 6 years of age and crop trees are high-pruned.

As the primary goal of the Eucalypt Sawlog Project is to produce a resource of high-grade sawlogs, rather than pulpwood, and because the main target area is the medium rainfall zone, it is likely that the wide-spaced approach will be the most suitable method. On some sites, at the wet end of the medium rainfall zone, it may be possible to plant at conventional plantation densities (1250 trees/ha) and produce pulpwood and sawlogs, but this is likely to be the exception rather than the norm. Silvicultural options are discussed in more detail in the section on Silviculture (page 15).

Pruning. Wide-spaced trees produce large branches and large branches mean large knots. Large knots generally result in timber being unsuitable for appearance grade. Therefore if the intention is to produce appearance grade timber from trees growing at wide spacing, pruning must be practiced. Pruning of green branches on time produces clearwood outside a small knotty core.

Dead branches are likely to occur only under dense plantation conditions and can be a problem. There is substantial evidence that branches larger than about 4 cm diameter have a high risk of fungal infection and rot commencing before occlusion (i.e. healing over after natural branch shed). Therefore branch size must be closely monitored.

Different species have different branch-shedding habits. Some eucalypt species such as spotted gum and sugar gum are very effective in natural shedding of branches, but others such as Tasmanian blue gum do not tend to shed their branches naturally. Natural shedding will only be an issue in dense plantations. It does not tend to occur on wide-spaced trees because branches remain green (at least for the first 25 years of the trees life), for most species.

Fertilising. Fertilising will generally result in increased growth rates, and therefore larger branches. A decrease in wood density often occurs with fertilising, but this would not matter with the medium to high-density wood in the eucalypts selected for this program.

Growth stresses. Growth stresses are generally a problem with fast-grown eucalypts. In general, there are advantages in growing logs intended for milling appearance grade timber for as long as possible to reduce the growth stress gradient from circumference to pith. The New Zealand Forest Research Institute recommended to forest growers that plantation eucalypts should be grown to 70 cm diameter to allow efficient processing. Particular handling and processing techniques and equipment are required to deal with the growth stresses found in young eucalypt logs (see Section on Milling and Seasoning – page 31).

Features and defects. The following characteristics are either 'features' or 'defects' in timber. The wood properties or the silviculture affects them:

- **Knots** - face, edge, arris, spike, and cluster knots are the result of the angle at which the branches in the log are sawn. Size depends on the original branch size.
- **Taper** – the taper is the rate of change in log diameter along the length of the log. Taper of the pruned section of wide-spaced trees tends to be less than that of trees grown in dense stands.
- **Tension wood** - produced on the upper side of leaning trees results in processing problems and lower wood quality.
- **Kino** - these compounds are protective mechanisms in the tree, in which special cells form kino to repair damage caused by insects, fire or mechanical means. Kino (often referred to as 'gum') is produced by hardwoods as veins or pockets.
- **Insect attack and rot** - wood defects include insect galleries as the result of larvae burrowing through the sapwood and then pupating in the heartwood. The insects often carry fungal spores into the galleries, and rot can develop. Large branch stubs are the usual infection sites for fungal attack.

Harvesting. As well as inherent problems in the standing tree, harvesting can also cause problems. Shakes are mechanical failures observed on log ends after the tree is felled, and layers of wood cells separate as a result of felling damage or other stresses in the timber as the log dries out. Ring or cup shakes occur parallel to the growth rings, and the latter involve only a partial ring. Star or heart shakes occur radially along the rays in the cross-section of the log, and result from growth stresses.

Existing resource

It will be about 20 years before the resource to be established in the medium rainfall zone under this project will be ready for use. During the intervening period there is likely to be a gradual increase in the use of plantation grown sawlogs. This plantation resource is predominantly Tasmanian bluegum in the high rainfall zone. These plantations are generally dense and the trees unpruned. Therefore the timber will be knotty and suitable for different uses to that to be produced under the new project described in this report.

Even in 20 years time there may continue to be two types of eucalypt sawlogs:

1. **Pruned sawlogs for appearance grade uses.** These logs will possibly be the main type of log from the new plantings in the medium rainfall zone

2. **Unpruned sawlogs (with knots) for non-appearance grade uses.** These logs are most likely to come from conventional plantation in the high rainfall zone.

This study has focussed on the feasibility of producing high-grade timber (pruned logs) in medium rainfall zone. However it is recognised that likely production of eucalypt sawlogs on cleared agricultural land in high rainfall areas will need to be taken into account at the broad planning level for the whole industry. Broad planning for the whole hardwood industry is beyond the scope of this study.

Table 2 gives a basic description of the appearance of species considered suitable for the eucalypt sawlog project, as well as wood density estimates and potential and previous utilisation.

Table 2. Wood properties and utilisation of prospective eucalypts for high-grade sawlogs in the medium rainfall zone of WA

Species	Wood description	Air-dry density (kg/m3) Mature (young)	Utilisation (potential and previous)
600-700 mm rainfall			
E. globulus	Heartwood pale brown sometimes with a pinkish tinge. Texture medium and even, grain often interlocked.	900 (730)	Flooring and furniture potential. General building timbers.
E. saligna	Heartwood pink to red-brown. Texture moderately coarse and even, grain straight or slightly interlocked.	850 (700)	Furniture and flooring potential. Easy to work, dress & finish. Important structural timber.
E. grandis	Heartwood pink to pale red-brown. Texture moderately coarse but even, grain straight.	750 (640)	Furniture and flooring potential. Easy to work, dress & finish. Panelling, joinery, furniture, construction.
E. botryoides	Heartwood reddish brown (similar to *E. saligna*). Texture medium and even, grain interlocked.	920 (?)	Furniture and flooring potential. General structural use, flooring.
E. viminalis	Heartwood pale to dark brown. Texture moderately coarse, grain variable.	750 (?)	Flooring, plywood potential. Slightly greasy, affects gluing, not difficult to work. Heavy engineering, poles.
Corymbia maculata	Heartwood pale to dark brown. yellow. Lyctus-susceptible. Straight grain with moderately coarse texture.	950 (785)	Flooring and furniture potential. Framing, floors, panels, joinery, and hardboard.
450-600 mm rainfall			
E. cladocalyx	Heartwood pale yellow-brown. Texture fine and uniform, grain commonly interlocked.	1030 (?)	Flooring potential. Posts, poles, general construction and railway sleepers.
E. tricarpa	Heartwood dark red. Texture moderately fine with interlocked grain.	Est 1120 (?)	Flooring potential. Use as for other ironbarks, eg. engineering/sleepers.
C. maculata	As above	As above	As above
E. saligna	As above	As above	As above
Salinity areas			
E. occidentalis	Heartwood pale, somewhat straight grained.	Est	Durable, so general farm use.

Table 3 is extracted from a review by Waugh *et al.* (1997), who summarised potential uses for these species and several others.

Table 3. **Predicted product suitability* of wood products from selected species on a 20-25 year rotation (from Waugh, Yang and Ozarska 1997)**

Species	Round timbers	Sawn appearance	Sawn engineering	Engineering veneer	Fibre composites	Pulp and paper
E. botryoides	*	*	?	**	**	*
E. globulus	*	*	***	*	**	***
E. saligna	***	***	***	***	*	*
E. grandis	**	**	**	***	**	**
C. maculata	***	**	***	**	*	**

Product suitability
Very good *** Good ** Acceptable * No reliable data ? Unacceptable n.s.

While the species differ in strength, appearance and other properties, all of the species are generally deemed suitable for utilisation in furniture and other added-value applications. It should be noted however, as indicated by differences in density, that wood from young trees is noticeably different from wood of mature trees. That is to say the plantation resource will be quite different from the traditional native forest resource. This will not present insurmountable problems with utilisation, it simply highlights that the industry will be dealing with a new range of forest products and will have significant development and marketing issues to consider.

Growth rates

Growth data from experimental sites established by CALM in the 1980s show that sawlogs 45 to 50 cm in diameter could be produced within 20 years in the medium rainfall zone. Twenty five to 30 years is required to produce sawlogs on infertile and/or dry sites within the zone. Wide-spaced regimes are required to produce sawlogs within this time span.

A 12-year-old study site near Dinninup, with an average rainfall of 550 mm per year, provides data on growth rates for wide-spaced *E. saligna* and *C. maculata*. The site is a gravelly loam 0.5 to 2.0 m deep over heavy clay or broken laterite. The trees were planted at a spacing of 15 m between rows and 2 m between trees in the rows (333 trees/ha). The poorer formed trees were culled leaving the best 125 trees/ha by 6 years of age. Pruning to 5 to 7m was completed by 6 years of age. Growth data from the Dinninup site are presented in Table 4.

Table 4. Mean diameter at breast height over bark (DBHOB), height, basal area, volume per tree and volume per hectare for 12-year-old *E. saligna* and *C. maculata* grown at 125 trees/ha near Dinninup.

Species	Diameter (DBHOB) (cm)	Height (m)	Basal area (m^2/ha)	Total vol/tree (m^3/tree)	Total vol/ha (m^3/ha)
Eucalyptus saligna	33.0	19.4	10.9	0.56	69.5
Corymbia maculata	27.3	14.9	7.5	0.29	36.1

Average annual increase in diameter (DBHOB) from age 10 to 12 years has been used to estimate mean DBHOB and volume of pruned logs at 20 years (see Table 5). The diameter of the pruned log at its mid-point has been estimated from the DBHOB, assuming a taper of 1 mm per 100 mm of log length. Mean volume of the pruned log has been calculated using mean mid-log diameter and mean length of pruned log.

Table 5. Estimated diameter increment, diameter at 20 years, mid-log diameter and length and volume of pruned log for 20-year-old *E. saligna* and *C. maculata* grown at 125 trees/ha near Dinninup.

Species	Estimated diameter increment, year 12 to 20 (DHBOB) (cm/yr)	Mean diameter at 20 years (DHBOB) (cm)	Mean diameter at mid-log (cm)	Mean length of pruned log (m)	Mean volume of pruned log (m^3/tree)
Eucalyptus saligna	2.0	49.0	46.8	7.0	1.2
Corymbia maculata	1.6	40.1	38.6	5.6	0.65

The data shows that by 20 years of age the mean diameter (DBHOB) of an *E. saligna* sawlog is estimated to be 49 cm, with the pruned log having a mean volume of 1.2 m^3 per tree. The mean diameter of *C. maculata* logs by 20 years is expected to be 40 cm. *C. maculata* would need to be grown for a further 6 years to reach the target log diameter of 50 cm.

Silviculture

It seems likely that wide-spaced regimes will generally be the most cost-effective method of growing eucalypts in the medium rainfall zone. Wide spacing (about 150 trees/ha) maximises growth of individual trees and minimises rotation length. Wide spacing also reduces the risk of death from drought, a likely risk in medium rainfall areas if trees are grown at conventional plantation densities. Total production of wood per hectare is less compared with that of stands at conventional plantation densities, but this is a necessary trade-off if large high-grade sawlogs are to be produced within 20 to 25 years (Reid and Stephen, 1999).

Pruning is a major cost of growing trees at wide spacing. Wide-spaced trees must be pruned if appearance grade timber is to be produced (AGWEST/CALM, 1998 and Reid and Stephen 1999). Various milling studies of young eucalypt sawlogs both in Australia and overseas have shown that knots are the main cause of degrade in sawn hardwood timber [Brennan *et al.* (1992), Washusen (2000) and Maree and Malan (2000)].

Silvicultural options

Four silvicultural options applicable to the medium rainfall zone are examined in this study:

1. **Plant 625/ha, cull to 150** crop trees/ha at 6 years
2. **Plant 833/ha, cull to 150** crop trees/ha at 6 years
3. **Plant 1250/ha, cull to 150** crop trees/ha at 6 years
4. **Plant 1250/ha, thin commercially to 150** crop trees/ha at 6 years

Silvicultural option No. 1, described in Table 6, involves planting as few seedlings per hectare as possible. Planting fewer trees reduces the cost of several operations including site preparation, planting and culling. The regime also enables substantial amounts of grazing to be carried during the first 10 years of the growing cycle.

Table 6. **Silvicultural option No. 1**, a regime designed to produce high-grade sawlogs in as short a time as possible with minimum cost.

Age (yrs)	Operation
0	**Plant 625 seedlings per ha** (e.g. 2 m between trees in rows 8 m apart)
4	Cull to 300 trees/ha (i.e. cull about 1 tree out of 2) Prune to ½ height (about 2.5m)
5-6	Cull to 150 trees/ha (i.e. cull 1 tree out of 2) Prune to ½ height (about 4.5m)
6-7	Prune the 150 sawlog trees/ha to ½ height (about 6.5m)
20 to 26	Harvest trees

Silvicultural option No. 2, outlined in Table 7, involves planting more seedlings per hectare than option No. 1. Additional seedlings provide extra choice in selecting crop trees. Extra choice is useful if poor tree form occurs due either to genetic characteristics or to damage from environmental factors, such as parrots (see Parrot Control section – page 21).

Table 7. **Silvicultural option No. 2**, a regime designed to produce high-grade sawlogs in as short a time as possible but with extra seedlings to provide additional choice in selecting well formed crop trees.

Age (yrs)	Operation
0	**Plant 833 seedlings/ha** (e.g. 3 m between trees in rows 4 m apart)
4	Cull to 300 trees/ha (i.e. cull about 5 trees out of 8) Prune to ½ height (about 2.5m)
5-6	Cull to 150 trees/ha (i.e. cull 1 tree out of 2) Prune to ½ height (about 4.5m)
6-7	Prune the 150 sawlog trees/ha to ½ height (about 6.5m)
20 to 26	Harvest trees

Silvicultural option No. 3 involves planting trees at a conventional plantation density (1250 trees/ha). Such a planting density provides even more choice in selecting crop trees. The main disadvantage is the extra cost. The cost of site preparation, planting and tree tending are all higher. There would also be some reduction in growth rate of crop trees through competition in years 3 and 4. Furthermore the opportunity to graze would be substantially reduced because of the large amount of debris created by culling. The regime is outlined in Table 8 below.

Table 8. **Silvicultural option No. 3**, a regime designed to produce high-grade sawlogs from a stand planted at a conventional planting density. The high planting rate provides extra choice in selecting crop trees, should damage occur, eg. from parrots.

Age (yrs)	Operation
0	**Plant 1250 seedlings/ha** (e.g. 2 m between trees in rows 4 m apart)
4	Cull to 300 trees/ha (i.e. cull about 3 trees out of 4) Prune to ½ height (about 2.5m)
5-6	Cull to 150 trees/ha (i.e. cull 1 tree out of 2) Prune to ½ height (about 4.5m)
6-7	Prune the 150 sawlog trees/ha to ½ height (about 6.5m)
20 to 26	Harvest trees

The fourth silvicultural option examined in this study involves planting at a conventional plantation density (1250 trees per hectare) and thinning commercially for pulpwood. The thinning would be carried out as early as possible (about 6 years) to avoid reducing growth rate of crop trees through competition and extending the rotation length significantly. Income from a thinning is expected to improve profitability.

Thinning would be from about 1250 to 150 trees per hectare. It is estimated that such a thinning would produce about 70 m^3/ha of pulpwood. However this volume would only be possible with *E. saligna* and *E. globulus* on good sites at the wet end of the rainfall range. The regime is outlined in Table 9.

Table 9. **Silvicultural option No. 4**, a regime designed to produce pulpwood from a commercial thinning at 6 years of age as well as high-grade sawlogs.

Age (yrs)	Operation
0	**Plant 1250 seedlings/ha** (e.g. 2 m between trees in rows 4 m apart)
4	Prune 300 trees/ha to ½ height (about 2.5m)
6	Thin commercially to 150 crop trees/ha (i.e. thin from 1250 to 150/ha) Prune 150 crop trees/ha to ½ height (about 6.5m)
20-23	Harvest trees

Details of management will vary depending on species, growth rate and grower's objectives. For example, at slow growth rates of trees it may be possible to prune later and at high growth rates it may be more profitable to grow more than 150 trees/ha.

Planting layouts (i.e. blocks, belts and alleys) and management regimes are flexible. The optimum layout is likely to be a compromise to meet various objectives; e.g. maintaining income from agricultural activities, lowering water tables, providing shelter and enhancing aesthetic values. The wide-spaced approach can be used in whatever layout is chosen.

Costs

Costs vary greatly depending on the type of management regime adopted (e.g. dense or wide-spaced stands) and the equipment, skills and methods used to tend the trees. For the regime described in Table 5 (plant 625 trees/ha), the total of all establishment and management costs over the 20-year rotation is $2,177 per hectare (see Table 10). Costs are based on contract rates for undertaking the work. Costs include annual administration and maintenance costs. Some costs such as fencing, rabbit control and heaping debris (marked with "+"), may not be incurred. Other costs such as weed control and pruning can vary substantially. Therefore low, average and high total costs have been calculated and these are presented in Table 11.

Table 10. Site preparation, establishment and tree management costs associated with growing eucalypts for sawlogs under silvicultural option No. 1 outlined in Table 5.

Age (yrs)	Operation	Average Cost ($/ha)	
-1	Planning	20	
	Head office overheads	200	
	Fencing & rabbit control	77+	
	Ripping and mounding	90	
	Sub-total		**387**
0	Weed control	60	
	Seedling cost ($0.30/seedling)	190	
	Planting 625/ha (8x2m)	80	
	Pest control (insects & parrots)	50	
	Sub-total		**380**
1	Parrot control	20	
	Infill	50+	
	Field management	30	
	Sub-total		**100**
2	Parrot control	20	
	Sub-total		**20**
4	1st culling (625 to 300/ha @ 40c each)	120	
	1st pruning (300 trees/ha @ 60c each)	180	
	Coppice control	25	
	Heaping debris	5+	
5	2nd pruning (150 trees/ha @ $1.50 each)	225	
	Sub-total		**550**
6	2nd culling (300 to 150/ha @ 50c each)	75	
	3rd pruning (150 trees/ha @ $1.60 each)	240	
	Coppice control	20	
	Heaping debris	15+	
	Sub-total		**350**
Yrs 1-20	Head Office management @ $10/yr		**$200**
Yrs 2-20	Annual maintenance @ $10/yr		**$190**
	Total	**$2177**	

Note: - Costs marked with "+" may not be incurred in all situations.

Table 11. Low, average and high estimates of total establishment and management costs associated with growing eucalypts for sawlogs. The costs are shown for each species and for each of the four silvicultural options.

Species	Silvicultural Option	Total Establishment & Management Cost ($/ha)		
		Low estimate	Average estimate	High estimate
E. saligna & *E. globulus*	**Plant 625/ha, cull to 150** crop trees/ha at 6 years, clearfell at 20 years	$1640	$2187	$2734
	Plant 833/ha, cull to 150 crop trees/ha at 6 years, clearfell at 20 years	$1850	$2467	$3084
	Plant 1250/ha, cull to 150 crop trees/ha at 6 years, clearfell at 20 years	$2083	$2777	$3471
	Plant 1250/ha, commercially thin to 150 crop trees/ha at 6 years, clearfell at 20 years	$1565	$2087	$2609
E. cladocalyx	**Plant 625/ha, cull to 150** crop trees/ha at 6 years, clearfell at 26 years	$1730	$2307	$2884
	Plant 833/ha, cull to 150 crop trees/ha at 6 years, clearfell at 26 years	$1940	$2587	$3234
	Plant 1250/ha, cull to 150 crop trees/ha at 6 years, clearfell at 26 years	$2173	$2897	$3621
C. maculata	**Plant 625/ha, cull to 150** crop trees/ha at 6 years, clearfell at 26 years	$1730	$2307	$2884
	Plant 833/ha, cull to 150 crop trees/ha at 6 years, clearfell at 26 years	$1940	$2587	$3234
	Plant 1250/ha, cull to 150 crop trees/ha at 6 years, clearfell at 26 years	$2173	$2897	$3621

Additional detail is presented in Appendices 1 to 9.

Parrot control

The risk of damage to young trees from ring-necked parrots ("28s") is high in many districts. Parrots ring-bark the stem near the growing tip, destroying the form of the tree. The damage is commonly so severe that stands have no trees that are suitable as crop trees. The need to control parrots is therefore crucial if the eucalypt sawlog project is to be successful.

Methods of controlling parrots are being developed (Morgan and McNee, 1999). At this stage it appears that a combination of trapping and shooting is the most effective method. Best control is obtained where neighbouring farmers work together on a coordinated basis. Until growers are confident they can control parrots, planting extra seedlings can provide some help in producing a crop of well-formed trees.

Returns from wood

Returns from wood will vary depending on volume per hectare and price per cubic meter of log. Data from the study site near Dinninup enables sawlog volume per hectare at 20 years to be estimated for *E. saligna* and *C. maculata* (see Table 5). Sawlog volume for *E. globulus* is assumed to be the same as for *E. saligna*. The sawlog volume for *E. cladocalyx* is known to be less than *E. saligna* (180 m^3/ha at 20 years) but more than *C. maculata* (135 m^3/ha at 26 years). Sawlog volume for *E. cladocalyx* is estimated to be 150 m^3/ha at 26 years.

The volume of pulpwood from a commercial thinning of *E. saligna* and *E. globulus* at 6 years was estimated using growth data from *E. globulus* on relevant sites (R Hingston *pers. comm.).* Average volume per tree was calculated and then multiplied by the number of likely merchantable trees per hectare, giving an estimated volume of pulpwood of 70 m^3/ha. Thinning commercially for pulpwood at 6 years is likely to be feasible only with *E. saligna* and *E. globulus* at the wet end of the range.

The lack of growth data and the large variability in site types means that it is important to examine the economics for a range of sawlog and pulpwood yields. Table 12 presents low, average and high wood yields for each species and silvicultural option. Low and high values are approximately 20% above and below the average value. Additional detail on sawlog volumes is presented in Appendices 1 to 9.

Table 12. Summary of low, average and high wood yields (m³/ha) for each species and silvicultural option. Details are presented in Appendices 1 to 9.

Silvicultural option	Product	Wood yield (m³/ha)		
		Low	Average	High
E. saligna & E. globulus				
Plant 625, cull to 150/ha by 6, clearfell at 20 yrs	sawlog	150	180	210
Plant 833, cull to 150/ha by 6 yrs, clearfell at 20 yrs	sawlog	150	180	210
Plant 1250, cull to 150/ha by 6 yrs, clearfell at 20 yrs	sawlog	135	165	195
Plant 1250, thin to 150/ha by 6 yrs, clearfell at 20 yrs	sawlog	135	165	195
	pulpwood	50	70	90
E. cladocalyx				
Plant 625, cull to 150/ha by 6, clearfell at 26 yrs	sawlog	120	150	180
Plant 833, cull to 150/ha by 6 yrs, clearfell at 26 yrs	sawlog	120	150	180
Plant 1250, cull to 150/ha by 6 yrs, clearfell at 26 yrs	sawlog	105	135	165
C. maculata				
Plant 625, cull to 150/ha by 6, clearfell at 26 yrs	sawlog	105	135	165
Plant 833, cull to 150/ha by 6 yrs, clearfell at 26 yrs	sawlog	105	135	165
Plant 1250, cull to 150/ha by 6 yrs, clearfell at 26 yrs	sawlog	90	120	150

The price that can be expected for high-grade pruned eucalypt logs is uncertain but is likely to range between $30 and $90 per cubic metre (stumpage) under present economic conditions. The demand for, and the quality of, sawlogs will determine stumpage for sawlogs.

Using stumpages of $45 and $90 per cubic metre, returns for *E. saligna* sawlogs range from $9,720 to $19,440 per hectare at 20 years for average yields (see Table 13 below). Returns for *C. maculata* sawlogs range from $6,300 to $12,600 at 26 years. Sawlog returns for the full range of stumpages ($30, $45, $60, $75 and $90) are presented in Appendices 10 to 12.

Table 13. Sawlog returns for *E. saligna*, *E. cladocalyx* and *C. maculata* grown under silvicultural option No. 2 (833 trees/ha planted). Returns for two stumpages are shown - $45 and $90 per m³.

Species	Average sawlog yield (m³/ha)	Sawlog returns ($/ha)	
		$45/m³ stumpage	$90/m³ stumpage
E. saligna (at 20 yrs)	180	$9,720	$19,440
E. cladocalyx (at 26 yrs)	150	$6,770	$13,540
C. maculata (at 26 yrs)	135	$6,075	$12,150

Pulpwood returns from thinning *E. saligna* and *E. globulus* commercially at 6 years are outlined in Table 14. Returns are shown for a range of pulpwood yields and stumpages ($6, $12 and $18/m³).

Table 14. Pulpwood returns from a commercial thinning of *E. saligna* and *E. globulus* at 6 years. Returns are shown for 3 pulpwood yields and stumpages.

Species	Pulpwood yield (m³/ha)	Pulpwood returns ($/ha)		
		$6/m³	$12/m³	$18/m³
E. saligna & E. globulus (thinned commercially at 6 yrs)	50	$300	$600	$900
	70	$420	$840	$1260
	90	$540	$1080	$1620

It may be possible to obtain additional returns from pulpwood by selling the unpruned portion of the tree at clearfelling. Brennan and Hingston (*in prep.*) found that 40% of total tree volume of 19-year-old *E. saligna* near Darkan (600 mm/year rainfall) was the unpruned section. Assuming this section could be sold for pulpwood at a stumpage of $6/m³, this would produce an additional $600/ha. Returns from pulpwood would be greater in higher rainfall areas where a greater proportion of the tree is pulpwood and stumpage is higher. It is unlikely that returns from pulpwood would be economical at the drier end of the medium rainfall zone. It may be possible to sell the unpruned section as bio-energy (including firewood) in some regions. Returns from the unpruned section of the tree have not been included in economic analyses in this study

Returns from grazing

Returns from grazing can be substantial, especially for silvicultural options 1 and 2. which involve planting low numbers of trees per hectare. Consequently debris from culling is low and pasture growth quite high, especially during the first 10 years of the growing cycle. Table 15 shows estimated grazing levels and returns year by year as a percentage of grazing levels and returns for an open paddock. The estimates are based on observations at the experimental site near Dinninup.

Table 15. Estimated level of and returns from grazing as a percentage of that for an open paddock.

Tree age (yrs)	Grazing level (% of open paddock grazing)	Grazing return ($/ha) (% of average return[2] from grazing open paddock)
0	75 [1]	$49
1	75 [1]	$49
2	75 [1]	$49
3	75	$49
4	75	$49
5	75	$49
6	75	$49
7	70	$45
8	64	$41
9	59	$38
10	54	$35
11	48	$31
12	43	$28
13	38	$24
14	32	$20
15	27	$17
16	21	$14
17	16	$10
18	11	$7
19	5	$3
20	0	$0

1. No understorey grazing takes place during these years, but hay is cut, providing 75% of the initial returns from grazing before the trees were planted

2. Average returns from grazing an open paddock are assumed to be $65/ha.

Economic evaluation

The economic performance of growing eucalypts for high-grade timber was assessed using Internal Rate of Return (IRR).

Impact of species

Table 16 shows the impact of species on IRR. Assumptions were silvicultural option No. 2 (833 trees/ha planted), average sawlog yield, $60/m^3 stumpage, average cost and no grazing. IRR was 9% for *E. saligna* and *E. globulus* and 6% for *E. cladocalyx* and 5% for *C. maculata*. The lower IRR for *E. cladocalyx* and *C. maculata* reflect their lower sawlog yields.

Table 16. IRR by species for silvicultural option No. 2 (833 trees/ha planted), average sawlog yield, $60/m^3 stumpage, average cost and no grazing.

Species	Internal Rate of Return (%)
E. saligna* and *E. globulus	9%
E. cladocalyx	6%
C. maculata	5%

Impact of silvicultural regime

Table 17 shows the impact of silvicultural regime on IRR. Assumptions were *E. saligna* and *E. globulus*, average sawlog yield, $60/m^3 stumpage, average cost and no grazing. The regime involving a commercial thinning was the most profitable (IRR = 12%). However there is likely to be limited scope for this regime in the medium rainfall zone. The next most profitable regime was the silvicultural option of planting 625 trees/ha. It produced an IRR of 10%. The overall pattern was lower IRR with increasing density of planting. This is because costs of establishment and management increase and sawlog yields decline with increasing numbers of trees planted.

Table 17. IRR by silvicultural regime for *E. saligna* and *E. globulus*, average yield, average stumpage, average cost and with no returns from grazing.

Silvicultural Regime	IRR (%)
Plant 625/ha, cull to 150 crop trees/ha at 6 years, clearfell at 20 years	10%
Plant 833/ha, cull to 150 crop trees/ha at 6 years, clearfell at 20 years	9%
Plant 1250/ha, cull to 150 crop trees/ha at 6 years, clearfell at 20 years	8%
Plant 1250/ha, thin commercially to 150 crop trees/ha at 6 years, clearfell at 20 years	12%

Sensitivity analyses

The Internal Rate of Return has been calculated for each species for a range of values of key parameters. The parameters are:

1. Cost of establishment and management (low, average and high) – see Table 10
2. Wood yields (low, average and high) – see Table 11
3. Sawlog stumpage ($30, $45, $60, $75 and $95 per cubic metre) – see Appendices 10 to 12.

Impact of costs on IRR

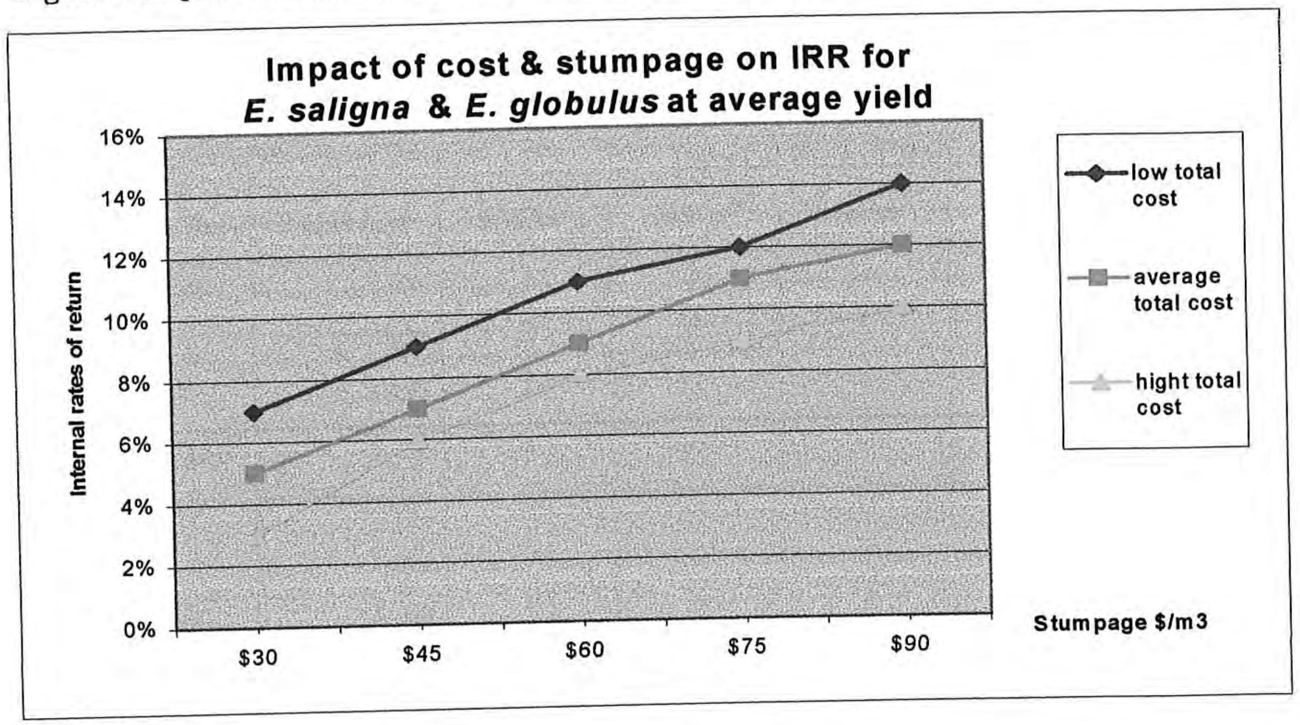
Table 18 presents IRR for *E. saligna* and *E. globulus* under silvicultural option No. 2 (833 trees/ha planted) for a range of costs, wood yields and stumpages. For $60/m^3 stumpage and average wood yields, the IRR for low, average and high costs are 11%, 9% and 8% respectively. If yields are low (180 m^3/ha) and costs are high, IRR at $60/m^3 stumpage is 7%. If yields are high (210 m^3/ha) and costs are low, IRR at $60/m^3 stumpage is 12%.

Table 18. IRR for *E. saligna* and *E. globulus* under silvicultural option No. 2 (833 trees/ha planted) for a range of costs, wood yields and stumpages.

Yields – m^3/ha	Total cost	Internal Rate of Return (%)				
		$30/m^3	$45/m^3	$60/m^3	$75/m^3	$90/m^3
Low – 150	Low	6	8	10	11	12
	Average	4	6	8	9	11
	High	2	5	7	8	9
Average – 180	Low	7	9	11	12	14
	Average	5	7	9	11	12
	High	3	6	8	9	10
High – 210	Low	8	10	12	13	14
	Average	6	8	10	12	13
	High	4	7	9	10	11

The impact of cost and stumpage on IRR for *E. saligna* and *E. globulus* is shown graphically in Figure 1.

Figure 1. Impact of cost & stumpage on IRR for *E. saligna* & *E. globulus* at average wood yields.



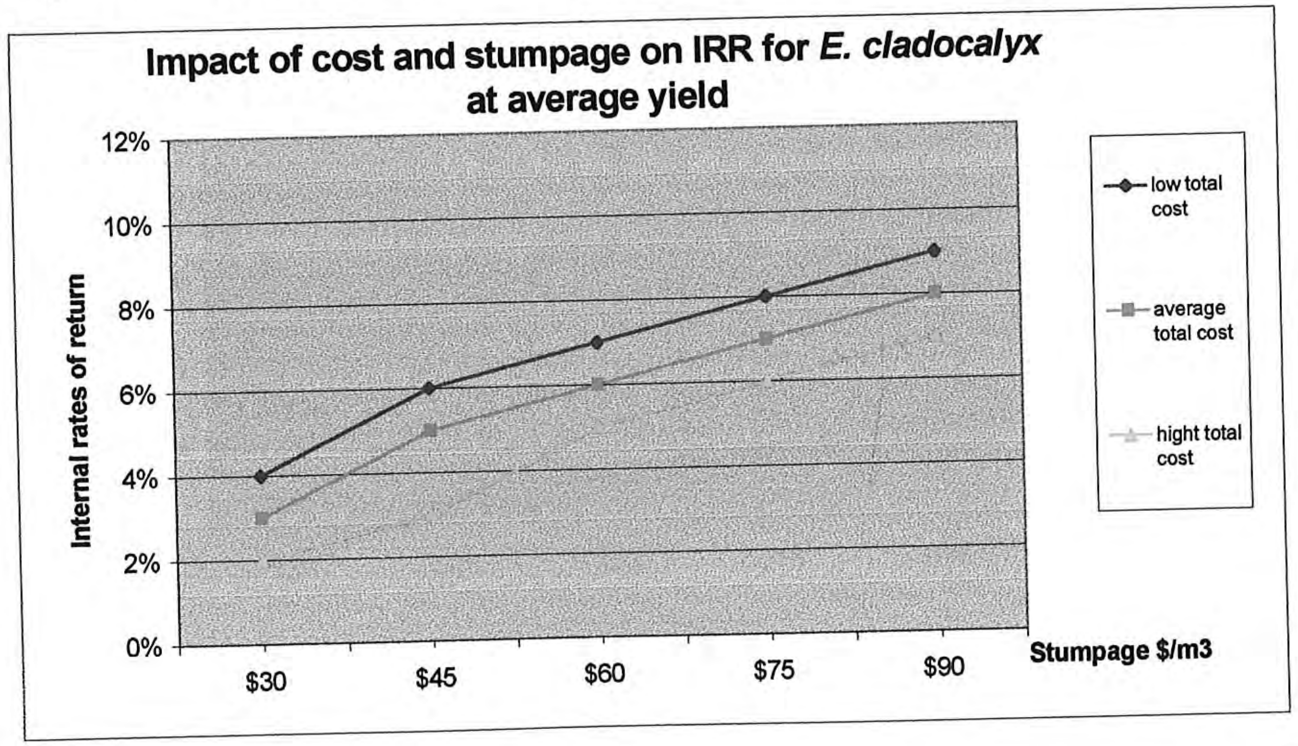
A similar pattern of variation in IRR with cost occurs for *E. cladocalyx* and *C. maculata*. IRR for *E. cladocalyx* at $60/m³ stumpage and low yield, range from 4% to 6% across the high cost to low cost range (see Table 19). At high yield, IRR range from 6% to 8% across the high cost to low cost range.

Table 19. IRR for *E. cladocalyx* under the plant-833/ha regime for a range of costs, wood yields and stumpage.

		Internal Rate of Return (%)				
Yields – m³/ha	**Total cost**	**$30/m³**	**$45/m³**	**$60/m³**	**$75/m³**	**$90/m³**
Low – 120	Low	3	5	6	7	8
	Average	2	3	5	6	7
	High	1	2	4	5	6
Average – 150	Low	4	6	7	8	9
	Average	3	5	6	7	8
	High	2	3	5	6	7
High – 180	Low	5	7	8	9	10
	Average	3	5	7	8	9
	High	2	4	6	7	7

The impact of cost and stumpage on IRR for *E. cladocalyx* is shown graphically in Figure 2.

Figure 2. The impact of cost and stumpage on IRR for *E. cladocalyx* at average wood yields.



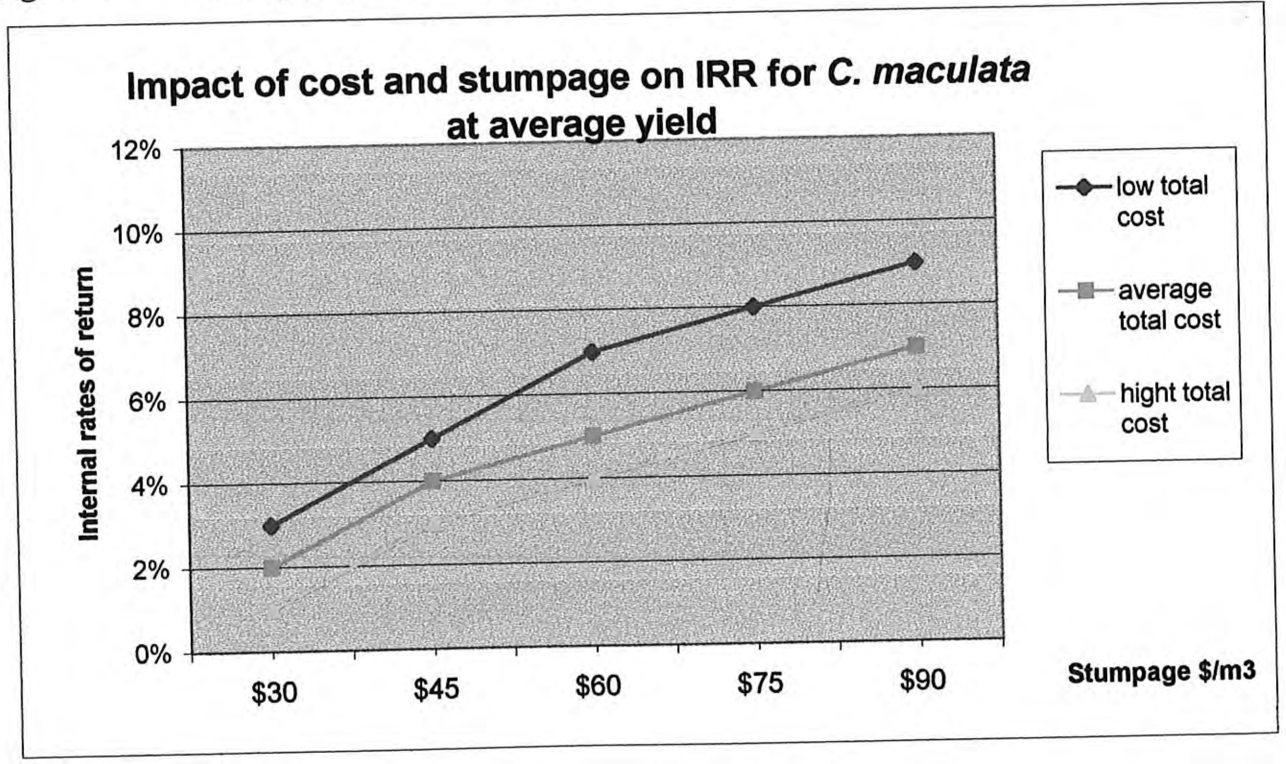
C. maculata, the slowest growing species, has IRR from 3% to 8% at \$60/m³ stumpage and across the range of costs and yields (see Table 20).

Table 20. IRR for *C. maculata* under the plant-833/ha regime for a range of costs, wood yields and stumpage.

		Internal Rate of Return (%)				
Yields – m³/ha	**Total cost**	**\$30/m³**	**\$45/m³**	**\$60/m³**	**\$75/m³**	**\$90/m³**
Low – 105	Low	2	4	6	7	7
	Average	1	3	4	5	6
	High	0	2	3	4	5
Average – 135	Low	3	5	7	8	9
	Average	2	4	5	6	7
	High	1	3	4	5	6
High - 165	Low	4	6	8	9	10
	Average	3	5	6	7	8
	High	2	4	5	6	7

The impact of cost and stumpage on IRR for *C. maculata* is shown graphically in Figure 3.

Figure 3. The impact of cost and stumpage on IRR for *C. maculata* at average wood yields.



Impact of grazing returns

The impact of returns from grazing on IRR is shown in Table 21. Grazing returns increase IRR by one to two percentage points.

Table 21. IRR for *E. saligna*, *E. globulus*, *E. cladocalyx* and *C. maculata* with and without returns from grazing. The assumptions used were silvicultural option No. 1 (625 trees/ha planted), average sawlog yield, $60/m^3 stumpage and average cost.

Species	Internal Rate of Return (%)	
	Wood Revenues Only	Wood + Grazing Revenues
E. saligna & E. globulus	10%	12%
E. cladocalyx	6%	8%
C. maculata	6%	7%

Milling and Seasoning

The following section reviews the key steps in converting plantation grown eucalypts to value-added products.

Harvesting

Growth stresses can cause logs to split during harvesting, transport and storage. Common sense must, therefore, be applied in felling and handling. The logs must not be severely jarred when falling or moving them because the input energy can initiate splitting. Moisture loss must also to be avoided, because the associated shrinkage can also initiate splitting. It is important to end-seal the logs, transport them to the sawmill and store them under water spray as soon as possible after felling, particularly in summer. Recommendations from the IUFRO conference were: mechanical harvesting gives best results, harvest tree length to reduce splitting, haul within one day, store under water spray, and crosscut just prior to conversion.

Stockpiling and Other Pre-treatments

Research at Timber Technology in the late 1980s confirmed the need to stockpile logs under watersprays to prevent end splitting. Watering schedules of 15 minutes in every three hours were shown to minimise log defects and indicated that growth stresses could be reduced to improve sawing behaviour. Although blue gum was not included in this trial it is anticipated that the principles would apply.

Other pre-treatments to reduce longitudinal stresses can include: hot water soaking; pre-steaming; pre-freezing; pre-treatment with urea; pre-soaking in polyethylene glycol, urea or urea-sorbitol solution; pre-heating; pre-compression or dynamic transverse compression. Many of these have not been thoroughly researched.

Sawing techniques

Backsawing and quartersawing

Backsawing is recommended in preference to quarter sawing because; growth stresses are released as bow rather than spring, the timber dries more quickly, recovery rates are higher, and the timber has a more attractive face figure. Quarter sawing can reduce seasoning degrade, but it is anticipated that seasoning degrade can be managed using proper drying practices. Timber with bow will straighten during seasoning but quartersawn boards with spring cannot be straightened in the drying process.

In small diameter eucalypt logs, growth stresses often cause deflection of the log during saw milling. A single initial cut in one side of a stressed log will cause the two sections to bow outward from one another, with the thinner section (wing) bowing more than the thicker section (flitch). A second cut made simultaneously on the opposite side of the log will tend to balance these effects and to produce a stable section for re-sawing. If no action is taken to prevent movement, boards can be several millimetres thinner at each end due to movement during sawing.

With conventional sawing equipment, intermediate straightening cuts are needed to remove the bow from the flitch. Straightening cuts are effective, but wasteful. A number of more efficient methods can be employed to accurately break down stressed logs without such waste.

A twin saw is probably the lowest capital cost alternative to produce a stable central flitch suitable for resawing, because both wings are removed simultaneously. Unfortunately, the twin saw technique is not able to deal well with offset and/or wandering heart.

A higher capital cost alternative is a line-bar carriage, which ensures that a uniform thickness board or flitch for re-saw is produced. Sawing short logs will reduce the effect of growth stresses but the cost of production is likely to rise.

Valuwood International consider the use of a fine kerf frame saw is an appropriate method for converting very small diameter logs. The frame saw produces a mixture of backsawn and quartersawn boards and the machinery required is quite expensive (though not as expensive as a linebar carriage).

The Timber Technology Centre, Harvey, has processed small diameter stressed logs on a Woodmizer horizontal bandsaw that can turn the logs between cuts to minimise the distortion of the flitch. Although the process is reasonably effective, it is very slow and, therefore, not commercially viable.

The use of saw milling principles and specialised equipment to control the release of growth stresses are equally important in re-sawing processes. The use of twin or multi-rip saws that balance stress release to produce straight or slightly bowed rather than sprung timber sections, is essential.

Fine kerf saws produce higher recoveries than heavy gauge saws because less of the log is converted to sawdust. It is therefore essential to utilise fine kerf sawing, particularly when sawing small section sizes. The use of fine kerf saws may necessitate debarking of the logs, particularly those with stringy bark, which can foul the bandsaw. Another option is a device that removes bark from just in front of the saw, thus preventing fouling.

Grade sawing techniques have evolved to saw native sawlogs with variable defects. They are not suitable for plantation eucalypt logs, particularly the unpruned logs that will be available for the next 15-20 years. A strategy that combines efficient program sawing with upgrading of the product at later stages of processing will be more viable than grade sawing.

Sawing studies

Mill studies of Tasmanian bluegum sawlogs by CALM's Timber Technology Centre show that it is feasible to mill and season timber from pruned, fast-grown eucalypts. Moore *et al.* (1996) reported the results of milling 13-year-old Tasmanian bluegum grown near Busselton. Mean log diameter was 33 cm and total recovery of green sawn timber was 34.7 per cent. The percentages of appearance grade for 25 mm and 38 mm boards were 63 per cent and 60 per cent respectively.

Brennan and Hingston (*in prep.)* reported recoveries and grades for 17-year-old Tasmanian bluegum logs from the same site. Log diameter (small end diameter under bark – SEDUB) ranged from 34.2 to 51.8 cm. Logs were cut to 2.5 m length and sawn on site into 25, 38 and 50 mm thick flitches using a back-sawing pattern with a "Woodmizer" portable bandsaw. Flitches were re-sawn with a "Jonsereds" bandsaw. Mean recovery of green sawn timber was 48.8 per cent.

The strip-stacked timber was dried in solar-assisted kilns using drying schedules developed for marri (*Corymbia calophylla*). Some of the 50 mm boards showed signs of cell collapse, which was recovered by re-conditioning the boards with steaming treatment. The overall recovery into appearance grade products was 30 per cent based on log volume and 84 per cent based on dry-dressed volume (Brennan and Hingston, *in prep.*).

Slicing and Peeling

The utilisation of 13-year-old blue gum as a peeled veneer for plywood or LVL (laminated veneer lumber) production was assessed by Wesply. Unfortunately, the results were inconclusive and additional trials are required to determine the suitability of young pruned eucalypt logs for veneering.

Valuwood International produced both sawn and sliced blue gum veneers for glue laminated pre-finished flooring, and concluded that fine kerf sawing was a more economic option than slicing for thick veneers. It seems unlikely that a stable flitch could be cut from a small diameter stressed log for the production of thin decorative veneers using traditional methods. The heart would have to be boxed within the flitch, and because there are problems in using the heart, the flitch would have to be turned repeatedly during the cutting process. Unless it was stabilised by hot soaking or other means, one also would expect the flitch to deflect away from the cutting knife.

Drying

Plantation timber can be dried successfully by various means, but some species are more susceptible than others are to collapse and or surface checking. The challenge with drying plantation timber, as it is with any timber, is to dry to uniform moisture content as quickly as possible with minimum degrade. Air-drying is too slow and the quality of the product is reduced, so some type of kiln is required to be able to reliably achieve satisfactory drying results.

Conventional drying requires the following steps to progressively evaporate moisture from the timber:

- Low speed of air flow (0.5 to 1 m/s) across boards is critical in the early stages of drying.
- High humidity and low temperature conditions until the timber attains about 25 - 30% moisture content.
- A reconditioning treatment at 20 per cent moisture content may be required in some cases to recover collapse (corrugation of the timber surface).
- A final drying phase of declining humidity and increasing temperature to drive outbound water.
- Possibly an equalisation and or steaming treatment to relieve drying stresses in the timber and to assure uniform moisture distribution within the boards and the pack.

A range of driers is available for the conventional drying process. Heat and vent kilns release humid air to the environment at a controlled rate to ensure gradual drying. They require substantial energy inputs in the latter stages of drying to raise the temperature of the timber. This energy can come from the sun, or the burning of wood waste or fossil fuels. Dehumidifying kilns gradually lower humidity by condensing water vapour on cooling coils (evaporators). They also heat the air using heating coils. A range of novel drying processes is being investigated and in time these may help speed the drying process. Research in these areas is very important, but the research need is not specific to plantation timber.

The most significant drying problem facing plantation eucalypt timber is movement during drying. It is critical that the timber is cut accurately to size (very accurately by current industry standards), neatly strip-stacked and then held in place by weights during drying. Poorly sawn and/or stacked plantation timber tends to cup and twist during drying and this leads to poor recovery. Once this problem has been overcome, other issues relating to shrinkage during drying may surface, but presently they are not as critical as sawing and stacking accuracy.

Tree breeding and genetic deployment

Tree breeding

There are a number of ways to increase returns from a tree crop. One approach is to improve the genetic quality of the stock used in the project via a tree selection and breeding program. Thus with no additional silvicultural cost, and using the same site, the productivity of the tree can be increased. As this project is long term, it makes economical sense to use genetically superior trees to maintain above average growth on the land resource.

Potential gains from provenance selection have been estimated in trials of three sawlog species (Mazanec *pers. comm.).* The greatest gain estimates come from those trials with wide variation between provenances (often a reflection of wide geographical dispersion between seed sources). Thus for each species, the gain will vary. Whilst such estimates are indicative of genetic variation between the provenances within a trial, the magnitude of those differences are specific to that trial. Extrapolation to a wide variety of environments is risky without adequate replication of the trial on a number of sites.

To demonstrate the variation between provenances within a trial, the best provenance can be compared against the worst (Table 22). The *Eucalyptus saligna* and *E. viminalis* trials possessed the greatest variation and hence the greatest gains at provenance level. *Corymbia maculata,* recently separated from *C. variegata,* yielded a difference of only 26% in individual tree volume between best and worst provenances and likewise the smallest gain (Table 22). The best three provenances of *E. saligna* and *E. viminalis* yielded average tree volumes of 27 and 57% higher than their respective trial means. The best provenance of these two species yielded mean tree volumes of 52% and 95 % higher than their respective trial mean (Table 22).

To attain greater genetic gains than those demonstrated at provenance level, and particularly where the variation is narrow, higher selection intensities need to be applied. These can be made either at the family or, more successfully, at the clonal level. The gain, however, can only be predicted once the weighting of the traits for the selections has been agreed upon and the outcrossing rate known. It should be noted that it is only when a selection is carried out specifically for a given trait that improvements can be made, unless there happens to be a positive genetic correlation between one or more desirable traits, eg. tree volume and stem straightness. There is little control with native seed collections.

Table 22. Improvement in growth (%) of three sawlog species when the best and worst provenances are compared to indicate the diversity and the three best provenances and the best provenance are compared against the average performance.

Species	Best provenance over worst provenance (% gain)	Three best provenances over average provenance performance (% gain)	Best provenance over average provenance performance (% gain)
E. saligna	297	27	52
E. viminalis	298	57	95
C. maculata	26	8	15
Average	273	42	77

Genetic deployment

Genetic deployment is to develop the fastest method to get the genetic improvement into plantations whilst retaining maximum genetic gain. Three deployment routes are available to the project, native seed collections, sexual reproduction such as seedling or clonal seed orchards and vegetative propagation such as rooted cuttings or a tissue culture method. Each of these methods has limitations as to their effectiveness in passing on the genetic gain and the resulting cost of each plant.

Whilst native collections are regarded an easy option, there have been a number of problems experienced with sub-contracting to other seed collectors in quality and accuracy of collection. The threat of inbreeding from easy roadside collections is always a concern. Additionally, many of these provenances where the original collections were made have been affected by environmental change.

Seed orchard seed production is the safest form of deployment to reach predicted gains. There are two types of orchard, an open pollinated seedling seed orchard (OPSSO) or a clonal seed orchard (CSO). The former orchard is established from seedlings of better families and the latter from selections grafted from those better families. The selection intensity of the CSOs is higher and thus the genetic gain is higher. For each of these seedlings or clones to contribute to the gene pool in the seed orchard, they must flower and successfully cross. The nesting of selections into provenances within an orchard can synchronise flowering and overcome out-crossing concerns. Additionally, selections can be biased towards flowering to provide greater amounts of seed in a shorter time with a sacrifice of some genetic gain.

Vegetative propagation has had varied success depending on the species ability to form adventitious roots. The standard nursery system developed for *E. grandis* and its hybrids is expected to produce rooting rates in the 80% range. In comparison, preliminary studies have shown that *E. occidentalis* has a rooting success in the 30% range, *C. maculata* and *E. sideroxylon* in the 20% range with *E. cladocalyx* below 10%. It is regarded that to commercialise a vegetative propagation system, a level above 70% rooting rate must be achieved. However, the development of a vegetative propagation technique in eucalypts opens the door to clonal forestry, and the highest and fastest genetic gain possible.

The method of genetic deployment is based on a consideration of time to deployment (Table 23), cost of plant production and possible genetic gain of that plant. Each aspect has to be weighed up with the ultimate value of the crop and silvicultural methods in mind. Generally, the higher the genetic gain (for example clonal forestry), the greater number of stems will be carried through to final harvest, in other words fewer stems need to be established at planting. Some silviculture management schemes require thinning as part of the crop economics and play a role in whole crop management. Thus within a breeding and deployment strategy, whilst highest possible genetic gains remain attractive, a cost-effective approach in terms of the final management of the crop needs to be determined.

Table 23: Estimation of time required for a genetically improved product to be produced by the different propagation systems, native seed (Native), open pollinated seedling seed orchard (OPSSO), clonal seed orchard (CSO) and vegetative propagation.

Species	Native	OPSSO	CSO	Vegetative propagation
E. botryoides	1 year	5 years	3 years	unknown
E. cladocalyx				Poor
E. grandis				Good- 2 years
C. maculata				Poor
E. occidentalis				Poor
E. saligna				Unknown
E. tricarpa				Poor
E. viminalis				Unknown

Research and development

A comprehensive R&D program is required for the Eucalypt Sawlog Project, covering the range of aspects.

Products and Markets

- Investigating in more detail, the market and product options for appearance-grade eucalypt timber.
- Determining log specifications for major product types.

Silviculture and Economics

- Collecting data on wood yields for a wider range of sites and species, especially *E. cladocalyx* and *C. maculata.*
- Investigating stand certification schemes (especially for pruning).
- Assessing the economics of alternative silvicultural regimes for sawlog production in greater detail.
- Investigating the price that industry would be prepared to pay for high-grade hardwood sawlogs.

Harvesting.

- Improving log harvesting, handling and storage practices. As explained previously, the plantation eucalypts resource, particularly blue gum, is far more susceptible to degrade during felling, snigging, hauling, and storage than logs from native forest.

Processing

- Improving the ability to mill young eucalypt logs is fundamental. Currently, few sawmills in Western Australia have equipment suitable for processing stressed logs and fewer still have the knowledge to use the equipment efficiently and effectively.
- Improving manufacturing technologies to enable industry to achieve more with less. With limited technical support, industry is adept at introducing small incremental improvements in production and manufacturing technologies and this can be facilitated by normal extension services. In addition there is a need for the Timber Technology Centre to collaborate with other research bodies to investigate ways of increasing recovery rates, reducing drying times and drying losses, developing products that make use of the limited proportion of high quality sawn timber in conjunction with the other grades.

- Improving the ability of the industry to dry timber properly.

Tree Breeding and Genetic Deployment

- Identifying superior provenances of target species and making these available for growers.

Operational Planting Schemes

- Developing financial and cost-sharing mechanisms to support operational planting schemes.

Extension and training services

- Providing growers with a farm forestry service, initially supported by government that assists in planning, establishment, management, monitoring and harvesting.

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Appendix 1

Wood yields (low) and returns for *E. saligna* & *E. globulus*

Regime	Sawlog yields		Pulpwood yield		MAI	Grazing possible
	m^3/tree	m^3/ha	m^3/tree	m^3/ha	m^3/ha/yr	
Plant 625/ha • cull to 150 crop trees/ha by 6yrs • prune to 6.5 m by 6 yrs • clearfell at 20 years • grazing is an option	1.0	150	N/A	N/A	7.5	yes
Plant 833/ha • cull to 150 crop trees/ha by 6yrs • prune to 6.5 m by 6 yrs • clearfell at 20 years • grazing is an option	1.0	150	N/A	N/A	7.5	yes
Plant 1250/ha • cull to 150 crop trees/ha by 6yrs • prune to 6.5 m by 6 yrs • clearfell at 20 years • grazing is NOT an option	0.9	135	N/A	N/A	6.75	no
Plant 1250/ha • **commercially thin** to 150 crop trees/ha at 6yrs (thin about 900 trees/ha) • prune to 6.5 m by 6 yrs • clearfell at 20 years • grazing is not an option	0.9	135	0.055	50	9.25	no

Note:
1. *E. saligna* and *E. globulus* are suitable for average to good sites at the wetter end of the range.
2. Commercial thinning for pulpwood is likely to be viable on only the very best sites.
3. Returns from grazing are unlikely to be significant at 1250 trees/ha.

Appendix 2

Wood yields (average) and returns for *E. saligna* & *E. globulus*

Regime	Sawlog yields		Pulpwood yield		MAI	Grazing possible
	m^3/tree	m^3/ha	m^3/tree	m^3/ha	m^3/ha/yr	
Plant 625/ha • cull to 150 crop trees/ha by 6yrs • prune to 6.5 m by 6 yrs • clearfell at 20 years • grazing is an option	1.2	180	N/A	N/A	9	yes
Plant 833/ha • cull to 150 crop trees/ha by 6yrs • prune to 6.5 m by 6 yrs • clearfell at 20 years • grazing is an option	1.2	180	N/A	N/A	9	yes
Plant 1250/ha • cull to 150 crop trees/ha by 6yrs • prune to 6.5 m by 6 yrs • clearfell at 20 years • grazing is NOT an option	1.1	165	N/A	N/A	8.2	no
Plant 1250/ha • **commercially thin** to 150 crop trees/ha at 6yrs (thin about 900 trees/ha) • prune to 6.5 m by 6 yrs • clearfell at 20 years • grazing is not an option	1.1	165	0.077	70	11.75	no

Note:
1. *E. saligna* and *E. globulus* are suitable for average to good sites at the wetter end of the range.
2. Commercial thinning for pulpwood is likely to be viable on only the very best sites.
3. Returns from grazing are unlikely to be significant at 1250 trees/ha.

Appendix 3

Wood yields (high) and returns for *E. saligna* & *E. globulus*

Regime	Sawlog yields		Pulpwood yield		MAI	Grazing possible
	m^3/tree	m^3/ha	m^3/tree	m^3/ha	m^3/ha/yr	
Plant 625/ha • cull to 150 crop trees/ha by 6yrs • prune to 6.5 m by 6 yrs • clearfell at 20 years • grazing is an option	1.4	210	N/A	N/A	10.5	yes
Plant 833/ha • cull to 150 crop trees/ha by 6yrs • prune to 6.5 m by 6 yrs • clearfell at 20 years • grazing is an option	1.4	210	N/A	N/A	10.5	yes
Plant 1250/ha • cull to 150 crop trees/ha by 6yrs • prune to 6.5 m by 6 yrs • clearfell at 20 years • grazing is NOT an option	1.3	195	N/A	N/A	9.75	no
Plant 1250/ha • **commercially thin** to 150 crop trees/ha at 6yrs (thin about 900 trees/ha) • prune to 6.5 m by 6 yrs • clearfell at 20 years • grazing is not an option	1.3	195	0.1	90	14.25	no

<u>**Note:**</u>

1. *E. saligna* and *E. globulus* are suitable for average to good sites at the wetter end of the range.
2. Commercial thinning for pulpwood is likely to be viable on only the very best sites.
3. Returns from grazing are unlikely to be significant at 1250 trees/ha.

Appendix 4

Wood yields (low) and returns for *E. cladocalyx*

Regime	Sawlog yields		Pulpwood yield		MAI	Grazing possible (yes/no)
	m^3/tree	m^3/ha	m^3/tree	m^3/ha	m^3/ha/yr	
Plant 625/ha • cull to 150 crop trees/ha by 6 yrs • prune to 6.5 m about 6 years • clearfell at 26 years • grazing is an option	0.8	120	N/A	N/A	4.6	yes
Plant 833/ha • cull to 150 crop trees/ha by 6 yrs • prune to 6.5 m about 6 yrs • clearfell at 26 yrs • grazing is an option	0.8	120	N/A	N/A	4.6	yes
Plant 1250/ha • cull to 150 crop trees/ha by 6 yrs • prune to 6.5 m about 6 years • clearfell at 26 years • grazing is an not option	0.7	105	N/A	N/A	4.0	no

<u>**Note:**</u>

1. *E. cladocalyx* is suitable on a wide range of sites including at the drier end of the range.
2. Thinning is unlikely to be commercially viable.
3. Returns from grazing are unlikely to be significant at 1250 trees/ha.

Appendix 5

Wood yields (average) and returns for *E. cladocalyx*

Regime	Sawlog yields		Pulpwood yield		MAI	Grazing possible
	m^3/tree	m^3/ha	m^3/tree	m^3/ha	m^3/ha/yr	(yes/no)
Plant 625/ha • cull to 150 crop trees/ha by 6 yrs • prune to 6.5 m about 6 years • clearfell at 26 years • grazing is an option	1.0	150	N/A	N/A	5.8	yes
Plant 833/ha • cull to 150 crop trees/ha by 6 yrs • prune to 6.5 m about 6 yrs • clearfell at 26 yrs • grazing is an option	1.0	150	N/A	N/A	5.8	yes
Plant 1250/ha • cull to 150 crop trees/ha by 6 yrs • prune to 6.5 m about 6 years • clearfell at 26 years • grazing is an not option	0.9	135	N/A	N/A	5.2	no

Note:
1. *E. cladocalyx* is suitable on a wide range of sites including at the drier end of the range.
2. Thinning is unlikely to be commercially viable.
3. Returns from grazing are unlikely to be significant at 1250 trees/ha.

Appendix 6

Wood yields (high) and returns for *E. cladocalyx*

Regime	Sawlog yields		Pulpwood yield		MAI	Grazing possible
	m^3/tree	m^3/ha	m^3/tree	m^3/ha	m^3/ha/yr	(yes/no)
Plant 625/ha • cull to 150 crop trees/ha by 6 yrs • prune to 6.5 m about 6 years • clearfell at 26 years • grazing is an option	1.2	180	N/A	N/A	6.9	yes
Plant 833/ha • cull to 150 crop trees/ha by 6 yrs • prune to 6.5 m about 6 yrs • clearfell at 26 yrs • grazing is an option	1.2	180	N/A	N/A	6.9	yes
Plant 1250/ha • cull to 150 crop trees/ha by 6 yrs • prune to 6.5 m about 6 years • clearfell at 26 years • grazing is an not option	1.1	165	N/A	N/A	6.3	no

Note:
1. *E. cladocalyx* is suitable on a wide range of sites including at the drier end of the range.
2. Thinning is unlikely to be commercially viable.
3. Returns from grazing are unlikely to be significant at 1250 trees/ha.

Appendix 7

Wood yields (low) and returns for *C. maculata*

Regime	Sawlog yields		Pulpwood yield		MAI	Grazing possible
	m³/tree	m³/ha	m³/tree	m³/ha	m³/ha/yr	(yes/no)
Plant 625/ha • cull to 150 crop trees/ha by 6 yrs • prune to 6.5 m about 6 years • clearfell at 26 years • grazing is an option	0.7	105	N/A	N/A	4.0	yes
Plant 833/ha • cull to 150 crop trees/ha by 6 yrs • prune to 6.5 m about 6 yrs • clearfell at 26 yrs • grazing is an option	0.7	105	N/A	N/A	4.0	yes
Plant 1250/ha • cull to 150 crop trees/ha by 6 yrs • prune to 6.5 m about 6 years • clearfell at 26 years • grazing is an not option	0.6	90	N/A	N/A	3.5	no

Note:
1. *C. maculata* is suitable on a wide range of sites including at the drier end of the range.
2. Thinning is unlikely to be commercially viable.
3. Returns from grazing are unlikely to be significant at 1250 trees/ha.

Appendix 8

Wood yields (average) and returns for *C. maculata*

Regime	Sawlog yields		Pulpwood yield		MAI	Grazing possible
	m³/tree	m³/ha	m³/tree	m³/ha	m³/ha/yr	(yes/no)
Plant 625/ha • cull to 150 crop trees/ha by 6 yrs • prune to 6.5 m about 6 years • clearfell at 26 years • grazing is an option	0.9	135	N/A	N/A	5.4	yes
Plant 833/ha • cull to 150 crop trees/ha by 6 yrs • prune to 6.5 m about 6 yrs • clearfell at 26 yrs • grazing is an option	0.9	135	N/A	N/A	5.4	yes
Plant 1250/ha • cull to 150 crop trees/ha by 6 yrs • prune to 6.5 m about 6 years • clearfell at 26 years • grazing is an not option	0.8	120	N/A	N/A	4.6	no

Note:
1. *C. maculata* is suitable on a wide range of sites including at the drier end of the range.
2. Thinning is unlikely to be commercially viable.
3. Returns from grazing are unlikely to be significant at 1250 trees/ha.

Appendix 9

Wood yields (high) and returns for *C. maculata*

Regime	*Sawlog yields*		Pulpwood yield		MAI	*Grazing* possible
	m^3/tree	m^3/ha	m^3/tree	m^3/ha	m^3/ha/yr	(yes/no)
Plant 625/ha • cull to 150 crop trees/ha by 6 yrs • prune to 6.5 m about 6 years • clearfell at 26 years • grazing is an option	1.1	165	N/A	N/A	6.3	yes
Plant 833/ha • cull to 150 crop trees/ha by 6 yrs • prune to 6.5 m about 6 yrs • clearfell at 26 yrs • grazing is an option	1.1	165	N/A	N/A	6.3	yes
Plant 1250/ha • cull to 150 crop trees/ha by 6 yrs • prune to 6.5 m about 6 years • clearfell at 26 years • grazing is an not option	1.0	150	N/A	N/A	5.8	no

Note:
1. *C. maculata* is suitable on a wide range of sites including at the drier end of the range.
2. Thinning is unlikely to be commercially viable.
3. Returns from grazing are unlikely to be significant at 1250 tree/ha.

Appendix 10

Returns from sawlogs at low wood yield, for range of stumpage, for each species and for each silvicultural regime. Sawlog stumpages are \$30, \$45, \$60, \$75 and \$90 per cubic meter.

Silvicultural regime	Sawlog returns (low wood yield and range of stumpage) (\$/ha)				
	\$30/m³	**\$45/m³**	**\$60/m³**	**\$75/m³**	**\$90/m³**
E. saligna & E. globulus					
Plant 625, cull to 150/ha by 6, clearfell at 20 yrs	\$4500	\$6750	\$9000	\$11250	\$13500
Plant 833, cull to 150/ha by 6 yrs	\$4500	\$6750	\$9000	\$11250	\$13500
Plant 1250, cull to 150/ha by 6 yrs	\$4050	\$6075	\$8100	\$10125	\$12150
Plant 1250, comm. thin to 150/ha by 6 yrs	N/A	N/A	N/A	N/A	N/A
E. cladocalyx					
Plant 625, cull to 150/ha by 6 yrs	\$3600	\$5400	\$7200	\$9000	\$10800
Plant 833, cull to 150/ha by 6 yrs	\$3600	\$5400	\$7200	\$9000	\$10800
Plant 1250, cull to 150/ha by 6 yrs	\$3150	\$4725	\$6300	\$7875	\$9450
C. maculata					
Plant 625, cull to 150/ha by 6 yrs	\$3150	\$4725	\$6300	\$7875	\$9450
Plant 833, cull to 150/ha by 6 yrs	\$3150	\$4725	\$6300	\$7875	\$9450
Plant 1250, cull to 150/ha by 6 yrs	\$2700	\$4050	\$5400	\$6750	\$8100

Appendix 11

Returns from sawlogs at average wood yield for the range of stumpages, for each species and for each silvicultural regime. Sawlog stumpages are $30, $45, $60, $75 and $90 per cubic meter.

Silvicultural regime	Sawlog returns (average wood yield and range of stumpage) ($/ha)				
	$30/m³	$45/m³	$60/m³	$75/m³	$90/m³
E. saligna & E. globulus					
Plant 625, cull to 150/ha by 6, clearfell at 20 yrs	$5400	$8100	$10800	$13500	$16200
Plant 833, cull to 150/ha by 6 yrs	$5400	$8100	$10800	$13500	$16200
Plant 1250, cull to 150/ha by 6 yrs	$4950	$7425	$9900	$12375	$14850
Plant 1250, comm. thin to 150/ha by 6 yrs	N/A	N/A	N/A	N/A	N/A
E. cladocalyx					
Plant 625, cull to 150/ha by 6 yrs	$4500	$6750	$9000	$11250	$13500
Plant 833, cull to 150/ha by 6 yrs	$4500	$6750	$9000	$11250	$13500
Plant 1250, cull to 150/ha by 6 yrs	$4050	$6075	$8100	$10125	$12150
C. maculata					
Plant 625, cull to 150/ha by 6 yrs	$4050	$6075	$8100	$10125	$12150
Plant 833, cull to 150/ha by 6 yrs	$4050	$6075	$8100	$10125	$12150
Plant 1250, cull to 150/ha by 6 yrs	$3600	$5400	$7200	$9000	$10800

Appendix 12

Returns from sawlogs at high wood yield, for range of stumpage, for each species and for each silvicultural regime. Sawlog stumpages are $30, $45, $60, $75 and $90 per cubic meter.

Silvicultural regime	Sawlog returns (high wood yield and range of stumpage) ($/ha)				
	$30/m³	$45/m³	$60/m³	$75/m³	$90/m³
E. saligna & E. globulus					
Plant 625, cull to 150/ha by 6, clearfell at 20 yrs	$6300	$9450	$12600	$15750	$18900
Plant 833, cull to 150/ha by 6 yrs	$6300	$9450	$12600	$15750	$18900
Plant 1250, cull to 150/ha by 6 yrs	$5850	$8775	$11700	$14625	$17550
Plant 1250, comm. thin to 150/ha by 6 yrs	N/A	N/A	N/A	N/A	N/A
E. cladocalyx					
Plant 625, cull to 150/ha by 6 yrs	$5400	$8100	$10800	$13500	$16200
Plant 833, cull to 150/ha by 6 yrs	$5400	$8100	$10800	$13500	$16200
Plant 1250, cull to 150/ha by 6 yrs	$4950	$7425	$9900	$12375	$14850
C. maculata					
Plant 625, cull to 150/ha by 6 yrs	$4950	$7425	$9900	$12375	$14850
Plant 833, cull to 150/ha by 6 yrs	$4950	$7425	$9900	$12375	$14850
Plant 1250, cull to 150/ha by 6 yrs	$4500	$6750	$9000	$11250	$13500