EUCALYPT PLANTATION SILVICULTURAL REGIMES

BRADEN M. JENKIN

1990 GOTTSTEIN FELLOWSHIP REPORT

JOSEPH WILLIAM GOTTSTEIN MEMORIAL TRUST FUND

The Joseph William Gottstein Memorial Trust Fund was established in 1971 as a national educational Trust for the benefit of Australia's forest products industries. The purpose of the fund is *"to create opportunities for selected persons to acquire knowledge which will promote the interests of Australian industries which use forest products for the production of sawn timber, plywood, composite wood, pulp and paper and similar derived products."*

Bill Gottstein was an outstanding forest products research scientist working with the Division of Forest Products of the Commonwealth Scientific Industrial Research Organization (CSIRO) when tragically he was killed in 1971 photographing a tree-felling operation in New Guinea. He was held in such high esteem by the industry that he had assisted for many years that substantial financial support to establish an Educational Trust Fund to perpetuate his name was promptly forthcoming.

The Trust's major forms of activity are,

1. Fellowships - each year applications are invited from eligible candidates to submit a study programme in an area considered to be of benefit to the Australian forestry and forest industries. Study tours undertaken by Fellows have usually been to overseas countries but several have been within Australia. Fellows are obliged to submit reports on completion of their programme. These are then distributed to industry if appropriate.

2. Seminars - the information gained by Fellows is often best disseminated by seminars as well as through the written reports.

3. Wood Science Courses - at approximately two yearly intervals the Trust organises a week-long intensive course in wood science for executives and consultants in the Australian forest industries.

4. Study Tours - industry group study tours are arranged periodically and have been well supported.

Further information may be obtained by writing to,

The Secretary,
J.W. Gottstein Memorial Trust Fund,
Private Bag 10,
Clayton, Victoria,3168 Australia

FOREWORD

In view of the current high level of interest in eucalypt plantations within Australia the Gottstein Trustees have decided Braden Jenkin's report should be given a wider than normal distribution.

The report summarizes a large body of practical information on eucalypt plantation silviculture from Portugal, South Africa, France and the Congo and relates this to Australian practice. It was not intended that the report would also cover financial and economic aspects. The economics of establishing eucalypt plantations for pulpwood and/or sawlog will be the subject of later Gottstein Trust reports.

Braden Jenkin has obviously returned from his Gottstein Fellowship full of enthusiasm and new ideas. However, the task ahead is not without difficulty. New systems have to be made to work here in Australia where suitable land is scarce and labour relatively expensive. Existing eucalypt technologies and equipment are largely geared to old-growth, native forests of large trees with variable characteristics. Despite acknowledgement that the development of plantation eucalypts represents a major technical and economic challenge, many organisations and individuals throughout Government, industry and the community are keen to give plantation eucalypts every opportunity of success.

The Trustees believe that this is an excellent review of international practice and development in eucalypt plantation silviculture. It should provide a valuable reference for those who are either already involved or contemplating involvement in such plantation development projects.

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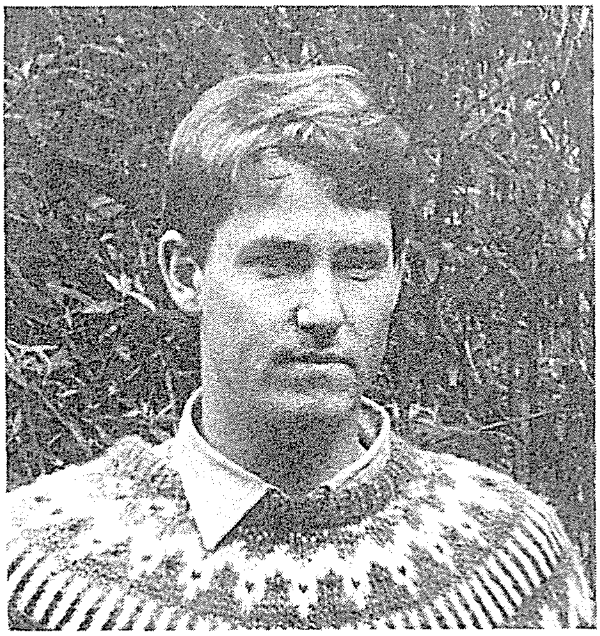
1990 GOTTSTEIN FELLOWSHIP REPORT

Braden Jenkin is a District Forester with APM Forests Pty. Ltd., based at Morwell in Victoria. He controls around 7,000 hectares of eucalypt plantations established in the 1960's and early 1970's and has initiated several thinning operations. He is very interested in improving post-establishment management techniques and this was one of the study topics during his 1990 Gottstein Fellowship.



Braden holds a B.Sc. (Forestry) from the Australian National University and prior to joining APM Forests Pty. Ltd., in 1988 was with W.A. Chip and Pulp Co.

CONTENTS

1.0: SUMMARY AND RECOMMENDATIONS

The following recommendations are based on the knowledge gained from this Gottstein Fellowship Study tour and my experience in the area of eucalypt plantation silviculture.

A: EUCALYPT PLANTATION POTENTIAL

Australia has a great potential to become a major developer of eucalypt plantations with world competitive growth rates (table 19.1), provided that adequate and suitable land is available. Plantation grown wood could easily supplement native forest harvesting. It could also increase wood production towards self sufficiency and increased export potential, provided we can compete economically.

B: ESTABLISHMENT

Establishment technique must aim to grow a complete and vigorous tree root system to allow full site utilization. Cultivation to depth, floral competition control, fertilizer application, quality planting stock and correct planting techniques are all essential. Any short cuts may jeopardize realisation of optimal production.

C: COMPETITION

Competition for a sites' resources is both between the planted trees and with other vegetation. Management must aim to reduce competition, within the bounds of good land management. Application of residual herbicides at establishment is Australia's most significant advantage. In the first dry season after planting, the inter row vegetation strip should be cultivated to reduce moisture competition.

D: PHORACANTHA SEMIPUNCTATA FABRICUS

P.semipunctata and other members of the tribe Phoracanthini are a potential threat to Australian eucalypt plantations. Threat will turn to reality with a combination of infection source (scattered native forest), stressed trees (planting in long term low rainfall areas and too long a rotation) and the chance of drought (inducing even more stress). The only short term solution is to reduce stress by early clearfalling or thinning.

Other natural eucalypt predators may also become a problem in stressed plantations

E: SAWLOG PRODUCTION

Australian plantations could grow South African size sawlogs. However, in South Africa they have genetically improved planting stock to enhance sawing characteristics. Therefore we need to include sawing parameters into eucalypt genetic improvement programmes. Such logs could be cut using Australian softwood sawmilling technology. Local drying schedules would be required for each species. Marketing to promote plantation origin sawn products would be required.

F: COPPICING

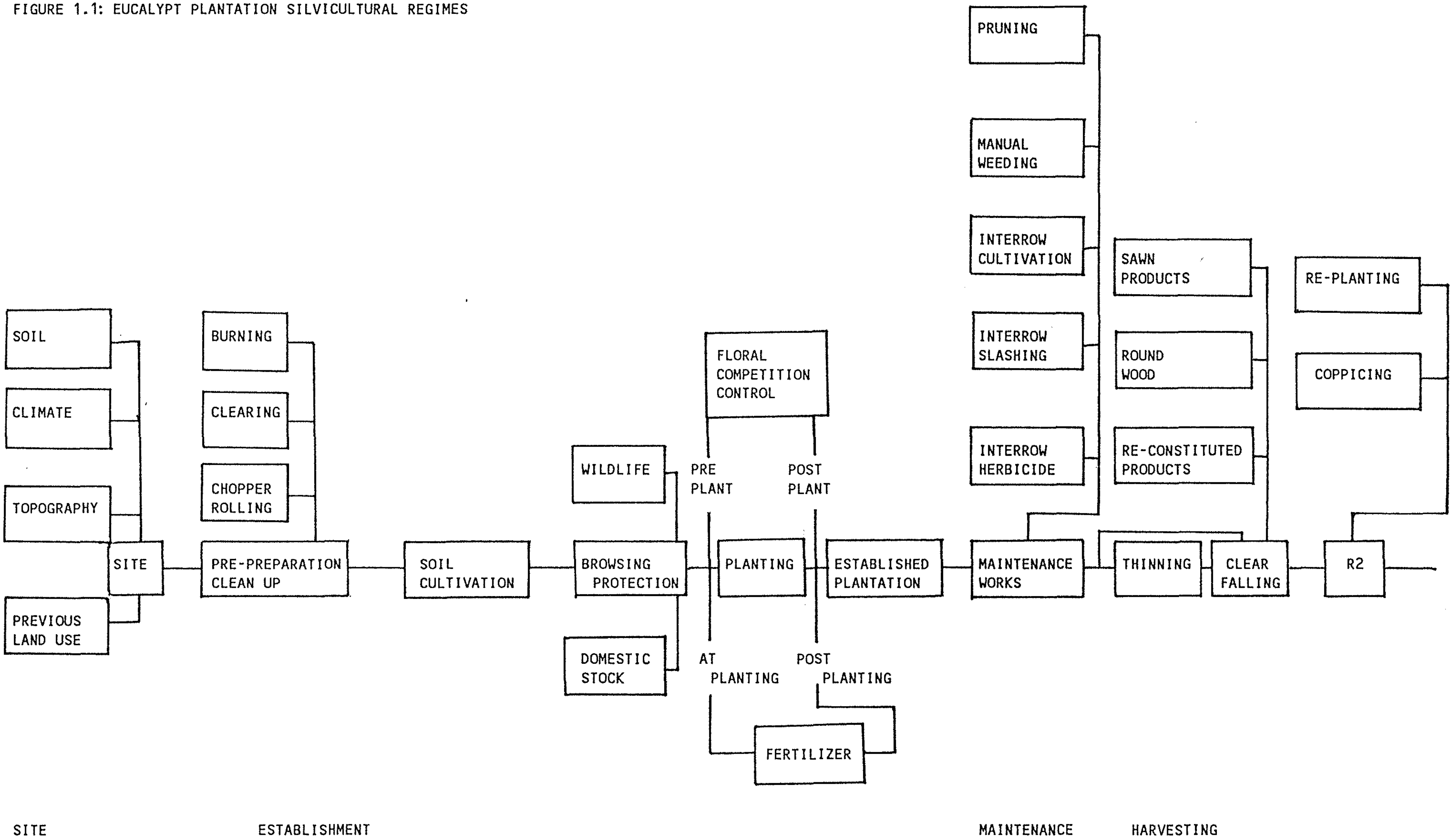
Coppicing of Australian plantations is not recommended based on the following considerations. A coppice regime requires increased costs in harvesting the R1 crop. At least two, if not three manual individual stump treatments in the first three years are required to ensure selection of the most suitable stems. A coppice rotation will forfeit genetic and silvicultural advances, and handicap the full potential of any site. Coppice crops will require hand falling increasing the delivered wood costs and the chance of operator injury.

G: PIECE SIZE

Small piece size products (pulp, post and poles) can be from short rotations or as residues from "large" piece size rotations. Lower quality sites can be utilized. Short rotations require initial stocking rates that prevent self thinning prior to clearfalling. Between 800 and 2000 stems per hectare are recommended dependant upon site quality.

Large piece size production (for sawlogs) requires high quality sites and a long rotation with thinning to reduce stress. Initial stocking rates of 1100 stems per hectare should be followed by thinning down to a final crop of 250 to 300 stems per hectare.

FIGURE 1.1: EUCALYPT PLANTATION SILVICULTURAL REGIMES



2.0: ACKNOWLEDGEMENTS

I am grateful to the Joseph William Gottstein Memorial Trust Fund for providing the opportunity to undertake my chosen study topic. In particular I wish to thank Mr. W.G. Keating for his invaluable advice and encouragement at all phases of my project. It is felt that greater access was gained to information through representing the Trust rather than an individual company or organisation. I must thank Mr. W. Briggs, Manager of APM Forests Pty. Ltd. for allowing me the time to undertake my study tour. As well, thanks are due to Mr. R.B. McCarthy, Operations Superintendent APM Forests Pty. Ltd., for supporting my initial application and continued support throughout the project.

During the projects initial stages many people assisted in the collection of contact addresses and provided invaluable advice as to which companies were best to visit. Once overseas, the organisations and companies visited afforded great hospitality and assistance and for that I am grateful.

It is hoped that the information collected during my fellowship will help advance Australia's eucalypt plantation development programmes.

3.0: INTRODUCTION

Through genetic improvement Pinus radiata D.Don, a sometimes windswept tree growing in small areas of the Monterey Bay and Cambria areas of California (USA) has become a highly significant plantation species in southern Australia (New Zealand and Chile). Other members of the pinus genus have followed into areas not suited to P.radiata. During the period of P.radiata plantation development in Australia, management of most natural eucalypt stands continued on a much less intensive scale. In several overseas countries parallel scenarios were in place with members of the eucalypt genus. However, with natural good form and vigour their initial planting stock was genetically ahead.

One scenario was as follows. In 1790, eucalypts were first planted in the palace garden at Nandi Hills (near Mysore) India (FAO (1979)), only two years after the genus was named by Charles - Louis L'Heritier de Brutelle (Boland et al (1984)). Captain Cotton of the Madras Engineers then successfully introduced Eucalyptus globulus to India in 1843, after which regular trial plantings continued. His initial plantings were at Wellington in the Nilgiri Hills, (plantings from 1863 are maintained today as a preservation plot). Commercial development of the genus followed with widespread plantings for a range of end uses. Eucalypts are now grown commercially within all but the most arid and cold climatic zones. The genus is well represented in the African and American continents, as well as mediterranean Europe.

While work on P.radiata continued in Australia, eucalypt plantations were largely of no interest due to the resource available from natural stands. However, E.grandis Hill ex Maiden and E.regnans F.Muell were established in plantations in Australia prior to 1950. Plantings continued on a variable scale until a renascence of interest in the early to mid 1980's. Since then planting has continued in Western Australia, Victoria and Tasmania (with limited scale plantings in the other states).

Australian research into plantation establishment and genetic improvement has increased initial growth rates. Now we must consider plantation management to give an overall silvicultural regime. Therefore by documenting and studying overseas operations to establish the link between establishment and management we can determine silvicultural options for Australia. Consideration of end products (or objectives of management), can then be linked to Australia's plantation silvicultural options.

It is the aim of this report to present the silvicultural regimes observed in the countries of interest, together with examples of Australian practices. Presentation will be on an individual operation basis to allow comparison, analysis and development of links to management objectives.

4.0: COUNTRIES OF INTEREST

4.1: SUMMARY

Eucalypt plantations have been established on a range of sites, with great variation in climatic conditions. Due to land availability, development has moved into other non traditional areas. Therefore commercial eucalypt plantations are now within a much broader range of site conditions. Within both the existing and new areas of plantation development overseas, similar sites to any area of Australia can be identified. Experience within such sites can be extrapolated to the Australian situation, providing a valuable insight as to what can be expected. It must be noted that any extrapolation must take into full consideration all factors involved.

4.2: INTRODUCTION

As stated in the project brief, it was aimed to visit countries with similar climatic conditions to Australia's eucalypt plantation zones. Although the countries of interest covered similar climates, they also covered zones not presently utilized in Australia for eucalypt plantations. As well as land availability, the question of displacing agriculture and government regulation are all pushing eucalypt plantations out of the traditional zones.

Eucalypt growing organizations were visited in South Africa, France and Portugal. While in France information was collected on the Congo (a former French colony).

By studying the countries of interest, useful information can be collected for Australia's present regions of eucalypt plantation development and the future potential of alternative land resources.

4.3: LATITUDE AND LOCATION

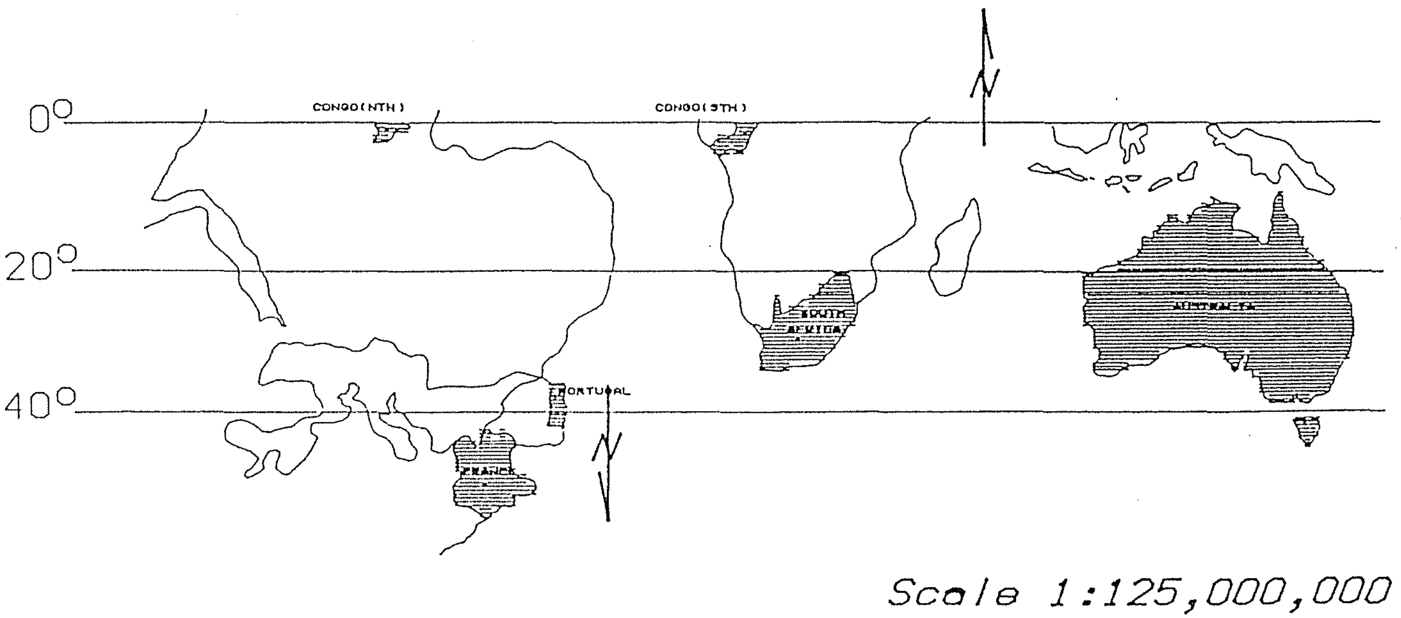
Continental (including Tasmania) Australia runs from 10 degrees south through to 47 degrees south. Map 4.1 shows the latitudes of the countries investigated compared to those of Australia.

4.4: CLIMATE

Macro and micro climatic characteristics will effect plantation development through influences on soils and determination of conditions suitable for plant growth and development. Presently biocline techniques are being developed to allow specific site matching and modelling of plantation development within Australia (Personal Communication 1).

Temperature will dictate water budget characteristics, through effects on relative humidity and therefore evaporation and evapotranspiration. The two extremes of temperature; 30 - 35^{o}C plus

MAP 4.1: LATITUDINAL RANGES OF THE COUNTRIES OF INTEREST IN RELATION TO AUSTRALIA



* A diagrammatic depiction of the countries of interest, with the northern hemisphere inverted to align with southern hemisphere latitudes.

and less than $0^{o}C$, dominate some environments. High temperatures heat up surface soil and cause root damage through desiccation, where as low nocturnal temperatures may result in frost at ground level rupturing plant cells. Both can have a significant effect at early stages of tree growth. As such, both high temperature and frost create special problems for plantation management.

FAO-UNESCO (1977) prepared a series of climatic region maps, which can be consulted for full climatic details of the countries of interest. Table 4.1 presents a summary of current eucalypt plantation climatic zones.

TABLE 4.1: EUCALYPT PLANTATION CLIMATIC ZONES (BASED ON FAO-UNESCO (1977))

COUNTRY:	DESCRIPTION:
Australia (Tas.)	Temperate Mediterranean Warm Marine Humid Patagonian
(Vic.)	Marine Pampean Warm Marine
(WA)	Subtropical Mediterranean Marine Mediterranean
Congo	Humid Semihot Equatorial
France	Warm Temperate
Portugal	Subtropical Mediterranean Marine Mediterranean Temperate Mediterranean
South Africa	Low Tierra Fria Medium Tierra Fria Semihot Semitropical

4.5: SOILS

Detailed soil surveys have been carried out by many organisations. A range of soil classification systems have evolved for use under local conditions. To compare the different soil types, detailed information can collected from FAO-UNESCO (1977).

4.6: FORESTS AND WOOD USE

The following tables present forestry and wood production statistics for both hardwood and softwoods. They were extracted from 1989 Commonwealth Forestry Handbook (compiled from FAO (1988A) and FAO (1988B)). At present, eucalypt plantation estates are rapidly expanding and therefore the figures presented are out of date. However, they still serve as a useful comparison of the relative importance of forestry. The purpose of including the following tables is to put each countries forestry operations into relative perspective. As shown, with the exception of the Congo, all countries still rely on imported wood products. The present expansion of eucalypt plantations is aimed to reduce imports where possible. In the case of the Congo, they are attempting to develop a pulp export operation.

TABLE 4.6: FORESTS AND ANNUAL WOOD USE STATISTICS FOR THE COUNTRIES OF INTEREST (ANON (1989))

AUSTRALIA

Area:	761,793,000 ha	Population:	14,695,000
Forest Area:	41,658,000 ha (5.5%)		
Productive Forest:	36,688,000 ha (4.8%)		
Total roundwood production: including	19,999,000 cu.m.		
Industrial roundwood:	17,119,000 cu.m	Fuelwood:	2,888,000*cu.m.

	Production	Export	Import
Saw/veneer logs	8,144,000	1,000	1,000 cu.m.
Sawnwood	3,194,000	34,000	1,256,000 cu.m.
Panels	923,000	16,000	116,000 cu.m.
Wood pulp	910,000	0	223,000 mt.

CONGO

Area:	34,150,000 ha	Population:	1,529,000
Forest Area:	21,357,000 ha (62.5%)		
Productive Forest:	13,707,000 ha (40.1%)		
Total roundwood production: including	2,574,000 cu.m.		
Industrial roundwood:	946,000 cu.m	Fuelwood:	1,628,000*cu.m.

	Production	Export	Import
Saw/veneer logs	715,000	287,000	0 cu.m.
Sawnwood	77,000	23,000	8,000 cu.m.
Panels	58,000	46,000	0 cu.m.
Wood pulp	0	0	0 mt.

FRANCE

Area:	54,563,000 ha	Population:	53,714,000
Forest Area:	13,875,000 ha (25.4%)		
Productive Forest:	13,340,000 ha (24.4%)		
Total roundwood production: including	39,115,000 cu.m.		
Industrial roundwood:	28,685,000 cu.m	Fuelwood:	10,430,000*cu.m.

	Production	Export	Import
Saw/veneer logs	18,920,000	1,415,000	1,118,000 cu.m.
Sawnwood	9,078,000	904,000	2,213,000 cu.m.
Panels	2,537,000	575,000	1,256,000 cu.m.
Wood pulp	2,044,000	1,469,000	1,755,000 mt.

PORTUGAL

Area:	9,164,000 ha	Population:	9,884,000
Forest Area:	2,627,000 ha (28.7%)		
Productive Forest:	2,590,000 ha (28.3%)		
Total roundwood production: including	9,038,000 cu.m.		
Industrial roundwood:	8,440,000 cu.m	Fuelwood:	598,000*cu.m.

	Production	Export	Import
Saw/veneer logs	4,000,000	13,000*	380,000 cu.m.
Sawnwood	2,573,000	1,359,000	27,000 cu.m.
Panels	650,000	429,000	1,000 cu.m.
Wood pulp	1,226,000	1,004,000	45,000 mt.

SOUTH AFRICA

Area:	122,104,000 ha	Population:	28,612,000
Forest Area:	1,347,000 ha (1.1%)		
Productive Forest:	1,057,000 ha (0.9%)		
Total roundwood production: including	19,022,000 cu.m.		
Industrial roundwood:	11,944,000 cu.m	Fuelwood:	7,078,000*cu.m.

	Production	Export	Import
Saw/veneer logs	4,129,000	2,000*	26,000 cu.m.
Sawnwood	1,510,000	25,000	221,000 cu.m.
Panels	398,000	33,000	21,000 cu.m.
Wood pulp	1,284,000	315,000	56,000 mt.

* An estimate or from non-official sources.

4.7: EXAMPLES OF EUCALYPT PLANTATION HISTORIES

4.7.1: COUNTRIES OF INTEREST

4.7.1.1: AUSTRALIA

Of all the eucalypts, only E.deglupta Blume and E.urophylla S.T.Blake are not endemic to Australia. E.alba Reinw. ex Blume, E.papuana F.Muell. and E.tereticornis Smith occur on islands north of Australia, as well as in Australia (Boland et al (1984)). The remaining species are variously naturally distributed across Australia.

Due to the availability of wood from natural stands, eucalypt plantation development in Australia has been relatively slow. One early planting took place some 40 to 50 years ago, with 8000 hectares of E.astringens (Maiden) Maiden planted in Western Australia for tannin extraction and tool handle production. Other early plantation species include E.youmanii Blakely and McKie and E.macrorhyncha F.Muell. ex Benth. planted for rutin (a medical drug) production (FAO (1979)). Older plantations of E.grandis Hill ex Maiden and E.regnans F.Muell. exist today.

4.7.1.2: CONGO

In 1954 over 50 species of eucalypts were planted out on the dry savannah plains around Pointe Noire. The main plantings of eucalypts commenced in 1973, based on the results of the early works (FAO (1979)).

4.7.1.3: FRANCE

Although French botanists have played an important role in the nomenclature of the genus (L'Heritier gave it the name eucalyptus the year before the French Revolution), commercial plantations commenced in the early 1980`s. However in ex French colonies the genus is well represented (FAO (1979)).

4.7.1.4: PORTUGAL

It is thought that the first eucalypts were planted in Portugal in 1829 at Vila Nova de Gaia (near Porto), but if reliable records are consulted, the first plantings were in 1852 (FAO (1978)). Several people in Portugal suggested that the genus may have been introduced up to 400 years ago by early explorers.

4.7.1.5: SOUTH AFRICA

Eucalypts were first introduced into South Africa in 1807. They were brought across from Mauritius in containers. Since the last quarter of the nineteenth century increased demand for fuelwood, mining timbers and later pulpwood has seen a rapid expansion of the eucalypt estate (FAO (1979)).

4.7.2: OTHER COUNTRIES

4.7.2.1: BRAZIL

The Rio de Janeiro botanic gardens have the oldest known eucalypts in Brazil. Specimens of E.robusta Smith and E.tereticornis were planted in 1825 by Emperor Pedro 1 of Brazil. Edmundo Navarro de Andrade (the father of Brazilian plantation forestry) established 144 eucalypt species in trials some 80 years later for the Panlista Railway Company. Later he established a eucalypt arboretum and plantations at Rio Claro in Sao Paulo State (FAO (1979)). Brazil now has the largest eucalypt plantation estate in the world.

4.7.2.2: INDONESIA

At least three species of eucalypts are indigenous to Indonesia; E.alba, E.deglupta, and E.urophylla. Trials of 48 species including E.deglupta were established between 1937 and 1940 to find a quick growing species of commercial interest (FAO (1979)).

4.7.2.3: ISRAEL

E.camaldulensis Dehnh. was first planted in 1884 on the coastal plain at Mikve in an attempt to drain malaria infested swamps. The original provenance details are unknown, however seed is believed to have come from the lower reaches of the Murray river. Today, other eucalypts are of interest, but E.camaldulensis remains the primary species for posts, fuelwood, charcoal, sawnwood, chipboard and fibreboard production (FAO (1979)).

5.0: ORGANISATION PROFILES, LANDBASE AND LANDUSE CONTROLS

5.1: SUMMARY

The history of eucalypt plantation forestry companies varied greatly, with present day structure the result of either evolution or creation to suit a specific resource demand. The scale of Companies operations varied from AFOCEL (at present with under 1000 hectares) through to Mondi (with a total (all species) 340,000 hectares). The size of company estates was dictated by plantation productivity and the wood resources required by industry. In most cases, companies were expanding their operations, which in turn has created some conflict. Table 5.1 presents a summary of plantation areas for the organisations visited.

TABLE 5.1: PLANTATION ESTATES

COUNTRY:	ORGANISATION:	AREA (HA):
AUSTRALIA	APMF	8000
	BUNNINGS TREEFARMS	5278
CONGO	CTFT/ENGREF	25000 (+)
FRANCE	AFOCEL	100
PORTUGAL	CELBI	60000
	EMPORSIL	10000
	PORTUCEL	80000
STH. AFRICA	HM HOLDINGS	5200 (#)
	HL AND H	138000
	MONDI	250000 (*)
	NTE	80000
	SAPPI	105000

* ALL SPECIES INCLUDED
\+ AREA FOR STAGE 1, STAGE 2 IS TO BE ANOTHER 25 000 HECTARES
\# TZANEEN OPERATIONS ONLY

As a single landuse expands, conflict over competition for a limited and finite resource is unavoidable. This is especially the case with plantation forestry where large tracts of land are required. The most basic issues underlying most conflicts are the displacement of agriculture and the supposed threat to conservation values. Presently in Australia conflicts, as mentioned above, exist. If in order to control development, specific zoning of land as used overseas (ie based on soil type) is introduced, it must recognise plantations as a legitimate landuse.

5.2: INTRODUCTION

The formation of a forestry company is usually in response to resource demand from a processing centre or in preparation for the construction of a processing centre. The most fundamental requirement of any plantation programme is an adequate and appropriate land base. Land availability can either be via ownership or the right of access given to an organisation or company by either the legal owner or a controlling body. Suitability of land for plantation development is dependant upon individual site characteristics compared with the species requirements.

As land within the present plantation zones declines either through economic constraints or availability, plantation development will be forced into areas previously discounted as suitable. As a result new silvicultural techniques are presently under development. Superimposed over land availability and suitability can be a range of government controls, which, via zoning or regulation, dictate the allowed potential development of a site. Such controls can be direct ie zoning or indirect through secondary requirements placed on the use of a given area of land. The following section presents an outline of the history of the organisations visited as well as details of their landbase and any local landuse controls.

5.3: AUSTRALIA

Australia's land use policy controls vary according to Federal, State and Local government requirements. For example the Federal Government does not have any direct powers over the States, but through secondary control they can influence landuse issues. For example by placing conditions on export licence requirements, the Federal Government can control State activities. Generally most landuse decision and regulation activities occur at State and Local Government level.

5.3.1: APM FORESTS PTY. LTD.

In 1939 APM Limited commenced production of wood pulp at its Maryvale Mill in Gippsland. To ensure an economic perpetual supply of pulpwood, APM Forests Pty. Ltd. was formed in 1951.

APM Forests Pty. Ltd. has a total land base of some 82,000 hectares of freehold and leasehold land with softwood plantations (primarily Pinus radiata D.Don), hardwood plantations (8000 hectares; primarily Eucalyptus regnans F.Muell), natural forest and other land for plantation development. The eucalypt plantation programme is primarily confined to company controlled land including areas of abandoned agricultural land in the Strzelecki Ranges. On certain sites, after clearfalling P. radiata plantations, eucalypts are established. Operational scale plantings of eucalypts on some lower quality sites have taken place.

In 1989 APM Forests Pty. Ltd. launched a Farm Forestry Agreement to grow eucalypts. As an aid to the promotion of trees on farms, a National Afforestation Programme (NAP) grant was gained to assist in the establishment of demonstration eucalypt plantations on routine farms.

In 1989, the State Government introduced "A Code of Forest Practice". It includes controls on the establishment of plantations on private property (for full details refer to DCE (1989)). Local Government controls vary with the individual Shires. Presently, some Shires require a planting permit before a plantation can be established.

5.3.2: BUNNINGS TREEFARMS LTD.

Bunnings Limited is one of Australia's largest vertically integrated forest product companies. The Bunnings Group of Companies covers all aspects of timber production harvesting, transport and processing logs from Western Australia's State Forest. Both saw and chip logs are recovered from fully integrated operations under the control of the Department of Conservation and Land Management. Through a fully owned subsidiary WACAP, Bunnings Limited, has a licence to export up to 900,000 tonnes of eucalypt woodchips per annum for manufacturing into high quality papers. Woodchip exports are under agreement with the Federal Government.

In 1980 the first Eucalyptus globulus Labill subsp. globulus plantation was established by WACAP. In 1989 Bunnings Treefarms was created, leaving WACAP as a processor and exporter of woodchips. Bunnings Treefarms is responsible for the establishment of eucalypt plantations on both company freehold and lease land. Their objective is to establish 30,000 ha of hardwood plantations in the South-west of Western Australia over the next 10 years. Several investment and sharefarming arrangement schemes have been created by the company. Map 5.1 shows Bunnings Treefarms Limited potential land resource zone. It is controlled by the 700 millimetre (long term) rainfall isohyet and 120 kilometres from Bunbury (from where WACAP presently exports woodchips and has a site for a potential pulpmill). Presently Bunnings Treefarms has a total of 5278 ha under eucalypt plantations.

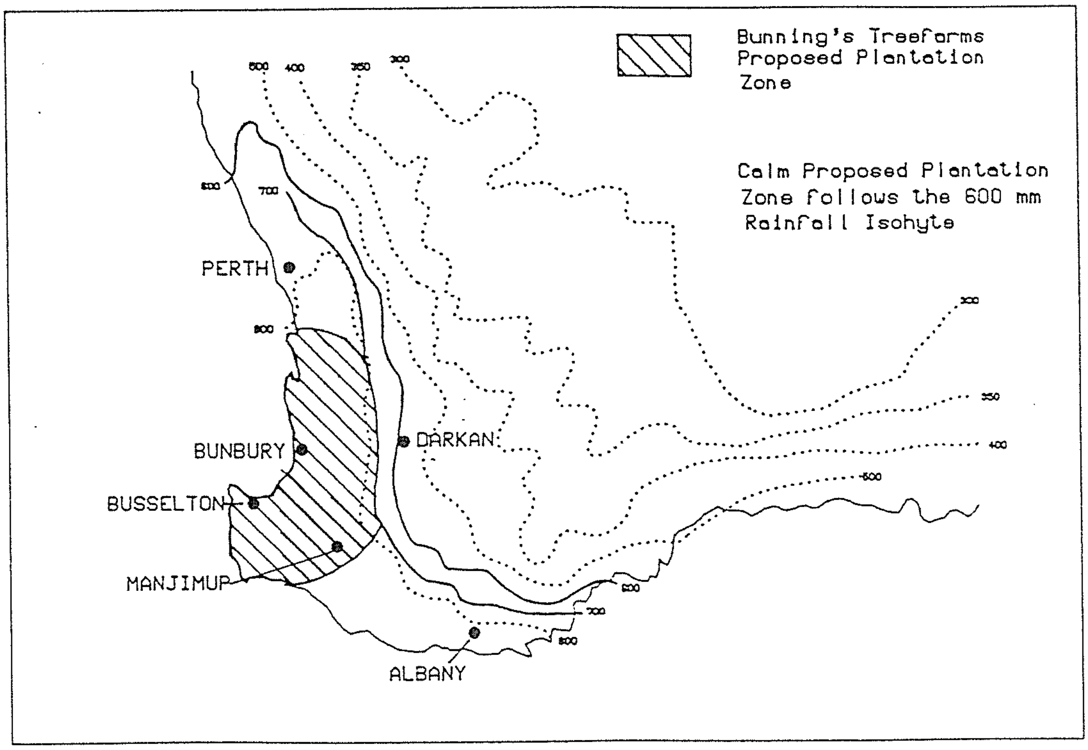
At the State level, Bunnings Treefarms plantation development is controlled by a number of Acts. The most notable is the 1989 Water Authority Act under which the Water Authority of Western Australia operates. Due to the problem of salting, there are controls over clearing in an attempt to maintain the status of the water table. The Authority allow the removal of vegetation cover within certain areas, but only if a tree plantation cover is to be established.

Plantation development can be restricted at the Local Government level by interpretation of both State and Local Government laws. An example, is fire break widths. Plantations of greater than 50 hectares require only a 15 metre fire break next to main roads. In some Shires a 25 metre firebreak is required, regardless of plantation size. They are both interpretations of the Bushfires Act of 1954 which requires a minimum firebreak of 15 meters, with the actual size requirements at the discretion of the Shire.

5.3.3: THE DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

The Western Australian Government's Department of Conservation and Land Management (CALM) with three statutory controlling bodies, was established under the Conservation and Land Management Act 1984. The controlling bodies are the Lands and Forests Commission, the National Parks and Nature Conservation Authority and the Forest Production Council. All are responsible to the Minister for Conservation and Land Management (CALM (1989A)). The functions of each of the controlling bodies can is presented in CALM (1989A).

MAP 5.1: WESTERN AUSTRALIA'S POTENTIAL EUCALYPT PLANTATION ZONES AS DEFINED BY BUNNINGS TREEFARMS AND CALM



Under legislation, pine and eucalypt plantations are only established on ex-pasture or as second rotation crops on previous plantation sites. Therefore in 1990 CALM launched a timber belt sharefarming project, to compliment the Tree Trust Scheme. Both are aimed at developing on private freehold land, a Government grown eucalypt plantation resource. Map 5.1 shows the area specified as suitable by the CALM project. It was stated by CALM (CALM (1989B)) that the aim is to plant 100 million trees. At stocking rates of 1428 to 1667 stems per hectare 60,000 to 70,000 hectares are to be planted. They are subject to the same controls on landuse as Bunnings Treefarms.

5.4: FRANCE

5.4.1: AFOCEL

France, as a member of the EEC, will be bound by the quota system for all produce, as part of the changes to take place in 1992.

Further expansion of the implications of 1992 are discussed in the section dealing with Portugal.

Association Foret - Cellulose (AFOCEL) was founded in 1962 by the Federation of pulp and paper manufacturers to promote intensive silviculture and forest production. The main function of AFOCEL is research. Most of their eucalypt operations are on private property located within 100 kilometres of the Cellulose du Rhone et d'aquitaine (CDRA) pulpmill located at St. Gauden in the lowlands at the base of the Pyrenees Mountains. The aim is to establish 15,000 hectares of plantations. In order to be accepted into the scheme a minimum of five hectares must be made available. The Government covers 50% of establishment costs with the pulpmill acting as a guaranteed market with royalties at an indexed rate. By 1982, 1200 hectares had been established but an intense frost of 1985 all but wiped out every plantation. Their programme has recommenced, but at an understandably cautious rate. Planting is on degraded oak forests and farmland sites. As well, CDRA purchases some freehold land for plantation establishment.

5.4.2: CTFT

The Centre Technique Forestier Tropical (CTFT) is based in Paris and is the forestry arm of Centre de Co-operation Internationale en Research Agronomique pour le Developement (CIRAD). The function of CIRAD is to carry out research and assistance programmes in a wide range of developing countries. CIRAD developed from the Institute Colonial which carried out similar programmes in French colonial territories. CIRAD commenced in 1950, and in 1968 expanded to include forestry programmes with the formation of CTFT. Establishment and management are of interest, especially for tropical indigenous and introduced plantation species development.

The role of the CTFT is well documented by Delwaulle (1978) and Martin (1987) who described their work with clonal techniques. The Pointe Noire Project (stage one) was based on degraded agricultural land (savannah) and was completed in 12 years, planting 25,000 hectares. Due to the success of stage one and the requirement of 400,000 cubic metres/year input for a proposed pulpmill, stage two is planned to result in a total estate of 50,000 ha. This is to involve planting 3000 hectares per year on virgin dry savannah with a heavier tree and scrub component than the areas of stage One.

5.4.3: ENGREF

The Ecole Nationale Du Genie Rural, Des Eaux et De Forets (ENGREF) is the French National School of Rural Engineering, Water and Forests. It was formed in 1965 by the combination of the Rural Engineering School (established 1919) and the Water and Forests School (established 1825) and is located at Nancy.

A range of undergraduate and graduate courses are offered. Several research projects involving eucalypts in association with other organisations, include work in the Congo and investigations into salt tolerant eucalypts for afforestation work in Israel.

5.5: PORTUGAL

Plantation development in Portugal is regulated by the Government. Due to rapid expansions of eucalypt plantings, conservation groups saw the need to control and restrict such development. The primary form of the restriction is through the requirement for a planting permit issued by the State Forest Service. The main reason given for the need to regulate eucalypt plantings is the potential fire risk they present to local communities. But another reason, would be a general dislike of eucalypts by the (countries) conservation movement.

Portugal has been divided into zones where eucalypt plantations are acceptable. Within the acceptable zones only 60 percent of a given property can be planted. The choice of which 60 percent to plant is also regulated based on soil type. Portugal has five broad classes of soil. Classes A and B are the most fertile and therefore must remain under agriculture. As a result, when a company purchases a property, it is conditional upon the planting permit that olive and cork oak groves be retained. Generally if any vineyards are present they are retained as productive venture (adopting the Company label). Pinus pinasta Ait is regarded as an indigenous species and is also afforded protection. The overall result is that watercourses and patches of the species mentioned remain unplanted to eucalypts.

In 1992 as EEC adopts new trade and financial arrangements, a rationalization is to take place to eliminate agricultural surpluses and reduce overall imports (presently the EEC imports over 180 million cubic meters of forest products, Wilson (1989)). Portugal may be forced to modify landuse policy to reduce agriculture products and concentrate on forest products.

5.5.1: ALHERS LINDLEY LDA

ALHERS LINDLEY LDA is a family based merchant company. Approximately 12 months ago Alhers Lindley Lda formed a forestry division, to market NORCAR (a 70 percent Finnish group) forestry machinery. As part of their venture into forestry, they have prepared a detailed market appraisal of the Portuguese forest industries (mainly eucalypt plantation based industries).

5.5.2: CELBI

Celulose Beira Industrial, S.A. (CELBI), is controlled by IPE (Investimentos e Participacao do Estado, S.A.) organisation and the Swedish STORA group with the shareholding in capital stock divided 29% and 71% respectively. STORA is a 700 year old forestry and forest products company. Generally they have remained a forestry company, but participate at all stages of forest products production. STORA has some interests in Aracruz (Brazil). CELBI's first factory was built at Figuera da Foz for rayon production. In 1965 it was modified to a sulphate pulpmill to produce wood pulp for paper production.

CELBI's research programme centres around the "D95" project, with an aim to produce planting stock by 1995 (95) which will have the potential to double (D) the pulp produced per hectare per year. Four main areas of work constitute the project; hybridization, macropropagation, micropropagation and field trials. CELBI also has trials into site preparation and management as they realise that genetic gains can only be fully expressed under the best potential growing conditions.

At present they have 75,000 hectares of land with 60,000 hectares under eucalypt plantations. In order to allow further expansions, freehold land is currently being purchased (but within the guidelines of the stated controls)

5.5.3: EMPORSIL

Sociedade Portuguesa de Celulose, S.A. (SOPORCEL) produces high quality pulp and is owned by the Wiggins Teape Group Limited. Soporcel's forestry division, Empresa Portuguesa de Silvicultura Lda (EMPORSIL) commenced operations in 1985. The function of EMPORSIL is to purchase land for eucalypt plantation development and to manage plantations for wood production.

In 1986 SOPORCEL took the first steps towards the commencement of a research and development programme to improve plantation productivity. A series of complimentary research programmes were developed to increase both the quantity and quality of pulp yield. Their research programme is separated into the following topics; Tree Improvement, Establishment, Forest Protection, Physiology and Pulp Quality and Environmental Valorization. Presently EMPORSIL has 10,000 hectares of plantations, which they are rapidly expanding to meet the needs of SOPORCEL. All purchases are subject to the controls discussed above.

5.5.4: PORTUCEL

After the 1974 revolution, Empresa de Celulose e Papel de Portugal E.P. (Portucel) was formed by the fusion of five private pulp companies. It is regarded as the oldest pulp and paper company in Portugal with 80000 hectares of plantations. Portucel is currently purchasing freehold land to expand their plantation estate. Land purchase has been made difficult by conservation groups and Government regulation.

5.6: SOUTH AFRICA

Large areas of South Africa have been put under eucalypt plantations. In order to control such development, a planting permit must be sought from the Department of Environmental Affairs. Its main aim is to control the percentage of plantation within individual river catchments. Permits are issued on the condition that no more than 75 percent of a given property be put under plantations. As it is on a catchment basis, and combined with previous plantings, not all properties would be available for plantation development. A permit to plant a property can either be applied for by the owner prior to sale or by the potential purchaser.

It is of interest, that once a permit is granted a property's value increases. To limit the degree of speculation in plantation land, permits are only valid for 5 years, after which time an application for an extension is required. If there has been no progress towards plantation establishment, no extension will be given. Only one extension will be given after which the permit lapses and a new application has to be submitted.

It is illegal to clear native forest for plantation pursuits.

5.6.1: THE DEPARTMENT OF ENVIRONMENTAL AFFAIRS

The Department of Environment Affairs has under its control, all State Forests in South Africa. Only the J.D.M. Keet Forestry Research Station at Politsi in the northern Transvaal was visited. As such there was limited discussion of their land base for plantation development and the control under which they act. It can be assumed that the Department operates within the bounds stipulated for private company operations.

It was stated that the Government plans to privatise the research aspects of the Department, including the eventual sale of it's seed orchards. The plantation estates of the Department may follow.

5.6.2: HANS MERENSKY HOLDING (PTY) LTD

Dr. Hans Merensky was a renowned South African prospector, geologist and a devotee of nature, afforestation and agriculture. In a career of close on 50 years, Dr. Merensky discoveries included platinum, diamonds, chrome, gold and phosphate ores. It is stated that "In return, through his conservation work, he ploughed back into the soil a wealth of scientific knowledge" (Anon (1986)). Prior to his death, Dr. Merensky created the Foundation that bears his name.

The Foundations sawmilling enterprise is rapidly expanding. As such, technical staff have been able to convert softwood sawmilling equipment to cater for eucalypts. At present 230,000 cubic metres of eucalypt sawlogs are cut in three sawmills. The operations visited at Tzaneen operate on 5200 hectares of land and produce 85,000 cubic metres of sawlogs per annum. Dr. Merensky, through his interest in conservation did not only retain, but maintained and expanded native vegetation areas by the replanting of badly degraded agricultural land on slopes considered too steep for plantations.

5.6.3: H.L. and H. MINING TIMBER

Hunt, Lechers and Hepburn Mining Timbers (H.L. and H. Mining Timbers) is a division of H.L. and H. Timber Products. It's role is to grow, harvest, process and distribute timber to the mining industry. The Mining Timber Division was established in 1893, whereas the parent company commenced in the 1850's as a family Company. Controlling interests in the company rest equally with two of South Africa's largest organizations; Rembrandt and the Anglo American Corporation.

A vast infrastructure of plantations has been developed across South Africa. The Company owns or leases approximately 138,000 hectares of plantàble land; spreading from the Natal Midlands, Swaziland and into the north eastern Transvaal. H.L. and H. has 16 mills, producing mining timbers which are distributed to the gold and platinum mining areas of the Transvaal and Orange Free State. Annually, 1 million tonnes of mining timbers are supplied. As mining timbers are size specific, residues are utilized in the pulp, paper and fibre board industries.

As a tactic to increase their landbase, HL and H purchases existing plantations from smaller private growers. This ensures that all Government requirements are met. Any new freehold land would have to comply with Government requirements.

5.6.4: INSTITUTE FOR COMMERCIAL FORESTRY RESEARCH

The Institute for Commercial Forestry Research (ICFR) evolved on September 13, 1984 from the Wattle Research Institute (WRI). The WRI commenced operations in 1946 in response to the need for research into tan bark production from exotic acacia species.

The ICFR is presently the only privately funded forestry research institute in South Africa. Funding, is in part, via levies on the sale of timber and partly through direct contributions from timber producing companies and other forest industry organisations. Allocation of funding percentage to the ICFR is based on companies area of plantation. Therefore, as 80% of South Africa's plantation area is owned by 3 companies, they are the main beneficiaries of the ICFR activities and therefore they are the main sources of funds.

The research undertaken by the ICFR concentrates on all phases of plantation silviculture and is conducted in close collaboration with the various timber companies. Research priorities are based on recommendations from the ICFR Board of Control, the Research Advisory Committee of the South African Forestry Council and the Sectional Research Advisory Committees for each section of the ICFR. Therefore, through the above mechanism and the active participation of the Technology Transfer Support Group of the ICFR, research activities are kept relevant for both present and anticipated problems in South Africa's Forest Industries.

It must be noted that although the ICFR deals in both silvicultural and genetic research, individual companies have their own genetic improvement programme for strategic gains specific to individual companies requirements.

5.6.5: MONDI FORESTS

Mondi Forests is the Forestry Division of Mondi Paper Company Limited. It commenced operations as part of Mondi Timbers. Mondi Timbers was originally Acme Timber which commenced operations in 1918 in a tin shed located in Durban. Their first products were wooden boxes manufactured from second hand car cases and a small quantity of imported wood. The Company undertook several changes of name and ownership. Ownership eventually passed to the Anglo Industrial Corporation and thereafter as part of a rationalisation process to Mondi in 1979. Mondi Timber was taken as the Company name in 1982. Three years later, Mondi Timbers sawmilling and forestry operations were changed to two separate divisions; Mondi Forests and Mondi Timber Products.

Mondi Forests now has 340,000 hectares of plantations extending through the Eastern Transvaal, Zululand, Natal and the North East Cape. With such an extensive landbase Mondi complies with the Government requirements and are currently expanding their operations into the North East Cape with the purchase of 81,000 hectares of pasture and the creation of a new company North East Cape Forests (SAF (1990)). Within the Zululand area they are replacing excess sugar cane sites with eucalypts. The main area of replacement is ex- St. Lucia Sugar Co. properties. The extent of the replacement is subject to the 75% maximum planting requirement.

5.6.6: NTE LIMITED

Natal Tanning Extracts Limited (NTE Limited) is a sister company of Mondi Forests and has recently moved toward a more complete merger in terms of management and company policy. NTE Limited commenced operations to produce bark for tannin extraction. Their original plantations were primarily acacias (they still have an acacia plantation estate). Presently they supply two thirds of South Africa's wattle bark extracts. As well, the company has an extensive sugar cane estate which is in part being converted to eucalypt plantations. Presently NTE Limited has 75,000 to 80,000 hectares of plantations; eucalypt, acacia and pine extending from the south eastern Transvaal through to Natal. However, with the purchase of 81,000 hectares in the North East Cape by Mondi, NTE Limited will play a leading role in the establishment of eucalypt plantations through assistance to North East Cape Forests (SAF (1990)).

NTE Limited has continued with sugar cane ventures, but is reducing the area under crop to allow plantation expansion. The area not to be planted also contain a series of native flora reservations.

Although originally for tan bark production, the wood of acacias is now used in pulp and paper making. All eucalypts grown are for pulp and paper production by Mondi Paper Company Limited.

5.6.7: SAPPI FORESTS

SAPPI Forests is the forestry division of the SAPPI Group of companies. Presently the SAPPI Group consists of six pulp and paper mills producing pulp, dissolving pulp, kraft liner boards, tissues and fine paper. The original SAPPI pulp and paper production utilized straw as a raw material. SAPPI Forests role is to supply wood for a wide range of manufacturing industries producing reconstituted wood fibre products; ranging from pulp and paper through to laminate fibre boards. SAPPI first purchased forests in 1954 and has continued to expand plantation estates in the Transvaal, Natal, Zululand and Swaziland. Presently SAPPI has a plantation estate of 260,000 hectares consisting of 113,000 hectares of softwoods and 105,000 hectares of eucalypts.

Present expansions are into the Highveld areas of the Eastern Transvaal. Such areas are degraded due to continued grazing and frequent burning. Within their conservation areas, Sappi is undertaking to remove noxious weeds and re-establish native tree species.

5.7: UNITED KINGDOM

5.7.1: OXFORD FORESTRY INSTITUTE

The Oxford Forestry Institute (OFI) is part of Oxford University, Department of plant Sciences. It has a long history of training undergraduate as well as graduate students. Research work is also undertaken by departmental as well as visiting scientists. The OFI has the most complete forestry library in the Western World and it was used to access eucalypt references on a range of topics.

5.7.2: THE WIGGINS TEAPE GROUP LIMITED

The Wiggins Teape Group Limited is one of the largest producers of pulp and paper products in the world. It is a multinational company based in England. There Forestry Group has controlling interests in SOPORCEL of Portugal. As such they have a policy and directional input into SOPORCEL'S operations.

5.8: DISCUSSION

As eucalypt plantations expand, concerns over the two main issues of displacement of agriculture and conservation value decline follow in varying degrees of intensity. Following such concerns, controls have been placed over eucalypt plantation development.

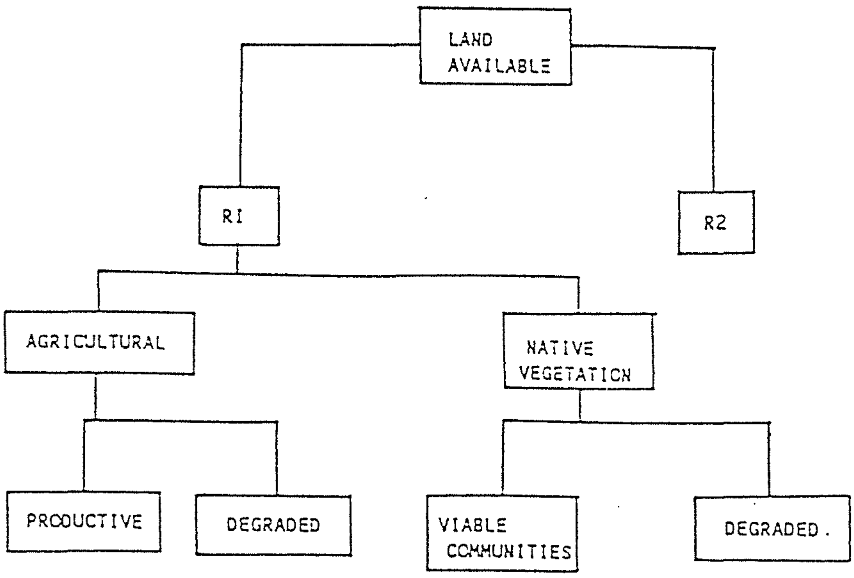
Compared with main stream agriculture pursuits, eucalypt plantations are a longterm crop with high visual impact. Plantations in agricultural areas maybe regarded as an inappropriate landuse and a threat to agriculture. Issues such as fire, vermin and noxious weed control are all raised in attack of plantations. In overseas countries conflict with eucalypt plantations is taken to the extreme of suspected arson. During the Portuguese revolution eucalypts became a political symbol and were referred to as the "fascist tree" (Wilson (1989)). As a measure of defiance arson became common and continues today. One solution in an attempt to reduce conflicts, was to zone for plantation development in areas not of prime agricultural land.

In the South African situation with a requirement to leave 25 percent of each water catchment without plantation cover, native vegetation can be conserved as required. Eucalypt plantations have long been accused of drying catchments. Water consumption by plantations is under study. FAO (1988c) found that trees in general require more water than grass lands and annual crops.

Location control for plantation development is an option, however "suitable areas" need to be defined. Figure 5.1 presents a breakdown of the land available for plantation development. Conditions that determine the suitability to plantation development can be defined and potential projected using modelling. In Australia, if zoning for plantation forestry is to be more formally adopted, it is essential that plantation development be recognised as a legitimate landuse. Input from experienced practitioners, as well as research would be required to ensure a realistic definition of suitability.

In terms of conservation, replacement of agriculture by a tree cover would be highly desirable on some sites to combat our most serious conservation issue, soil degradation and erosion. The option of an integrated approach with trees on farms must be viewed with caution, as such a broad distribution on small woodlots potentially is not a secure resource for industry. As woodlots develop their aesthetic and the protection properties may create a reluctance to clearfall (thinnings would be more likely but again not assured). The degree of reluctance to clearfall would depend on the individual landowner. This would be more the case where native species rather than exotic conifers are planted. The above is not to say that trees should not be planted on farms, but rather that it potentially would not be secure industrial resource base.

FIGURE 5.1: PLANTATION LANDBASE OPTIONS



R1 - First Rotation

R2 - Second Rotation

6.0: SOIL SURVEY INFORMATION

6.1: SUMMARY

In order to make the best possible decision regarding land use, detailed and specific soil surveys are required. In the absence of such information it is only logical to take account of what information is available and apply educated judgement. If regulation of plantation development is to occur, knowledge of the requirements for plantation development must be obtained and incorporated into any specifications.

As computer based geographic information system (GIS) packages increase in use, it is desirable that uniform soil data codes be used to allow system interaction. This is of particular importance for Government departments.

6.2: INTRODUCTION

The most basic requirement of any plantation programme is a suitable land base, with quality and quantity both desirable but not necessarily available. Presently, plantation development is moving away from traditional areas to satisfy the demand for quantity, resulting a compromise on site quality. In order to optimise the decision making process, greater site detail is required.

Individual countries soil type characteristics have been detailed by FAO/UNESCO (1977). Such information is on a very broad scale and is only of general interest in decision making. In order to make specific, rather than strategic decisions, detailed individual property soil data is required. The following presents information on the various soil survey techniques encountered.

6.3: AUSTRALIA

Mapping of Australian soils was carried out by Northcote (1978) and resulted in a 1:5 000 000 scale map. Northcote (1979) presents a detailed key for the recognition of Australian soils. Subsequently, soil maps of individual states have been produced by various State authorities.

6.3.1: APM FORESTS PTY. LTD.

A soil survey of APM Forests Pty. Ltd. estate was carried out in the late 1970's and early 1980's. The main objective was to provide a basis for classification of tree growth and responses to intensive silvicultural regimes. Details of the survey were presented in Turvey and Poutsma (1980). A complete map system was prepared at 1:10 000 scale. Within the last 12 months, all soils information has been digitized onto a G.I.S. system. Therefore in planning all plantation related operations, soil type information is available.

6.3.2: BUNNINGS TREEFARMS

Bunnings Treefarms does not have a formalised soil survey system, but relies on both large scale State soil maps and visual evaluations. Visual evaluations are a combination of ground inspection and analysis of aerial photographs. Generally they recognise the basic soil types of clay loams, lateritic and grey sands. In some instances existing tree cover or remnant trees are used to indicate soils and therefore site potential.

6.3.3: DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

Through a long history of softwood plantation development, CALM has a solid background in soil surveying. Their techniques were refined to carry out soil surveys for softwood sharefarming. A 100 metre square grid system is used to complete a soil mosaic map.

6.4: PORTUGAL

6.4.1: CELBI

CELBI aims to fill increased demands for eucalypt wood by increasing the production from each hectare. In order to achieve the planned increases, site classification systems are under development and will include soil surveys.

6.4.2: EMPORSIL

Presently EMPORSIL is undertaking to increase their knowledge of site requirements. As a result they are working towards a growth model based on site characteristics. As part of their research effort they have developed a 1:50 000 scale map of the soils of their plantation regions. Further surveys are done of individual properties to a scale of 1:5000, from which they are able to divide properties into productive units.

6.5: SOUTH AFRICA

In South Africa the importance of soil type is well appreciated and forms an integral part of all aspects of eucalypt management. There has been a great deal of work done on soils, primarily as a result of the significance of agriculture and mining. The need for an easily utilized soil identification system resulted in the Department of Agricultural Technical Services developing a handbook of South African soils (Macvicar et al (1988)).

6.5.1: HANS MERENSKY HOLDINGS PTY. LTD.

Recognition of the different soil types and potential is based on Macvicar et al (1988). There was no reference made to a formalised Company soil survey technique.

6.5.2: HL AND H MINING TIMBERS

As a complement to their tree improvement programme, HL and H Mining Timbers are endeavouring to match clones to sites.

Therefore, they are aiming to classify sites based on characteristics such as soil type. Detailed site descriptions for all trial and routine plantings of individual clones are carried out, in an attempt to define site class.

6.5.3: ICFR

In all trials, a soil survey is completed and presented in any publications, to achieve the objective of matching silvicultural prescriptions to soil type.

6.5.4: MONDI

Mondi Forests has a comprehensive and integrated approach to soil surveying. Their overall aim was to design a system of landuse capability classes based on overall forestry objectives and then working back to design a soil survey technique. Two surveys were developed; a pilot survey for the evaluation of land for purchase and a full scale detailed survey technique.

Pilot soil surveys are completed by consultants sampling at 30 plots per 100 hectares, with plot location stratified based on landform units. The decision to purchase a property is based on the pilot survey. Routine soil surveys are completed once a property is purchased. Surveys are stratified based on information required to plan site preparation, species selection and harvesting.

Maps are currently prepared by hand, but they aim to utilize a computer ground inventory system (GIS) data base as soon as possible. Maps are used to assign compartment boundaries based on uniform soil productivity units. As well, they allow road location decisions and the joining of conservation areas by corridors making use of the poorer soil types. Presently trial sites are surveyed based on 30 metre square grid. Once the GIS is up and running, all trial sites will be linked to the soils data base to allow data cross referencing.

6.5.5: NTE LIMITED

Prior to the complete annexing by Mondi Forests, NTE Limited had developed their own soil survey system. Now with Mondi Forests they are attempting to make matching systems. Their existing system cannot be converted to Mondi Forest's system due to incomplete data.

6.5.6: SAPPI FORESTS

Sappi Forests currently surveys on a 150 metre square grid. Soil survey information is used to determine establishment techniques.

6.6: DISCUSSION

As plantations are forced into new locations, greater detail soil information is required. The development and introduction of clonal material overseas requires clone / site matching and the optimisation of site preparation techniques.

In Australia, if a more formal zoning system for plantation development is desired, greater emphasis on soil surveys will be required. In order that site data is to be of greatest use, a uniform classification system is required. Based on the South African experience, unless uniform data bases are created, there will be limited opportunity for information transfer. As GIS packages become more common, the aim should be to maximise the potential for information transfer.

Within and between Government authorities it will be essential to maintain uniformity of soil classification. In Australia, there exists a large amount of information regarding soils in relation to agriculture and conifer plantation development. In the absence of eucalypt specific data, such information should not be over looked. It could be used as a starting point for site classification system. Follow up research into the specific requirements for eucalypts must be undertaken. Such work would best be done in conjunction with soil scientists.

The intensity of sampling and the exact methodology will be very much a function of the local situation. The degree of inherent variation, will influence the sample size in order to maintain statistical significance and practical reliability. In all cases any soils maps produced can only be regarded as a guide, with onsite inspections to confirm map detail prior to the commencement of operations.

7.0: PLANTATION SPECIES

7.1: SUMMARY

If a plantation programme is to be successful, the best genetic material must be available to match the conditions of site and the desired end use. This becomes more critical as plantations are pushed into areas that are not presently planted to eucalypts. Experience overseas has shown the need for extensive species and provenance trials in both traditional and non - traditional areas. Based on trial results, management can best decide which species to plant and in which areas to purchase land. A greater diversity of acceptable species, gives more flexibility to management.

Many guides to species selection are available and combined with common sense can be used to screen species for inclusion in trials. The inclusion of "wild card" species can not be discounted. The development of artificial hybrids should only follow once the best species and provenances are identified.

7.2: INTRODUCTION

The genus eucalyptus is divided into a number of sub-genera (under the Pryor and Johnson (1971) classification system). The following gives details of the species currently used in commercial plantations. In some cases, hybrids are being planted. Where available parental species will be presented. Provenance information was often lacking, due to the formation of local genetically distinct populations (land races).

7.3: AUSTRALIA

7.3.1: APM FORESTS PTY. LTD.

SPECIES: Eucalyptus regnans F.Muell.; Mountain Ash (Ex Seed Orchard)

Generally E.regnans is planted on sheltered frost free sites, with high quality soils and rainfall greater than 900 millimetres. Such sites are usually, above 400 meters in elevation. Species natural occurrence is used as guide to species selection.

SPECIES: E.nitens (Dean and Maiden) Maiden; Shining Gum (Ex Seed Orchard)

E.nitens is planted on sites similar to E.regnans, but with greater exposure and the chance of frost.

SPECIES: E.globulus Labill subsp. globulus; Tasmanian Blue Gum (Wild seed, Jeeralang Provenance)

E.globulus subsp. globulus is planted on drier sites. Generally it is planted on the poorer soils with an annual rainfall between 700 to 900 millimetres. In steeper areas where full site preparation proves impossible, E.globulus subsp. globulus is planted as it is able to compete with woody weeds.

Comprehensive species trials to find alternative species/provenances, are underway with replications based on soil type. Trials established in 1987 include 35 eucalypt species composed of 90 provenances. The aim is to maximise flexibility across a range of sites.

7.3.2: BUNNINGS TREEFARMS

SPECIES: E.globulus Labill subsp. globulus; Tasmanian Blue Gum

The preferred provenance is King Island (Tas), but seed is often in short supply and they have to use whatever is available.

SITE: Areas suited to E.globulus subsp. globulus are defined by Bunnings Treefarms as down to the 700 millimetre long term rainfall isohyte (Map 5.1). Grey sands or widespread water logged sites are avoided if possible. Both pasture and ex-bush sites are utilized.

7.3.3: DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

SPECIES: E.globulus Labill subsp. globulus; Tasmanian Blue Gum

In the absence of seed orchard seed, CALM is in a similar situation to Bunnings Treefarms.

SITE: The development of E.globulus subsp. globulus plantations by CALM is within areas down to the 600 millimetre long term rainfall isohyte (Map 5.1). All soil types are considered but production variations are well noted. Only pasture sites are established.

Other species; E.botryoides Smith, E.brookerana A.M.Gray, E.globulus Labill subsp. bicostata, E.saligna Smith and E.viminalis Labill are under investigation. Included in trials is the naturally occurring hybrid of E.botryoides x E.saligna.

7.4: THE PEOPLES REPUBLIC OF THE CONGO

SPECIES: "12ABL"; 12ABL is a clone of E.tereticornis Smith that was introduced from Madagascar. (A local land race hybrid).

SPECIES: "PF1" is believed to be a hybrid between E.alba Reinw. ex Blume x E.urophylla. S.T. Blake. (It was introduced from Java and is considered as a land race).

12ABL and PF1 are planted on uniform coastal plains with a rainfall of 1200 to 1600 millimetres per year. Other species planted include E.alba (which is not successful as a pure species) and E.urophylla.

7.5: FRANCE

7.5.1: AFOCEL

SPECIES: E.gunnii Hook.f.; Alpine Cider Gum (Three provenances from the Great Lakes area of Tasmania are preferred; Projection Bluff, Breona and Shannon).

E.gunnii is planted out within the minimum frost zone of Southern France. 40 other species and hybrids with E.gunnii have been tested but were proven unsuitable by the 1985 frost.

7.6: PORTUGAL

Due to an early introduction of E.globulus subsp. globulus, the original provenance detail is unknown. It is now considered to be a land race.

7.6.1: CELBI

SPECIES: E.globulus Labill subsp. globulus; Tasmanian Blue Gum (All seed is either from seed orchards or plantation collections).

CELBI currently plants E.globulus subsp. globulus on sites typified by poor soils and a strong mediterranean climate. In order to establish plantations in more "non traditional" areas, artificial hybrids are currently under development by CELBI. In all cases the maternal genes are E.globulus subsp. globulus. For areas prone to drought conditions the paternal gene origin is E.camaldulensis Dehnh. As temperature decreases in the absence of frost, paternal genes are from E.viminalis. For areas prone to frost, E.gunnii becomes the source of paternal genes.

7.6.2: EMPORSIL

SPECIES: E.globulus Labill subsp. globulus; Tasmanian Blue Gum

(All seed is either from seed orchards or plantation origins).

EMPORSIL has planted out full provenance collections of E.globulus subsp. globulus using seed from the 1987 and 1988 CSIRO collections (see Gardiner and Crawford (1987) and Gardiner and Crawford (1988)). Their aim is to find suitable provenances for drier sites. Similar sites to CELBI are planted with E.globulus subsp. globulus.

Other species are under investigation for plantation establishment on more marginal sites. In areas prone to drought E.camaldulensis is the preferred species. If an area is prone to frost, the species options are E.dalrympleana Maiden, E.nitens, E.smithii R.Baker and E.viminalis.

7.6.3: PORTUCEL

SPECIES: E.globulus Labill subsp. globulus; Tasmanian Blue Gum

(Trials with Australian seedlots have made PORTUCEL confident that the local landrace is the best E.globulus subsp. globulus material).

Similar sites to the two previous companies are planted to

E.globulus subsp. globulus. A hybrid between E.globulus subsp. globulus and E.camaldulensis is being developed for planting in more dry areas. E.viminalis is currently under investigation as a possible species for frost sites.

7.7: SOUTH AFRICA

In several cases where capsules from plantations of E.grandis Hill Ex Maiden were examined, they appeared not to be a pure E.grandis. In some instances, valve structure appeared to be more like E.saligna. In only a number of plantations did the capsules appear to be pure E.grandis; for example those of the Langapan CCT trial in Zululand.

Again due to tree breeding and the early introduction of the species to South Africa, the original provenance detail has been lost. It has been suggested that a great deal of the early seed was from Coffs Harbour (NSW).

7.7.1: THE DEPARTMENT OF ENVIRONMENTAL AFFAIRS

The J.D.M. Keet Forestry Research Station has the main seed orchard producing E.grandis seed. They have also produced a range of hybrids which form the basis of a number of the countries hybrid programmes.

7.7.2: HANS MERENSKY HOLDINGS (PTY.) LTD.

SPECIES: E.grandis Hill Ex Maiden; Flooded Gum

E.saligna Smith; Sydney Blue Gum (All seed used is from seed orchards).

For plantations established in Westfalia, both species are planted on sites of uniform high quality. Soils are fertile clay loams and the climate is sub-tropical. The current species mix of E.grandis and E.saligna is somewhat confused. Sawn timber produced by the company is marketed as "Saligna Gum". Currently they are searching for species with specific wood colour properties. They are interested in E.botryoides, E.resinifera Smith, the hybrids E.grandis x E.camaldulensis and E.botryoides x E.saligna.

7.7.3: HL AND H MINING TIMBERS

SPECIES: E.grandis Hill Ex Maiden; Flooded Gum (All seed used is from seed orchards).

A range of sites are established to E.grandis. Generally they have high fertility soils with rainfall greater than 850 millimetres per annum. In an attempt to maximise growth response, HL and H are developing (from the J.D.M. Keet Forestry Research Station material) clones suited to a range of sites. E.grandis x E.camaldulensis clones are for use in areas with rainfall less than 850 millimetres per annum. When planted on sites with more rainfall they cannot compete with pure E.grandis. It has been found that E.grandis x E.camaldulensis clone is prone to brittle top damage.

E.grandis x E.urophylla clones have been tested. The maternal E.grandis was from Atherton (Queensland) and the paternal E.urophylla was from Timor (the clone was supplied by Brazil). Presently they are up to a second selection with the above clone.

E.grandis x E.nitens has proven very promising for sites prone to frost. At age 2 they have recorded an average growth rate of 18 millimetres per day.

E.grandis x E.macarthurii Deane and Maiden clones have grown well, but are prone to the development of speed wobbles. Height growth rates at 10 months on high quality site at Whiteriver (Transvaal) are as much as 17 millimetres per day.

7.7.4: ICFR

The ICFR presently has 22 percent of it`s budget devoted to species selection research (ICFR (1989)) and state that the aim is; "to provide guidelines for the selection of commercial tree species by investigating the suitability of a wide range of tree species under a range of South African conditions". Both species and provenance trials are undertaken across a range of sites. As a strategic measure, they aim to provide a viable alternative to E.grandis. As well as alternatives, the need for species more suited to the non-traditional plantation areas is under investigation.

SPECIES: E.dunnii Maiden; Dunn`s White Gum

A range of provenances were established, including seed from South African sources. Initial results show that Australian provenances are doing best. They noted that E.grandis was completely destroyed by termites on one site and that it showed signs of water logging on another. E.dunnii appeared to be more prone to wind damage than the other species.

SPECIES: E.macarthurii Deane and Maiden; Camden Woollybutt

In 1985 the South African Mining Timber Manufacturers Association (SAMTMA) sponsored an expedition to Australia to collect seed of several cold tolerant eucalypt species presently grown commercially in South Africa. The objective was to broaden the genetic base to allow a realistic tree improvement programme. In the case of E.macarthurii, 87 seedlots were collected from individual trees to make up nine provenances. During 1987 and 1988 trials were established on a range of sites. As yet no results are available. E.macarthurii is considered of importance for the establishment of plantations on sites prone to frost and colder conditions as typified by the Highveld.

SPECIES: E.smithii R.Baker; Gully Gum

In conjunction with Sappi a series of E.smithii trials were established on contrasting sites in 1987 and repeated using the same seedlots in 1988 on additional sites in Natal. The aim was to identify provenances for sites ranging from frost prone through to a hot dry north facing slopes.

In association with Sappi in 1979, the ICFR established a species trial consisting of a total of 178 seedlots from 15 species replicated on three sites in Natal. E.camaldulensis, E.melliodora Cunn.ex Schauer and E.globulus subsp. globulus all failed on the two sites affected by frost.

7.7.5: MONDI FORESTS

SPECIES: E.grandis Hill Ex Maiden; Flooded Gum (All seed used is from seed orchards. Clonal material is also routinely planted).

Sites suited to E.grandis are defined as those having more than 800 millimetres annual rainfall and it is planted through-out Mondi's landbase, even into areas of the Highveld. Mondi Forests regards the drier, rather than the frost zones as the most likely area for expansion and has a series of hybrids for dry conditions of the North East Cape region.

Provenance trials of E.camaldulensis have been established on drier and lower fertility sites in Zululand. The following hybrids are considered suited to areas with annual rainfall between 750 and 800 millimetres per annum; E.grandis x E.camaldulensis, E.grandis x E.tereticornis and E.grandis x E.urophylla.

By using hybrid clones, Mondi has been able to achieve some spectacular results on sites not suited to sugar cane in Zululand. One clone of E.grandis x E.camaldulensis has grown an average of 32.6 millimetres per day with a height of 11.8 metres in 12 months on a site with 750 millimetres per annum rainfall and poor Fernwood soil (which equate to humic greysols under the FAO system).

7.7.6: NTE LIMITED

SPECIES: E.grandis Hill Ex Maiden; Flooded Gum (All seed used is from seed orchards).

The majority of NTE LIMITED`s landbase is planted to E.grandis, but they are currently searching for species options for the Highveld around Peit Retief. They define an E.grandis site as an area with an average temperature of 16 degrees celsius and an average winter temperature of 11 degrees celsius. E.saligna is an option as it is known to cope with an average winter temperature of 8 degrees celsius.

E.macarthurii is of great interest. They have provenance trials which will be turned into seed orchards. At present it has poor pulping and debarking properties which they hope to amend through tree breeding/improvement and machinery development. E.smithii is under consideration for sites that receive approximately 850 millimetres rainfall per annum, as it is known to require less water. E.elata has shown very poor form and is only of marginal interest. E.nitens is of interest, but poor flowering poses management problems in regard to seed production. Supply of specific provenances of E.nitens is difficult due to restrictions to preserve those provenances presently under threat of destruction by over collection.

Two hybrids are of interest E.macarthurii x E.grandis for cooler sites and E.macarthurii x E.camaldulensis for drier sites.

7.7.7: SAPPI FORESTS

A range of species are planted by Sappi due to the diversity of the Company's landbase.

SPECIES: E.cloeziana F. Muell.; Gympie Messmate (No specific provenance was mentioned).

E.cloeziana is grown for poles, and is not considered suitable for planting above 1600 meters in altitude.

SPECIES: E.dunnii Maiden; Dunn`s White Gum (No specific provenance was mentioned).

E.dunnii is planted on good dry, but shallow soils were it will out perform E.grandis. If hit by a frost, loss of the apical tip results in the development of multi-stems.

SPECIES: E.elata Dehnh.; River Peppermint

E.macarthurii Deane and Maiden; Camden Woollybutt (No specific provenances were mentioned).

Both species have been tested as an option to E.grandis on colder frost prone sites, but they have poor stem form. It may be possible to improve stem form by changing silvicultural techniques. Corrective pruning is an option, but a higher initial stocking may force a more dominant apical tip. E.macarthurii performs well on very shallow soils.

SPECIES: E.fraxinoides Deane and Maiden; White Ash (No specific provenance was mentioned).

E.fraxinoides is considered as an option for mild frost sites as it is prone to slight frost burning of new shoots. It`s advantage is that it can easily be debarked all year round and has very good pulping properties.

SPECIES: E.grandis Hill Ex Maiden; Flooded Gum (All seed used is from seed orchards).

E.grandis is regarded as the standard species and is planted when ever possible.

SPECIES: E.nitens (Deane and Maiden) Maiden; Shining Gum

E.nitens seed is generally more difficult to obtain. There is a strong preference to N.S.W. provenances due to the disease susceptibility of juvenile foliage. Victorian provenances tend to retain juvenile foliage longer than those of N.S.W.

SPECIES: E.smithii R.Baker; Gully Gum (Northern provenances are reported to be the best).

On sites considered too cold for E.grandis in Natal and Piet Retief this species has been shown to perform well.

7.8: DISCUSSION

As shown most plantation programmes commence with a primary species, after which options for both traditional sites and new environments are explored, as their landbase expands. Therefore species and provenance trials across a range of site types are essential if the best decisions are to be made in regard to land purchase in both traditional and new plantation environments. Table 7.1 presents the location of the species mentioned, within the Prior and Johnson (1971) break down of the genus.

Table 7.2 presents primary species selection based on rainfall type. It is interesting to note that the various species (as shown by table 7.1) fall within clusters of the Pryor and Johnson (1971) system. Table 7.3 present the various groupings.

Table 7.3, can be used as a guide to decide which species to include in any species trials. Other members of the various sub-groupings, based on the performance of the primary species, can be evaluated and selected based on the species natural habit (refer to Boland et al (1984)) and indications of performance in any plantings.

There is always the possibility that a "wild card" species may perform well. However, it may only be by chance that the potential of a "wild card" species is recognised. For example E.macarthurii has a very limited natural distribution (Boland et al (1984)) and is relatively obscure, but it has proven of great value overseas. Another species which has a very limited natural distribution (Boland et al (1984)) and has shown potential in Australia is E.oreades R.Baker. It must be noted at this stage that other non site factors such as disease and insects, can and will influence species selection.

The importance of provenance in terms of species selection is well known, although it is only a relatively new concept. It has been the answer to several problems (such as disease) faced by species under specific site conditions.

TABLE 7.1: PRYOR AND JOHNSON (1971) BREAKDOWN OF THE GENUS EUCALYPTUS

CORYMBIA			
	OCHRARIA		
		MACULATAE	
			citriodora
IDIOGENES			
	GYMPIARIA		
		CLOEZIANAE	
			cloeziana
MONOCALYPTUS			
	RENANTHERIA		
		OBLIQUAE	
			regnans
			oreades
			fraxinoides
MONOCALYPTUS			
	RENANTHERIA		
		PIPERITAE	
			elata
SYMPHYOMYRTUS			
	TRANSVERSARIA		
		DIVERSICOLORES	
			diversicolor
SYMPHYOMYRTUS			
	TRANSVERSARIA		
		SALIGNAE	
			grandis
			saligna
			botryoides
SYMPHYOMYRTUS			
	EXSERTARIA		
		ALBAE	
			urophylla
			alba
SYMPHYOMYRTUS			
	EXSERTARIA		
		TERETICORNES	
			tereticornis
			camaldulensis
SYMPHYOMYRTUS			
	MAIDENARIA		
		OVATAE	
			brookerana
SYMPHYOMYRTUS			
	MAIDENARIA		
		VIMINALES	
			dunnii
			nitens
			globulus subsp. maidenii
			globulus subsp. pseudoglobulus
			globulus subsp. bicostata
			globulus subsp. globulus
			macarthurii
			smithii
			viminalis
			dalrympleana
			gunnii
SYMPHYOMYRTUS			
	ADNATARIA		
		MELLIODORAE	
			melliodora

TABLE 7.2: BREAKDOWN OF SPECIES SITE LOCATION BASED ON CLIMATE

WINTER RAINFALL MAXIMUM *E.globulus* subsp *globulus* TRADITIONAL SPECIES	ALTERNATIVE SPECIES FOR TRADITIONAL SITES	*E.botryoides* *E.brookerana* *E.diversicolor* *E.globulus* subsp *bicostata* *E.regnans* *E.saligna* *E.viminalis* *E.botryoides* X *E.saligna*
	DRIER SITES	*E.camaldulensis* *E.globulus* subsp *globulus* X *E.camaldulensis*
	COLDER SITES (LIGHT TO NO FROST)	*E.dalrympleana* *E.nitens* *E.regnans* *E.smithii* *E.viminalis* *E.globulus* subsp *globulus* X *E.viminalis*
	FROST SITES	*E.gunnii* *E.globulus* subsp *globulus* X *E.gunnii*

TABLE 7.2: CONT.

SUMMER RAINFALL <u>E.grandis</u> TRADITIONAL SITES	ALTERNATIVE SPECIES ON TRADITIONAL SITES	<u>E.botryoides</u> <u>E.cloeziana</u> <u>E.citriodora</u> <u>E.dunnii</u> <u>E.resinifera</u> <u>E.saligna</u> <u>E.botryoides</u> X <u>E.saligna</u>
	COLDER (LIGHT TO NO FROST)	<u>E.elata</u> <u>E.fraxinoides</u> <u>E.macarthurii</u> <u>E.nitens</u> <u>E.saligna</u> <u>E.smithii</u> <u>E.grandis</u> X <u>E.macarthurii</u> <u>E.grandis</u> X <u>E.nitens</u> <u>E.macarthurii</u> X <u>E.grandis</u>
	DRIER* SITES	<u>E.camaldulensis</u> <u>E.smithii</u> <u>E.grandis</u> X <u>E.camaldulensis</u> <u>E.grandis</u> X <u>E.tereticornis</u> <u>E.grandis</u> X <u>E.urophylla</u> <u>E.macarthurii</u> X <u>E.camaldulensis</u>

* DRIER SITES ARE DEFINED AS THOSE WITH BETWEEN 750 AND 800 MILLIMETRES RAINFALL PER ANNUM , WITH A DRY WINTER AND AS LOCATIONS MOVE SOUTH RAINFALL BECOME MORE UNIFORMLY DRY.

TROPICAL WITH A TWO MONTH DRY SEASON		<u>E.alba</u> <u>E.urophylla</u> <u>E.alba</u> X <u>E.urophylla</u> ("PF1") <u>E.tereticornis</u> X <u>E.saligna</u> ("12ABL")

TABLE 7.2: SPECIES CLUSTERING UNDER THE PRYOR AND JOHNSON (1971) CLASSIFICATION.

PRIMARY SPECIES: MONOCALYPTUS-RENANTHERIA-OBLIQUAE; E.regnans

SYMPHYOMYRTUS-TRANSVERSARIA-SALIGNAE; E.grandis

SYMPHYOMYRTUS-EXSERTARIA-ALBAE; E.urophylla

E.alba

SYMPHYOMYRTUS-MAIDENARIA-VIMINALES; E.globulus

subsp.globulus

OTHER SITES: DRIER; SYMPHYOMYRTUS-EXSERTARIA-TERETICORNES

COLDER/FROST; SYMPHYOMYRTUS-MAIDENARIA-VIMINALES

TROPICAL; SYMPHYOMYRTUS-EXSERTARIA-ALBAE

The development and uses of hybrids is well advanced and has followed the selection of the best species (and hopefully provenances). Again we see the use of educated guessing as to the best combinations within species limitations. In the Australian situation we must be cautious as to the progress down the path of artificial hybrids until we are certain we have the correct species and provenances. Before artificial hybrids are considered, natural hybrids within the overlap of the species should be considered. Experienced seed collectors and taxonomists would be required to identify and collect the seed of natural hybrids. The seed collected will have a hybrid maternal component and an unknown paternal contribution.

Not all desirable species combinations will be available, but the use of natural hybrids would be a method of reducing the time consuming and difficult work of creating artificial hybrids. Such work is particularly difficult in Australia due to the lack of seed orchards. In most cases the only option would be to control pollinate wild individuals which again would prove difficult and expensive.

8.0: SITE PRE-PREPARATION

8.1: SUMMARY

A degree of pre-preparation is necessary depending upon the previous landuse. The overall aim is to allow access for the next phases of establishment. The methods employed are dependant upon the previous landuse and the equipment available.

R1 sites are the most controlled by legislation. The clearing of native vegetation is a significant issue in most countries. R2 sites pose a range of specific problems which require specialised equipment. The option of residue burning is often taken, but maybe limited in the future as greater knowledge of the full effect on site quality develops.

Where ever possible chopper rolling is a desirable option. However due to time and the equipment required it may not be possible. If species with the ability to coppice have been planted, chopper rolling rather than the use of herbicide would be a more environmentally sensitive and cheaper management option.

8.2: INTRODUCTION

Prior to the commencement of any establishment operations, a site may require an initial clean up of debris. The form and extent of the debris will be a function of the previous landuse. Detail of site types being put under plantations was presented in section 5. It is the aim of the following section to present pre-preparation techniques for plantation establishment as used by the organisations visited.

8.3: AUSTRALIA

8.3.1: APM FORESTS PTY. LTD.

On ex-agricultural land any derelict buildings are heaped and burnt. Where a scrub layer has developed, it is bladed off using 200 horsepower bulldozers. Any healthy trees remaining from the original farm, are kept to enhance the landscape and to act as habitat for native faunal species. Sheep are used to reduce pasture to a minimal level and in some cases goats have been used to remove thick Rubus fruticosus (blackberry) infestations. A variable proportion of establishment activities are on R2 sites that previously grew P.radiata. It has been shown by research that maximum site productivity can be achieved by retaining any harvesting residues. Slash is incorporated into the soil by chopper rolling. An initial chopper rolling is carried out for fire protection purposes and left to fallow. A second chopper rolling completes the break down of harvesting residues. The end result is an enhanced soil organic content.

8.3.2: BUNNINGS TREEFARMS

Bunnings Treefarms are only concerned with R1 sites. Ex-agricultural lands are treated as by APM Forests Pty. Ltd. except for the removal of paddock trees either commercially or by heaping up and burning. Grazing continues up to the application of herbicides.

Any forest blocks are harvested, and any residual trees pushed over, root raked (to 0.3 metres depth) into windrows and burnt. One windrow per hectare is usually created indicating the intensity of log recovery. The original technique of broadcast burning, followed by planting has been shown to be inadequate and resulted in the failure of earlier plantations.

8.3.3: DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

Only ex-pasture sites are established. Based on a comparison of nutrient status ex-bush sites were proven to be inferior to ex-pasture. Only very basic pre-preparation works are required.

8.4: THE PEOPLES REPUBLIC OF THE CONGO

Stage One of the Congo project was entirely on grass lands. Stage Two sites will require an initial clean up of the light scrub cover and any trees.

8.5: FRANCE

8.5.1: AFOCEL

Only R1 sites are established with any degrade oak forests removed to leave grasslands.

8.6: PORTUGAL

In Portugal, plantation management includes the use of a coppice rotation. Therefore in this section details will be presented of the operations undertaken when a coppice rotation is not undertaken.

8.6.1: CELBI

On R1 sites, debris is cleaned up which may hinder establishment. To establish a new R2 crop, CELBI may remove stumps using a bulldozer or modified excavator. Another option is to disc out the stumps using very heavy equipment. They have successfully tested a more simple approach of burying stumps using a plough.

8.6.2: EMPORSIL

Minimum pre preparation works are required as only R1 agricultural land is planted.

8.6.3: PORTUCEL

Very minimal pre-preparation works are carried out on R1 sites. R2 sites are deep ripped to remove stumps. One site visited had been previously burnt by wildfire and it was stated that burning of slash is generally not undertaken.

8.7: SOUTH AFRICA

As with Portugal, practices described are for areas not to be managed for a coppice rotation.

8.7.1: HANS MERENSKY HOLDINGS (PTY.) LTD.

At present only R2 sites are established. At clearfalling, stumps are killed by spraying with a mixture of diesel and triclopyr. Burning of the harvesting residues is only carried out if an inter-row peanut crop can be grown by the local villagers.

8.7.2: HL AND H MINING TIMBERS

R1 ex-pasture sites are converted to plantation with only minimal pre-preparation works. R2 sites are broadcast burnt.

8.7.3: ICFR

The ICFR has several projects underway to investigate methods of pre-preparation techniques. Firstly the question of de-stumping and secondly the effect of residue burning. Stump grinding at "the stump" has come under question due to the effect of the chips. In the long term chips would contribute to the organics of the site, but in the short term they become a nitrogen sink due to bacteria. Results are not available from trials into harvesting residue burning.

8.7.4: MONDI FORESTS

Some areas of R1 are planted each year. As the sites purchased are ex-agricultural lands, limited pre-preparation works are required. On R2 sites, all harvesting residues are burnt but on a reducing scale for fear of decreasing site productivity. Burning does kill the stumps to prevent competition with the next rotation. Any control burning is done during the dry winter months. R2 site stumps are retained, taking up to 10 years to decay. On one site visited there was estimated to be over 200 tonnes per hectare of stumps, as a result of seven coppice rotations since 1945. It was suggested that they may be harvested for charcoal. Due to residue burning, all had surface charcoal, prohibiting use by the pulp and paper industry.

Concerns were expressed that mechanical removal of stumps may cause serious compaction; both sub surface and in the hole left by stump extraction. Even if the site were to be ploughed, it would only fill in the holes and not ameliorate any compaction.

8.7.5: NTE LIMITED

NTE LIMITED carries out pre-preparation works on both R1 and R2 sites. R1 sites require minimal works as they are relatively clean ex-sugar cane areas. R2 sites have generally carried 5 to 6 coppice crops, resulting in large stumps (but not as large as those of Mondi). If mechanical systems are to be used to harvest the next crop, stump removal is necessary. A wheel tractor mounted de-stumper is used to chip the stumps 20 centimetres below the soil surface, taking eight machine hour per hectare. The resulting holes are disc ploughed. An alternative under trial is to push out stumps with a V-blade on a 370 horse power bulldozer.

NTE LIMITED is attempting to reduce the effect of burning harvesting residues, by reducing fire intensity and by only burning residue windrows, leaving the majority of the soil`s organic content.

8.7.6: SAPPI FORESTS

Scrub or residual understorey layers are slashed by labour. Stumps are sprayed using backpack units with the active ingredients varied specific to target woody weed species

R1 and R2 sites are control burned in the dry autumn months (primarily at the end of March for the Natal and Transvaal areas, and from April to July in Zululand to give low intensity burns). R1 sites are burnt to remove the grass cover and on R2 sites it is to remove harvesting residues. In both cases, the aim is to retain the soil surface humus. Overall it reduces the danger of fire in the first winter. Again the question of the detrimental effects of control burning were mentioned.

As an option to the burning of harvesting residues, Sappi has tested two different machine systems. In the Highveld, chopper rolling has been carried out on some R2 pine sites. In Natal, a bush rake on the front of a 170 horse power loader is used to discontinuous windrow the larger residues, leaving the finer components to decay. The windrows are not burnt, but are left to decay. They are discontinuous so as to prevent any wild fires from running along their length.

De - stumping is only taken as an option if a machine based inter-row maintenance operation is to be undertaken. A 370 horse power bulldozer is used with either a scalp blade or a ripper tine (for use on multi-coppice crop stumps).

8.8: DISCUSSION

An initial site clean up is required, in order to allow site preparation and later age operations to proceed. The degree of restriction on any pre-preparation works by local regulation will be dependant upon the previous landuse and will determine the percentage of a given property that is to become a productive plantation. R2 sites are different as they have already had a previous plantation cover. The area planted maybe expanded. If this is to be the case, legal controls maybe exerted by various authorities.

The method of pre-preparation clean up will depend upon the previous landuse and the equipment available. The removal of scrub on a derelict farm can either be by labour or by scalping with 200 horse power bulldozers.

R2 sites present a different situation, due to the presence of harvesting residues that create access difficulties, especially after a number of coppice crops. Although it is a cheap and easy method, control burning can only be considered as detrimental.

As awareness of the green house effect increases, pressure to reduce the input of carbon dioxide to the atmosphere will increase. One potential target maybe the use of fire as a silvicultural tool. Therefore it would be strategically astute to develop a range of silvicultural options.

The use of chopper rollers, combined with a fallow period would appear to be an optimal solution. In practice, chopper rollers are limited to certain sites. In steep areas of New Zealand, they gravity feed rollers down the slope and then extract by winch. In the ideal situation two chopper rollings of a site may be required. Both Sappi and APM Forests Pty. Ltd. have found chopper rollers to be a successful option on sites that had an R1 pine plantation. Due to the difference in the residues of eucalypts compared with pines, the method and chopper rolling equipment may have to be modified for eucalypt residues. Green eucalypt residues are more resilient than those of pine species. Better results maybe achieved after a fallow period. If a fallow period is not an option, heavier rollers maybe required. The length of any fallow period will depend on the pressure for land and a host of other management considerations. If reduced planting occurs for the same degree of clearfalling, a longer fallow period may result. If pressure for land is great, very short fallow periods may result with only one chopper rolling.

Sites that have been coppiced over a series of rotations may develop very large stumps. With normal survival rates, machine access maybe limited on such a site. It is necessary to initially kill the stumps so that they do not again coppice. In all cases fire or herbicides are an option. If stumps are low enough, they can be either chopper rolled or simply covered with soil by a plough pass.

The option of stump removal is difficult and expensive. It is also detrimental to the site due to soil compaction and a nitrogen sink effect. In the case of large stumps, a commercial recovery of the above ground portion, followed by a ploughing to cover the underground portion with soil would be an option, but would be dependant upon a suitable market. The best approach is to not let stumps become too big.

Where coppice development becomes a problem to the re-establishment of a site, under Australian conditions a chopper roller pass in the middle of summer would kill the stumps. As well, it would break down harvesting residues to a size which allows rapid decomposition. Fire risk during such an operation would be high due to the fuel layer, machine exhaust and sparks. Once residues were chopper rolled fire risk would be reduced.

9.0: SOIL CULTIVATION

9.1: SUMMARY

The options for soil cultivation are many and varied. However the principles and desired end effect are universal. The overall aim is to create the best possible environment for tree root development. It is only when a tree develops a complete and healthy root system, that it can make full use of any site, optimising wood production and returns from investment.

In all operations (apart from the primary goal of optimising wood production), the aim should be to protect the soil from erosion and horizon mixing. It is in the interest of long term production, as well as a responsibility to the environment.

Intensity of cultivation technique will vary with the resources available, as well as the treatment required. Full site cultivation is the most desirable approach, however if ploughing is not possible, a site should be deep ripped with cultivation over the rip line to prevent erosion. The last and least desirable option is to pit plant. In some instances a site may have a specific problem such as water logging or low nutrient status, in which cases ridging is required.

9.2: INTRODUCTION

After pre-preparation the next phase of establishment is soil cultivation. The degree and method of soil cultivation will vary from site to site, as it does from organisation to organisation. The overall aim is to enhance the structure of the soil to allow root development.

The following section presents the range of soil cultivation techniques utilized by the organisations visited.

9.3: AUSTRALIA

9.3.1: APM FORESTS PTY. LTD.

Based on soil type, APM Forests Pty. Ltd. either deep rips or ridges all sites where machine access is possible. Recognition is given that some sites require special attention and therefore each site is treated as an individual case. Where a site has been recently cleared, a broad cast plough is required to kill any regeneration of woody competition (only on flat sites).

Any soil that is either clay loam or compacted at the surface or at depth, is deep ripped. A winged ripper is used to a depth of 0.7 to 1.0 metre and is pulled by a 200 horse power bulldozer. The ripper tine shatters the soil, with the angled wing further lifting and fracturing the soil profile. The result is loose soil in a wedge rather than a single line. The shattering is best once the soil is dry. Ripping leaves a furrow which may cause soil erosion. This can be prevented by using a set of crowder discs to fill in the rip line. A small ridge is created over the rip line further enhancing the cultivation effect. Both the ripper tine and crowder discs are pulled in the one pass by a 200 horse power bulldozer. If an ex-pasture site is deep ripped, a rotary hoe pass is used to break pasture clods, reducing the chance of air pockets which would otherwise kill any planted tree.

Sand dominated soil or sites prone to water logging are ridged. The aim of the ridge is to concentrate the more fertile A horizon soil and to create an open soil where root development is not hindered. In the case of water logged sites, the aim of the ridge is to enhance drainage, preventing tree roots from drowning.

In both cases cultivation is one or two degrees of the contour to allow water drainage and prevent erosion. As well time is required to allow cultivated soil to settle, removing air pockets.

If a site is too steep for machine access, it will be pit planted. A 30 x 30 centimetre section of the soil surface is scalped to remove floral competition, followed by three strikes with a mattock to effect some degree of soil cultivation.

9.3.2: BUNNINGS TREEFARMS

The method of soil cultivation depends on the previous landuse and any site specific requirements. Ex-bush sites are root raked to 0.3 metres depth as part of the pre-preparation treatment, which acts as an initial cultivation. The next stage is to broad cast plough sites to remove any woody weed species germinants. A 4WD tractor is used to pull heavy off-set discs. Chisel ploughs are sometimes used in preference to discs. It must be noted that ex-bush sites typically are on lateritic or pure sands.

Areas of ex-pasture are assessed and allocated as requiring deep ripping or ridging, based on soil moisture status. Ripping is done using a single tine, to a depth of 0.5 metres. A furrow is left in the soil which may result in an air pocket. This is more so when ripping is done close to planting and there is not adequate time for the ground to settle. Areas of poorly drained soils are ridged to allow better drainage and hence aid tree survival. In extreme cases, ridging is done over a rip line.

9.3.3: DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

On most sites deep ripping is the preferred method of soil cultivation. A 0.7 metre rip line is created using a 150 horse power bulldozer. A normal ripper tine is used. Sites with poor water drainage have a laser graded drainage line constructed, after which ridges are thrown using a bedding plough. The combined result is reduce water logging to aid tree root survival.

9.4: THE PEOPLES REPUBLIC OF THE CONGO

As the Congo sites are grasslands, a broadcast plough is often the only soil cultivation operation. In very few instances ripping is carried out. Agricultural equipment is used with no modifications.

9.5: FRANCE

9.5.1: AFOCEL

A broad cast plough of the site is carried out, after which it is disc cultivated.

9.6: PORTUGAL

9.6.1: CELBI

Cultivation techniques vary according to the site. Soil type, texture and stability, combined with slope are the determinate factors. Previous landuse will also influence cultivation technique.

Due to the climate of Portugal, CELBI aims to enhance soil moisture properties by soil cultivation. They only have winter rainfall, with the duration variable and potentially over only a matter of two months. It is therefore important to maximise water capture to enhance plant growth. After rain, a tree can develop an adequate root system to depth to survive the dry periods. All site cultivation works are carried out in the dry (summer) months.

Flat sites, are broadcast ploughed up to one metre in depth, with a 150 horse power bulldozer. After which a contour plough line is prepared into which trees are planted. Both erosion protection and water uptake are enhanced.

On steep sites erosion potential is high, the entire site is terraced. A 200 horse power bulldozer creates a four metre wide terrace and 335 horse power bulldozer creates a five metre wide terrace. Terraces are deep ripped using a three tine ripper configuration. Only the two rear tines have wings. On flat areas or terraces a separate pass with a small set of twin disc crowders is used to fill in the rip line.

9.6.2: EMPORSIL

EMPORSIL is currently reviewing their soil cultivation techniques to optimise tree growth responses. A new prescription for soil cultivation is currently under introduction. The original method was to deep cross rip to 0.8 metres depth, on a two to three metre grid, followed by a broad cast discing. A small 0.5 metre ridge was then prepared to collect water with the tree planted at the base of the ridge. Now sites are still cross ripped, but with chisel ploughing to only 0.3 to 0.4 metres to prevent the dilution of the A horizon. Fertilizer is broad cast spread and lightly ploughed into the ground.

9.6.3: PORTUCEL

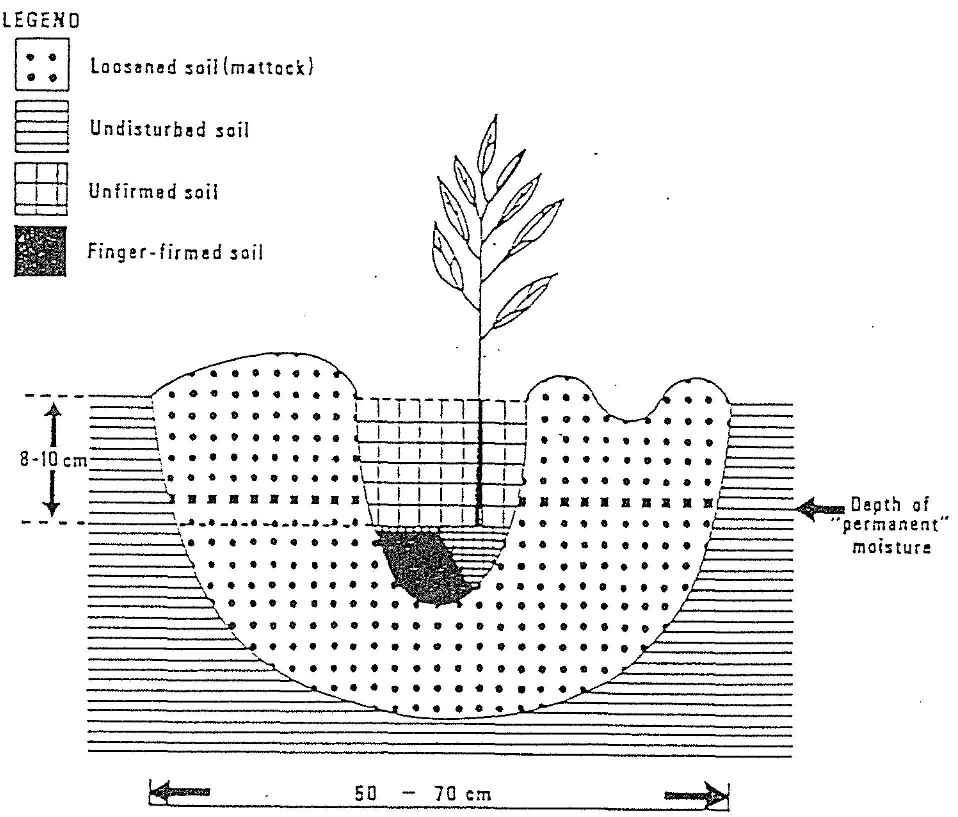
Steep and flat sites are treated differently. Flat sites are broadcast deep ripped using a three tine configuration behind a 160 horse power tractor. Any steep sites are terraced (four metres wide) and deep ripped using the same three tine configuration.

9.7: SOUTH AFRICA

9.7.1: HANS MERENSKY HOLDINGS (PTY.) LTD.

Two extreme levels of soil cultivation are employed on R1 sites; pit planting techniques and full mechanical cultivation. Pit planting is the pre-planting preparation by labour of 0.30 x 0.30 x 0.15 metre cultivated section of soil using an agricultural hoe. Pit planting is common to all South African companies, with specifications as recommended by the ICFR (shown in figure 9.1 taken from Sappi (1990)).

FIGURE 9.1: PIT PLANTING SPECIFICATIONS (SAPPI)



HM HOLDINGS (PTY.) LTD are investigating the use of 370 horsepower bulldozers to deep rip between stumps and cultivate in the one pass using a winged ripper to a depth of 1.2 metres. Two sets of twin discs are pulled in the same pass to cover the rip line with a small ridge.

9.7.2: HL AND H MINING TIMBERS

In the majority of situations R2 sites are established, with full cultivation as the objective. Deep ripping to 0.9 metres is carried out to break up any impervious sub-soil hardpans. A high wing ripper on a 200 horse power bulldozer creates a 0.4 metre wide zone of soil shatter. A complete broad cast ploughing to 0.2 metres depth then takes place and helps to reduce floral competition. Such operations continue all year round, but are most effective when the soil is dry as full ripper shatter can be achieved.

Where it is not possible to do complete cultivation works or resources do not permit, sites are pit planted.

9.7.3: ICFR

The ICFR has a continuous programme of research into soil cultivation techniques. Trials are multi-variant in design so as to be able to evaluate the effect of the addition of different components of site preparation. Such information allows the best allocation of limited fund to achieve optimal growth.

Three levels of cultivation have been tested with and without deep ripping (table 9.1).

TABLE 9.1: SOIL CULTIVATION INTENSITY VARIABLES.

Cultivation:- none (pit planting)

- shallow (using a rotary hoe or off set discs with 0.10 to 0.20 centimetres depth)
- deep (using a set of twin heavy gang discs or a chisel plough to 0.20 to 0.25 metres depth)

Deep Ripping:- none

- present (using a tine with a bottom wing attachment and flanges on the trailing edge with 0.40 to 0.45 metres width of soil cultivation)

The ICFR found that in isolation, individual soil cultivation techniques did little for tree growth, but when combined with the other factors of site establishment, spectacular improvements resulted.

Pit planting is the least satisfactory, with slow growth leaving trees vulnerable to competition and they never catch up to "fully cultivated" trees. Therefore pit planting should never be seen as a cheap option, but rather as a last resort.

Shallow and deep cultivation were best when combined with deep ripping. A good soil tilth promotes an even proliferation of roots in all directions. Investigation by the ICFR of the degree of root development have shown that the majority of roots colonise to the maximum depth of soil cultivation. In terms of broad cast ploughing, it is to 0.2 metres. If a site is deep ripped, potential root development is to a much greater depth.

The benefit of deep ripping was site dependant. Where soils are deep and well drained, tree root growth is unimpaired and there will only be a slight response to deep ripping. Where a hard pan layer is present, deep ripping will help root penetration through to the sub-soil. If a site has a grass cover, a flange on the top of the ripper tine will act as a scalp blade, with the scalped section of grass aiding with water retention. Deep ripping has been shown to be of greatest value on marginal sites.

It was shown that shallow ripping gave little benefit as only the A and part of the B horizon were cultivated, therefore ripping should be to at least 0.4 metres depth. Where a site has had full cultivation or ripping, it was found to be critical that sufficient time be allowed for the soil to settle. This is to remove any air pockets that maybe formed.

9.7.4: MONDI FORESTS

The most common form of site cultivation carried out by Mondi is pit planting, with pits pre-prepared by labour (to the specifications shown in figure 9.1) following the burning of harvesting residues. Generally it is between the rows of stumps from the previous plantation. In some areas broad cast ploughing is carried out as well as deep ripping to 0.6 metres. In conjunction with their intensive soil science programme, Mondi is working towards better soil cultivation techniques.

9.7.5: NTE LIMITED

On R1 sites the option of deep ripping is taken. If a site's soils are not over compacted, an agricultural tractor is used to rip to a maximum of 0.5 metres and in other situations, deep ripping is to 1.2 metres using a 370 horse power bulldozer. A set of three ripper tines are located on the ripper bar; the two outer tines rip to 0.9 metres depth and the central tine rips to 1.2 metres and has a 0.3 metre wide wing. All ripping is on the contour.

Presently NTE LIMITED is experimenting with terracing in steep country, following observations in Portugal. The trial was reported to be a success and that it met with the approval of the local conservation group.

Broadcast soil cultivation techniques are employed on sites that do not require any ripping. Where slopes are eight degrees or less, a rotary hoe is used as the potential for erosion is less. Up to 20 degrees slope sites can be chisel ploughed as it leaves an uneven surface less prone to soil erosion.

R2 sites are cultivated using an agricultural (three components) tractor mounted system. The first component is a cutter wheel to cut harvesting residues remaining after a cool control burn. A deep ripper to 0.45 metres follows. The rip line is the covered by soil using a chisel plough.

Pit planting is seldom used.

9.7.6: SAPPI FORESTS

Sappi has formal recognition of the need to balance full site cultivation and the need to conserve soil integrity. Table 9.2 presents Sappi's soil cultivation decision making process. (Sappi (1990)). In the field, cultivation methodology will depend on the soils present, degree of pre-preparation and the previous landuse.

If a site has never been ploughed before, the local agricultural extension officer is consulted to determine the best method of soil cultivation. Ploughing is to a depth of at least 0.20 to 0.25 metres. It is only carried out after at least 50 millimetres of rainfall, with a sufficient delay to allow the soil to dry before cultivation commences.

Where a site has an excessively hard surface, a stoneline or a plough plan, plough penetration is likely to be obstructed. In such cases it becomes necessary to deep rip to at least 0.45 metres after the first rain. Ripper tines are no more than one metre apart. In some cases it maybe necessary to cross rip, prior to broad cast ploughing.

A light surface cultivation is required to ensure a good tilth before planting and to control floral competition. This is achieved by the use of a rotary hoe, small disc or a set of harrows. The proviso is given that where there is a danger of erosion caution must be exercised.

If ploughing is not at all possible, deep ripping is required to at least 0.45 metres and is best carried out when the soil is dry. As an individual soil increases in clay percentage, soil dryness becomes critical to the success of deep ripping. The only exception is shale soils which tend to deep rip better when wet. This is to allow maximum soil shatter to be effected. After deep ripping sufficient time is required for the soil to settle to eliminate any air pockets. The prescribed period is to wait until at least 75 millimetres of rain has fallen. As much as a year fallow after deep ripping has been found to be advantageous.

Deep ripping should be orientated at right angles to any access roads. Care must be exercised in ripping on the contour. Although it will aid in water capture and retention, on some soil and site types it may create an erosion problem.

TABLE 9.2: CULTIVATION OPTIONS AND CONTROLS (SAPPI)

SLOPE (%) SOIL ERODIBILITY High	Low *	TYPE OF CULTIVATION	TILLAGE DIRECTION	REMARKS
0-8(4,5°)	0-12(7°)	Full conventional	Across Slope	Leave surface as rough as possible.
9-15(8,5°)	-	1. Full primary cultivation with tined implement only. 2. Strip cultivation with any implement leaving minimum 1 m between strips which may be ripped or sprayed.	Across Slope / Across Slope	-
	13-20(11°)	Full unrestricted primary cultivation followed by secondary cultivation along the plant line only.	Across Slope	-
16-25(14°)	21-30(17°)	Full primary cultivation with tined implement only	Across Slope	Plant within 1 month. Weed control via herbicide strip (1,5m wide or more) or hand hoe around the tree, no mechanical control.
26-30(17°)	31-30(22°)	Single rip/subsoiler tine along tree line.	Across Slope	Crawler tractor recommended. Weed control as above, spray prior to planting.
	41-50(27°)	Single rip/subsoiler tine along tree line, interrupt every 50m.	Down Slope	Crawler tractor recommended. Plant within 1 month. Weed control as above.
>30	>50	Pit	-	Maximum diameter 1m. Weed control as above, restrict hand hoeing to pitted areas.

* i.e. those soils with effective soil depth (excluding gleyed, plinthic and E horizons) and, where slope >8%, having topsoil with >500mm clay >15%. Excludes all soils with E horizons.

There is little benefit in ripping the top soil alone, generally the deeper the ripping the better. If possible more than one tine should be used, but only if it does not reduce ripping depth. A single ripper tine to 0.45 metres is considered better than three tines to only 0.30 metres. However, the best result comes from using a central ripper tine to 0.45 metres depth, with two outer tines ripping to a depth of 0.30 metres.

If a site has surface rock formations or is too steep and deep ripping becomes impossible, the loss of production by using pits is well recognised and, as such, pitting is regarded as a last resort.

R2 sites are treated as above under the limitations of the degree of any pre-preparation treatment. If a site has not been burnt or de-stumped, or has only been burnt, it is pit planted. In some cases a burnt R2 site can be ripped between the rows of stumps. Once a site has been burnt and de-stumped the option of full cultivation become available.

9.8: DISCUSSION

It is the objective of soil cultivation to maximise uniformity of tree growth on a given site. Soil cultivation for eucalypt plantation establishment ranges from little to very intensive, with the overall determinant as the availability of funds to carry out operations. If we assume the optimal situation of full funding, cultivation techniques are then determined by site characteristics, the most important of which is the soil. It's inherent nature and modifications due to previous landuse will dictate what corrective measures are required to optimise tree growth.

We need to specify what is important to tree growth, and therefore what are the objectives of site cultivation. The aim of any cultivation technique should be to promote the rapid and complete colonization of a soil profile by a tree's root system. This will allow the maximum uptake of moisture and the utilization of available nutrients, as well as provide mechanical support. Any broadcast surface cultivation will act as a primary floral competition control.

Boden (1990) stated that establishment practices will usually influence tree growth for approximately two years and thereafter site and climatic factors become the dominant influences. However, in all three experiments (see section 9.7.4) trends that developed at age one year continued and in many cases strengthened well into the third year. Therefore we can conclude that it is only by thorough soil cultivation practices, that the maximum potential root systems is realised allowing the greatest possible use of the attributes of a given site. Failing that, all trees will be limited in their ability to express the full potential of a site. Once a tree has developed a poor root system it is difficult for a recovery to take place.

To achieve full colonization there can be no physical or chemical barriers to tree root growth. Such barriers as a hard pan layer (caused by previous agricultural pursuit or a stone layer) or a water logged layer must be corrected to allow root exploration. The next controlling factor is the general freeness of a soil. In order to explore all the inter-particulate spaces and for root diameter to expand, a soil must be loose. Soils with the smallest particle sizes (such as clays or silts) will have a solid structure with minimal inter-particulate gaps. Similarly, a site that has been grazed by hard footed animals will have surface compaction and will prove difficult for tree roots to explore. Both require corrective measures. Eucalypt root systems require an aerated soil (with a few specialized exceptions). The same factors that control tree root exploration will determine soil aeration, with inter-particulate gaps and water logging as the most important factors.

After consideration of the desired modification, soil conservation must be considered. Any operation must prevent erosion or other forms of soil degradation. It is important to maintain a soil's structure and not dilute the nutrient rich top soil or A horizons by either inversion or layer mixing.

Figure 9.2 was prepared based on soil cultivation options as observed in the various organisations visited. It has been drawn up based on broad groupings of decision variables.

Broad cast ploughing is recommended by many organisations, with the initial floral competition control an advantage. However, on steep sites and with certain soil types it will promote soil erosion. If broadcast ploughing is to any great depth the A horizon maybe lost. The same can be said for the practice of terracing in steep country, as it would be very prone to erosion and there is a complete inversion of the soil horizons.

Deep ripping will ameliorate many soil structural problems. It should be carried out on the contour, once a soil has dried out to effect maximum shattering. The depth of ripping should be to at least below any impervious layer and as deep as possible. A single ripper tine with a basal wing is ideal, but if larger bulldozers are available, two out side ripper tines to a shallower depth would be an advantage. In extreme cases of extensive hard pans or stone layer, cross deep ripping maybe required prior to broadcast ploughing.

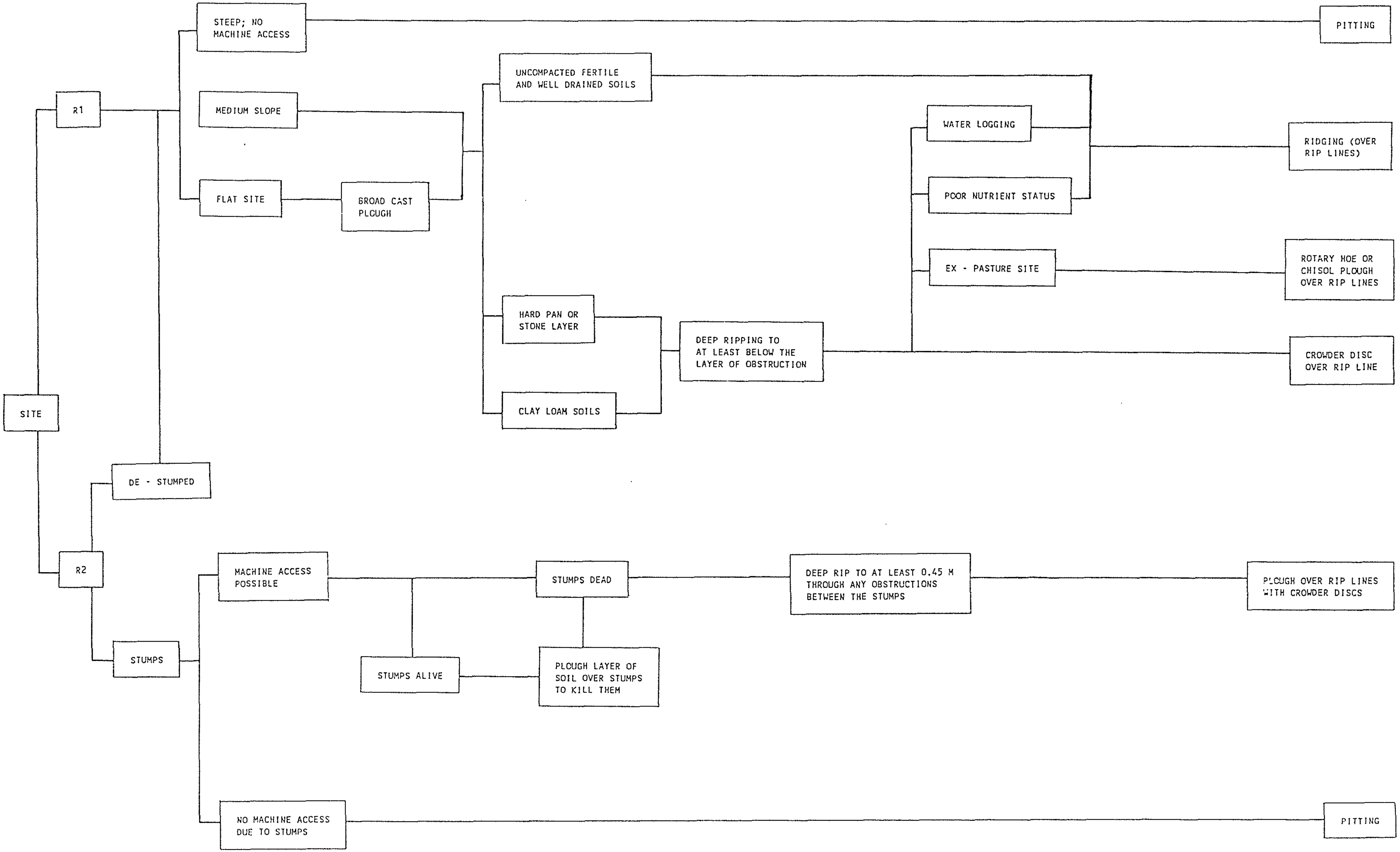
If broadcast ploughing is not to follow deep ripping, crowder discs should be used to fill in the rip line and create a small ridge, either in the same pass as the ripping, or as a separate operation. The advantage is that it helps to fill in any air pockets, creates a very loose soil and it helps to protect the site from erosion.

If on ploughing over the rip lines a soil breaks into clods, air pockets may result in tree death, and would require additional treatment.

On very poor or water logged soils, ridging is the best option. If any other soil defects are present, other operations are required prior to ridging. For example a site may have complete surface compaction and a hard pan layer. Therefore it will require a broadcast plough and deep ripping if conditions allow. In the case of poor nutrient status soils, any ridge will concentrate the more fertile surface soils. Ridging of water logged soils allows free drainage and enhances tree root growth. Care must be taken with ridging as it may have the reverse effect of allowing a soil to dry out killing the trees.

Pit planting must be regarded as a last option. The resulting poor tree growth and survival makes any perceived savings very much a false economy. In evaluating a site for purchase, if the only option for soil cultivation is pit planting, then the maximum potential returns from that site would be very much reduced.

FIGURE 9.2: SOIL CULTIVATION OPTIONS



10.0: INITIAL FLORAL COMPETITION CONTROL

10.1: SUMMARY

There is a benefit from the removal or reduction of floral competition. The expression of the degree of competition is dependant upon the competing species on a given site. In general, eucalypts are sensitive to mechanical damage by competing floral species as well the reduction in availability of the limited resources of a site.

Mechanical or chemical control methods can be taken in isolation or in conjunction; mechanical control can be inherent in the site cultivation or as an additional operation. Herbicides can be either contact or residual.

The use of herbicides is controlled by the local legal requirements, and the target species. The susceptibility of the planted crop will dictate the active ingredient options. The method of application and the degree of ground cover will be a function of the trade off between the minimal effective cover and the cost of the operation.

10.2: INTRODUCTION

Depending upon site characteristics, a range of floral species will be present, ranging from ground covers through to a mature or over mature tree canopy (either native to the area or introduced). The composition and number of species will reflect the previous landuse of a site.

Regardless of species and habit, any other plants present will be competing with the plantation for the limited resources of that site, which may result in the death of the planted trees. It is the aim of this section to detail the initial floral competition control methods employed by the various organisations visited.

10.3: AUSTRALIA

10.3.1: APM FORESTS PTY. LTD.

The first phase of floral competition control is the site cultivation. After the first autumn rains, seeds in the soil germinate in the cultivated portion. On areas of ex-pasture, a range of grass species and clover germinate (along with noxious weeds). If a site was cleared of scrub, woody species dominate regeneration. Both the previous vegetation cover and wildings from the R1 crop regenerate on R2 sites.

In all cases the aim is to carry out effective floral competition control using a pre-plant herbicide application. Herbicides are varied based on the target species (Table 10.1).

Application method depends on topography and previous landuse. With machine access, a two metre wide strip is sprayed, over the proposed planting lines as defined by any soil cultivation works

TABLE 10.1: HERBICIDES; TARGET SPECIES AND RATES (APMF)

ACTIVE INGREDIENT:	TARGET SPECIES:	RATE:*
GLYPHOSATE	CONTACT KILL OF NARROW AND BROADLEAF SPECIES	2.0
SIMAZINE	RESIDUAL HERBICIDE	6.0 - 8.0
TRICLOPYR	CONTACT KILL OF DIFFICULT TO KILL WOODY WEEDS	1.0

NOTE: * Rates presented are for kilograms of active ingredient per sprayed hectare.

(ie ridges). A combined deep ripping, crowder disc ploughing and spraying rig on a 200 horse power bulldozer has been used to great effect in steep country operations. If a site is too steep or rough for machine access, hand held spot guns are used to spray one metre diameter spots. It is only applicable on sites with vegetative ground cover that will show up where to plant.

10.3.2: BUNNINGS TREEFARMS

On some sites a broadcast ploughing is the first phase of floral competition control. After which the approach taken varies with the previous landuse. On ex-pasture and ex-bush sites the species present fall into the same groups as with APM Forests Pty. Ltd., requiring different herbicide regimes (table 10.2).

On ex-pasture sites if couch grass is present, it is first broadcast sprayed with glyphosate (late summer through to early autumn). After a fallow period, normal ex-pasture site regimes are applied.

If a site is to be ridged or is prepared late, the proposed cultivation line is strip sprayed with paraquat. A rapid effect results and allows the next phase of the operation to soon follow. The aim is to kill the pasture species before they are buried into a ridge. If this is not done, vegetation will grow from the buried root stock to compete with the planted trees. Once specific herbicide operations have been completed, glyphosate and atrazine are sprayed over the cultivation lines (table 10.2).

Ex-bush sites are left for a fallow period to allow regeneration, after which sites are broadcast sprayed (table 10.2).

Bunnings Treefarms have experienced some mortality under certain conditions due to the herbicides. Therefore they have a research programme investigating optional herbicide regimes. They are evaluating the residual herbicide sulfometuron methyl in combination or as an option to atrazine. It has been tested at rates from 8.75 to 56.25 grams per sprayed hectare.

TABLE 10.2: HERBICIDES; TARGET SPECIES AND RATES (BTF)

ACTIVE INGREDIENT:	TARGET SPECIES:	RATE:*
EX-PASTURE SITES		
PARAQUAT	PASTURE AND BROADLEAF SPECIES	0.4 - 0.6
GLYPHOSATE	COUCH GRASS CONTACT KILL	2.8
	NORMAL PASTURE CONTACT KILL	0.52
	PERENNIAL SPECIES CONTACT KILL	1.05
ATRAZINE	NORMAL PASTURE RESIDUAL	3.5 - 4.0
	PERENNIAL SPECIES RESIDUAL	5.0
EX-BUSH SITES		
GLYPHOSATE	WOODY SPECIES REGENERATION	1.75 - 2.1
METSULFURON METHYL	BRACKEN	0.012 - 0.015
ATRAZINE	RESIDUAL CONTROL OF REGENERATION	3.0 - 3.5

NOTE * All rates kilograms of active ingredient per sprayed hectare.

In order to develop an operational prescription, plant back periods are under investigation for the different combinations of sulfometuron methyl. Delays of one, two and four weeks after spraying before planting have been included.

10.3.3: DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

CALM's routine prescription for pre-plant herbicides on ex-pasture operations is under review. Their herbicide regimes are presented in table 10.3. If a site has either dock or sorrel, it is first broadcast treated with metsulfuron methyl. If couch or kikuyu are present, a site is broadcast sprayed with glyphosate. After which cultivation takes place. A two metre strip is sprayed over the line of cultivation. The herbicide mixture used is dependant upon the target species.

Broadcast treatments are to kill species which would otherwise survive and then grow out of ridge and through any residual herbicide layer. This would result in strong competition and tree death.

It has been shown by operational experience that when using simazine, constant agitation is required to prevent it precipitating out of solution. Therefore when tank mixing, it is

TABLE 10.3: HERBICIDES; TARGET SPECIES AND RATES (CALM)

HERBICIDE	TARGET SPECIES	RATES *
METSULFURON METHYL	SORREL AND DOCK	0.009 - 0.012
GLYPHOSATE	COUCH AND KIKUYU	2.1 - 3.5
	EX-PASTURE AND BROADLEAF SPECIES	0.7 - 1.4
SIMAZINE	RESIDUAL CONTROL	3.0 - 6.0

NOTE: * Rates presented are kilograms of active ingredient per sprayed hectare.

necessary to have a re-circulation system to prevent an initial settling. It has been found that simazine may causes damage to some species typified by inter-venation necrosis. Simazine has been found to have reduced residual effect on clay soils.

Sulfometuron methyl has been thrilled in combination with glyphosate and compared with simazine and glyphosate. Rates of sulfometuron methyl from 0.05 to 0.40 kilograms per sprayed hectare were included. It was found that under the local conditions, all rates retarded tree growth. Only those trees planted into 0.05 to 0.20 kilograms per sprayed hectare of active ingredient, recovered after the first spring. In the Western Australian situation it is imperative that tree growth is rapid through the first spring due to insect grazing and therefore such a retardation must be avoided.

It was noted that herbicides change the floral competition spectrum. With the higher rates of sulfometuron methyl clover species return. With other herbicides the most vigorous broadleaf species return to compete with the tree crop.

10.4: THE PEOPLES REPUBLIC OF THE CONGO

The initial floral competition control method in the Congo, is broadcast ploughing. Herbicides use is limited, due to high costs. It was also stated that labour skill was such, that it would be too great a risk to use herbicides, from a health and effectiveness point of view. The next phase of the project, (with woody species) may require greater input.

10.5: FRANCE

10.5.1: AFOCEL

Initial floral competition control is by broadcast ploughing. After which limited use is made of herbicides. Glyphosate is sometimes used as a general pre-planting spray. In some instances fluazifop butyl (narrow leaf contact control) and clopyralid (broad leaf contact control) are sprayed in the winter before planting. They are yet to find a suitable residual herbicide.

10.6: PORTUGAL

10.6.1: CELBI

Where possible all sites are broadcast ploughed removing any floral competition. No use is made of herbicides as a follow up operation. Within the first year after planting all sites are hand weeded around the individual trees.

10.6.2: EMPORSIL

EMPORSIL was the only company visited in Portugal attempting to develop a herbicide based floral competition control regime. Routinely all sites are broadcast ploughed to remove the initial vegetation, followed by hand weeding around the individual trees. They aim to replace both hand and mechanical floral competition control methods.

Presently they are having success with oxyfluorfen as a post planting herbicide. As yet it is to be registered for forestry use in Portugal. A one metre strip is sprayed over the planting line using a back pack. Two metres has been thrilled and was found to be no better than a one metre strip. Spraying must be completed within three weeks of planting (before the tree has recovered from planting shock) but is best within one to two weeks of planting. Best results were from spraying in winter and after rain which would stimulate the target species to grow with the trees still in planting shock.

A residual effect of one year is achieved with oxyfluorfen. The residual effect is lost if any soil disturbance takes place. Therefore, they exercise great care with any inter-row cultivation operations.

10.6.3: PORTUCEL

Initial soil cultivation is the only floral competition control works.

10.7: SOUTH AFRICA

10.7.1: HANS MERENSKY HOLDINGS (PTY.) LTD.

Floral competition regrowth is sprayed with glyphosate, either broadcast from the air or by hand crews who strip spray the planting lines. Due to climatic limitations, spraying is prioritised across all operations. R2 establishment takes precedence over maintenance works. As yet they have not developed a suitable residual herbicide regime.

10.7.2: HL AND H MINING TIMBERS

After the first rains of summer, vegetation is allowed to grow to five centimetres height. It is then broadcast sprayed with either glyphosate or paraquat. They aim to broadcast spray, but in the steeper areas strip spraying is done to prevent erosion. When it is not possible to pre-plant spray, post-plant spraying is done with a tree shield.

A rickshaw is used to do all strip spraying operations. It is a skirted aluminium frame with to micro spray heads inside and is carried by two people. The spray heads are run by hand pumps and create a herbicide mist which settles onto the vegetation in a strip.

10.7.3: ICFR

The ICFR has a programme to determine the best herbicide regimes for pre and post planting use with eucalypts. A range of herbicides and rates have been thrilled on the different floral competition groups. Development of an effective pre-emergent herbicide component is of particular interest as it would replace the need for hand weeding.

A range of herbicides have been tested; acetochlor, atrazine, metolachlor and oxyfluorfen. Glyphosate has been included as an initial contact kill herbicide.

When used post planting, oxyfluorfen was found not to be effective under the conditions of the trial. They are considering repeating the trial as it is relatively safe with eucalypts. The interaction between herbicide, soil type and floral competition species is to be considered in an attempt to maximise effectiveness.

The ICFR found differences in the duration of the herbicide effect, atrazine was found to have the longest residual life (15 weeks), with the rest only 10 weeks. The duration of the various herbicides is a function of the clay, organic and moisture content of the sites soils.

Once herbicides have become inactive, a site will be re-colonised. Broadleaf species will return through the mat of dead grass to change the floral competition spectrum. However, it was stated that competition exerted by grass was the same as for broadleaf species. The ICFR found that there is a growth response by using residual herbicides. At this stage, tree growth indices are used to measure any response. The main response in tree growth is that crowns are developing as wide as tree height. This is of considerable benefit as shading by the crown will suppress floral competition growth.

In the trials mentioned in section 9.7.4, the ICFR investigated the response of the addition of strip spraying. Glyphosate was pre-plant applied in a 1.2 metre strip over cultivation lines. In the control were a site was only strip sprayed and then pit planted, a tap root developed but with poor lateral roots. Hence it was concluded that spaying alone and pit planting is un-economic, but when combined with the other treatments, a very healthy root system developed, (more due to the better soil cultivation) giving maximum growth.

10.7.4: MONDI FORESTS

Limited use is made of glyphosate. On R2 sites, the slash is burnt and then the site is planted. Fire removes any floral competition. When planting is delayed, a strip of glyphosate is sprayed using a rickshaw. Pit planting follows into the strip sprayed line. Herbicide application maybe carried out post planting, with only the inter-row sprayed. If stumps are still alive, and a coppice crop is not required, an R2 site will be broadcast sprayed with glyphosate.

Mondi has observed an effect of glyphosate on E.grandis. The tree's growth tips on the lower branches loose their dominance and the other side branches grow to produce a feathering effect. As well, bark necrosis were noticed on the stem bark. Trials have shown that 0.035 percent (weight per volume) glyphosate when applied with a micro pipette to bark will cause tissue death. Therefore when glyphosate is used in a post-planting situation, care must be taken to protect the trees.

10.7.5: NTE LIMITED

Herbicide broadcast and strip spraying is used by NTE LIMITED. Glyphosate is the main active ingredient used on all sites. Broadcast spraying from the air is done in some cases. On routine sites with little risk of erosion, glyphosate is sprayed at 1.2 to 1.4 kilograms of active ingredient per hectare. The result is broadcast control of all species. On any sites with a high erosion potential it is desirable to maintain a ground cover, therefore glyphosate is sprayed at 0.5 to 0.7 kilograms of active ingredient per hectare which retards growth rather than killing.

Where possible a 1.2 metre strip is sprayed over the top of any line cultivation. Only contact herbicides are used at this stage.

10.7.6: SAPPI FORESTS

Sappi considers that it is only necessary to spray sites not broadcast ploughed, or when planting following burning is delayed. If the weather is not suited to pre-plant spraying, it is either omitted or precedes post-planting.

In the Highveld, termites are common, and if a site is broadcast sprayed, it will leave little of their natural food. The only food then becomes the planted tree roots. Under such conditions only strip lines 1.2 metres wide are sprayed. In such a harsh environment, the retained inter-row strip of vegetation also acts as a windbreak. Depending upon the season of planting in the Highveld, grass growth may have halted making it difficult to kill, but also unnecessary as there will be little competition.

Where strip spraying is the preferred operation, it is done over the line of cultivation. Where a site is to be pit planted, pits are prepared into the sprayed strip.

The main chemical used by Sappi is glyphosate. On sites that are

R2 from acacia plantations, it is necessary to aerially broadcast spray with a mixture of both glyphosate and paraquat.

10.8: DISCUSSION

In order to maximise the growth of eucalypts on a given site, floral competition must be removed or reduced. Competition will be a function of the limiting factors of the site and the species involved. The effect of the competition will be dependant upon the resilience of the planted eucalypt species.

In some cases, competition is through mechanical damage. Jacobs (1955) developed the concept of crown shyness in the genus eucalyptus. The location and sensitivity of naked buds make them easily damaged. When by wind, adjacent branches contact naked buds, they are destroyed. The result being a compact crown. The same effect may result when a planted tree is smothered by Pteridium esculentum (Frost. f.) Cockayne (bracken fern). The abrasive nature of the fern may remove the growth tip and lateral buds. The tree is either held back or killed.

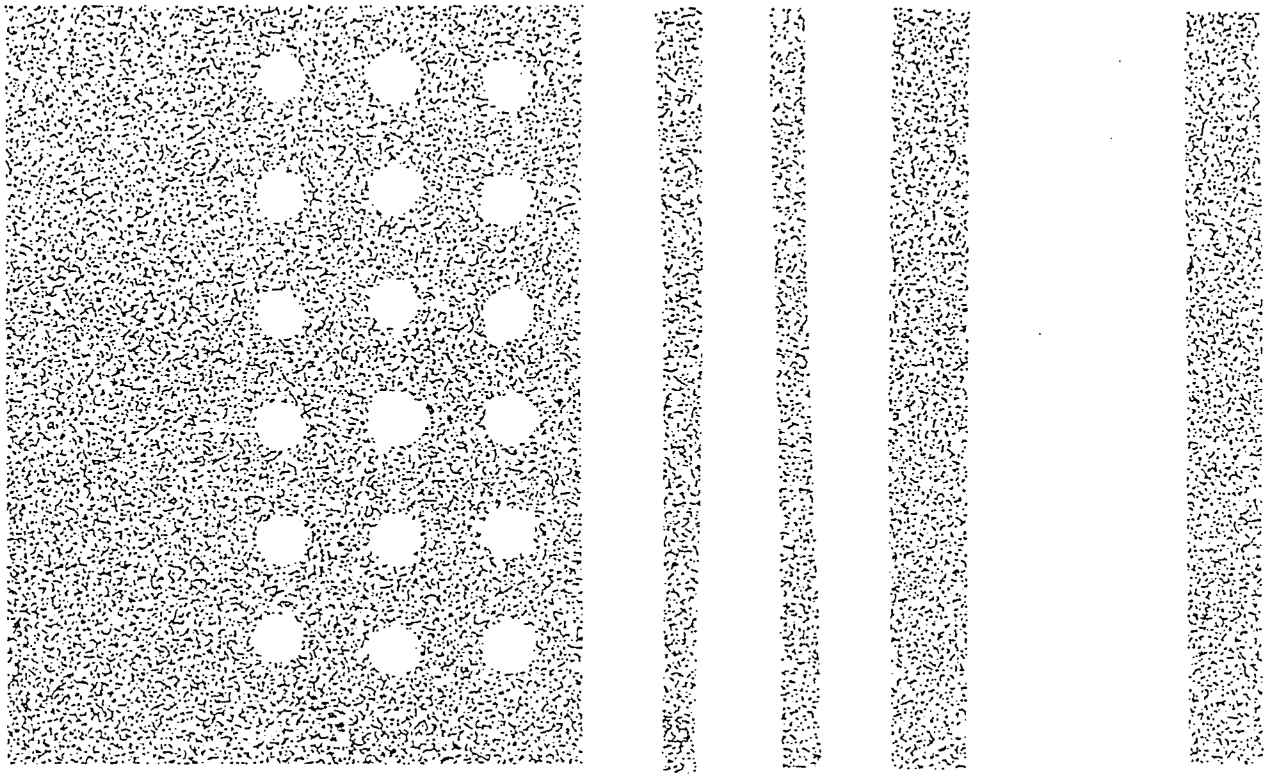
In South Africa and Portugal, floral species compete for water. The same can be said for the Australian situation. The degree of the effect is maximised when a strong seasonal pattern of rainfall is prevalent. Competition for the other factors of site will occur, but the most important is the competition for water. Water competition will determine tree survival and then tree growth.

The effect of other plants on a site will vary with the growth of the planted eucalypts. In the initial stages, competition will be from those plants in close proximity. As the tree roots develop and explore the soil, a larger radius of influence will develop, within which the tree is effected by other floral species. Concurrently, competition will be expressed by the planted eucalypt on the other floral species. As the tree develops a healthy crown, it will shade out those floral species below and eventually fully capture the site. Therefore, silvicultural practices are designed to promote site capture.

Initial floral competition control can be divided into two broad groups; mechanical and chemical. In all cases the techniques can be applied at four intensities; nothing, broadcast, strip and spot (figure 10.1).

Mechanical floral competition controls have already been discussed. Their benefit is in that floral species are removed and an initial degree of cultivation is afforded. Hand cultivation, both in pit planting and post-planting weeding is very labour intensive. Any post-planting operation may have the effect of damaging the lower branches of the tree as well as any surface lateral roots. If only mechanical means are required, it makes the operation much more economical (does not require the purchase of herbicides) and maintains the present floral species spectrum rather that allowing the proliferation of broadleaf species.

FIGURE 10.1: INTENSITIES OF INITIAL FLORAL COMPETITION CONTROL



NOTHING (0% COVER) | SPOT (7.8% COVER) | STRIP (60.6% COVER) | BROADCAST (100% COVER)

The use of herbicides to initially control floral competition species is wide spread to varying degrees of effectiveness. Contact herbicide regimes are well thrilled and operationally successful in pre-planting application. Post-planting applications are much more restricted due to the sensitivity of most eucalypts to herbicides. Residual herbicides are not commonly used, but are generally recognised as essential to avoid costly hand weeding operations prior to canopy closure.

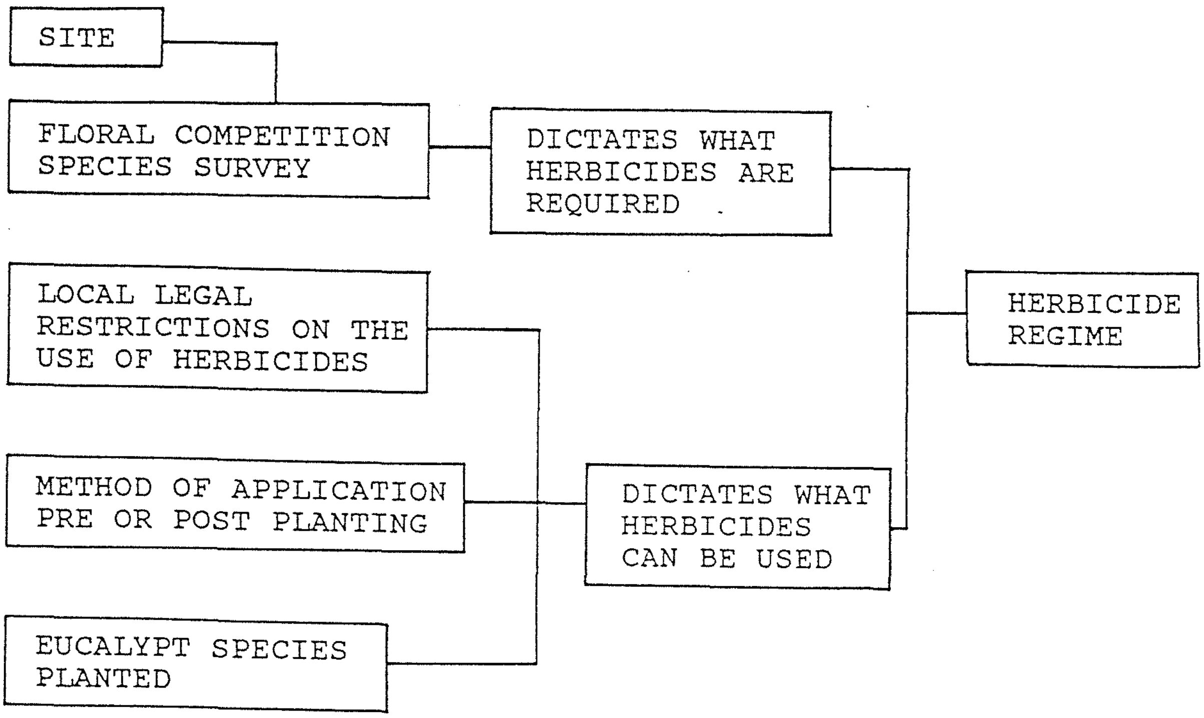
The degree of site cover (as presented in figure 10.1) will dictate herbicide costs. If it is possible to only spot spray less herbicide will be required. For example if 1000 stems per hectare are to be planted at 3.3 x 3.0 metres spacing and either 1.0 metre diameter spot, 2.0 metre strip or broadcast spraying is to be done, the percentage of the site sprayed will be as presented in figure 10.1.

The choice of degree of herbicide cover, will be determined by what is effective for the given floral competition species on a site. As shown, special consideration needs to be given to local requirements. One example is the need for alternative food for termites or the degree of shelter effected by the retained inter-row strip. Where a floral species has the capacity to regenerate from buried root stock, within any ridges, it is necessary to first broadcast spray. In all cases, consideration must be given to the need to protect the soil, and prevent erosion.

The decision to use herbicides will follow a number of steps (figure 10.2). The steps involved will be uniform, with the resultant herbicide regime dependant upon local legal requirements. The choice of active ingredient will depend upon the target species and the susceptibility of the eucalypt crop. The method of application will be dependant upon the equipment available and any legal requirements.

The method of application will depend upon the required percentage of ground cover and the technology available. Spot spraying can be achieved using back packs or hoses from a stationary unit. In the usual situation requiring spot spraying, greater mobility requirements will dictate the use of back packs. Strip spraying can be effected by a number of techniques. In most cases it is by a pass over the line of cultivation using either machines or labour. The development of the rickshaw in South Africa was very interesting and would have application in Australia. Broadcast spraying was mostly effected by aerial application. As controls on the aerial application of herbicides in forestry become tighter, it may not be an option in the future.

FIGURE 10.2: HERBICIDE REGIME DEVELOPMENT



11.0: PROTECTION FROM BROWSING ANIMALS

11.1: SUMMARY

The degree of browsing damage to eucalypt plantations depends very much on the local environment. Domestic stock and native species can cause damage. The methods of dealing with the threat of damage are varied, but revolve around exclusion or removal of the offending species. The level of threat must be assessed to identify and then deal with the offending species.

11.2: INTRODUCTION

Within the Australian environment, many faunal species rely on eucalypts as their primary, and in some cases exclusive food source. The most notable is the koala (Phascolarctos cinereus). Introduced vermin and domestic stock have become accustomed to eating eucalypts. The European rabbit (Oryctolagus cuniculus L.) is noted for nipping off, but not eating planted eucalypts. Domestic stock eat and trample planted eucalypts. However at a certain stage of plantation growth, stock can be introduced.

It is the aim of this section to detail the methods of browsing animal control as used by the organisations visited.

11.3: AUSTRALIA

11.3.1: APM FORESTS PTY. LTD.

Browsing damage occurs to planted eucalypts in all areas of APM Forests Pty. Ltd. estate. The degree of damage and the species responsible vary according to site. Montague et al (1990) have been involved in estimating the extent of the damage and confirmation of the species responsible. Research has been undertaken into the biology of the offending species.

The main identified browsing species is the swamp wallaby (Wallabia bicolor Desmarest). In most areas rabbits are a threat. Animal populations are a function of previous landuse. Wandering domestic stock and feral domestic stock also damage plantations. Sheep and goats are known to browse and cattle trample seedlings.

One method of preventing browsing animal damage is to remove the offending species. Domestic stock can be excluded by the construction of suitable fences and rounding up stray animals. Feral domestic stock can either be rounded up or destroyed.

Destruction of rabbits is the preferred method of control. Rabbit proof fencing is vulnerable to damage by wombats (Vombatus ursinus). 1080 (sodium monofluroacetate) has been the main method of destroying rabbits.

Wallabies have been traditionally controlled by the same methods as for rabbits. Under a grant from the National Afforestation Programme (NAP), APM Forests Pty. Ltd., has been investigating options to the destruction of wallabies. Although results from the use of extracted chemicals from dog's urine are promising, it has not been scaled up to an operational level. Prior to the NAP grant, electric fencing and tree guards were thrilled. Electric fencing is expensive to initially construct and to maintain. Tree guard nets are expensive and in-effective against wallabies as the exposed growth tip is removed and eaten. As well, the nature of the tree guard nets causes abrasive damage to the naked buds.

11.3.2: BUNNINGS TREEFARMS

Domestic stock pose the greatest threat to eucalypts planted by Bunnings Treefarms. Rabbits are also a threat. All stock are removed from sites prior to planting and any fence construction or repairs effected. Rabbits are poisoned with 1080 baited oats. Ripping of warrens or the use of fumigants are employed depending upon the scale of the problem. In all cases controls are prior to planting.

11.3.3: DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

As with Bunnings Treefarms, wandering stock and rabbits are the greatest threat to planted eucalypts. Similar methods of control are undertaken. The only difference is the involvement of the Agricultural Protection Board on State owned land. Controls are prior to planting.

11.4: THE PEOPLES REPUBLIC OF THE CONGO

The only threat to planted trees is from wandering domestic stock.

11.5: FRANCE

11.5.1: AFOCEL

In routine plantations domestic stock are removed from the sites prior to planting. In some locations, red deer (Cervis elaphus) browse and cause mechanical damage by rubbing their antler onto the trees.

11.6: PORTUGAL

11.6.1: CELBI

All domestic stock are removed and excluded from a site prior to planting. Rabbits, fallow deer (Dama dama) and wild pigs (C.elaphus) all browse planted eucalypts. The damage caused is minimal and if a large gap results, the area is replanted.

11.6.2: EMPORSIL

The biggest problem faced by EMPORSIL is from domestic stock; primarily goats (Capra hireus). Therefore once a site is planted, all stock are excluded by fence construction.

11.7: SOUTH AFRICA

11.7.1: HANS MERENSKY HOLDINGS (PTY.) LTD.

They do not have a browsing animal problem. From time to time it was stated that wandering bucks (various species) may browse eucalypts.

11.7.2: HL AND H MINING TIMBERS

From time to time wild bucks (various species) may browse seedlings. The biggest threat is from illegal grazing of cattle in the plantations.

11.7.3: ICFR

The level of browsing animal damage was said to be variable. One trial site visited had been heavily browsed soon after establishment. Fences are built to keep out bucks and hares (Lepus spp.).

11.7.4: MONDI FORESTS

Wandering bucks (various species) are the main and limited browsing animal threat to planted eucalypts.

11.7.5: NTE LIMITED

Limited browsing of eucalypts by bucks occurs, and is restricted to trees only 0.5 metres or less in height.

11.7.6: SAPPI FORESTS

Buck and baboons (Papio ursinus) were stated as the main browsing animals. Rats which live under ground in the Highveld will eat the roots and bark strip any planted eucalypts. The first control option occurs at the initial pre-preparation site clean up. Where a broadcast burn is used to remove the grass cover, it kills the rats. The second option is to trap the rats and either kill or relocate them to another area (which more than likely results in their death). Poison baited oats and honey can be used to kill the rats. Their last and most interesting option is to build four perches per hectare to encourage birds of prey. The rats are then eaten by their natural predator.

11.8: DISCUSSION

The threat of browsing animal damage will depend upon the palatability of the species planted in relation to the faunal species present. The degree of animal selectiveness will vary with the availability of alternative food supplies. Therefore the first stage must be to identify the offending species, study it's biology and develop specific control options. As stated in the introduction, both domestic (including feral domestic) stock and native fauna can cause browsing damage.

In countries where eucalypts have been introduced, domestic stock pose the greatest threat. In some areas of Australia the same is true, with the exception of sites inhabited by wallabies. Introduced vermin also pose a threat to planted eucalypts. In only few cases overseas did indigenous fauna browse planted eucalypts. This maybe due to the planting of eucalypts in agricultural zones were native fauna were not present.

Differences in eucalypt species palatability is well noted. FAO (1979) states that the unpalatable nature of E.globulus subsp. globulus allowed it to become important in Ethiopia, as fences were not required to keep out domestic stock. Such would explain the lack or reduced browsing problems faced in Portugal.

The management practices used to protect trees from browsing reflect the local environment. The aim of management can be to either remove or exclude browsing animals from a site. Fencing is only effective on some sites. In Australia, fencing is a restricted option especially in areas inhabited with wombats. As well, wallabies can from a standing start jump a 1.3 metre fence with ease.

Depending upon the browsing animal species, removal from the site would be an option. Poisoning of localised individuals would allow adequate time for the trees to grow beyond a susceptible height. After which time sites can be recolonised by the species with an enhanced habitat due to the planted eucalypts.

12.0: PLANTING AND PLANTING STOCK

12.1: SUMMARY

Of all the operations in establishing a plantation, planting and planting stock are the most important factors. After all the cost has been expended on site preparation, poor planting stock or planting technique can negate all the previous effort. Planting stock must leave the nursery with a sound root system, as well as a healthy leaf cover. Plastic cell block containers with greater depth than height appear to be the best. The use of copper paint root inhibiting techniques are of great benefit.

Transport to the field must be with full regard for the safety and well being of the planting stock. Fully enclosed vehicles must be used. Plants must be kept moist right up to the time of planting.

The season of planting and planting technique are very much dependent upon the individual site. The overall aim is to ensure adequate soil moisture to allow tree root development to a depth of year round moisture.

12.2: INTRODUCTION

The aim of site preparation is to allow the planted trees to quickly capture the site, maximising expected returns (wood volume produced), for a given site. Regardless of site preparation, planting stock quality will determine production on a given site. Conversely, it is only through thorough site preparation that the potential gains of a tree improvement programme can be fully realised.

It is the aim of this section to present planting stock details.

12.3: AUSTRALIA

12.3.1: APM FORESTS PTY. LTD.

APM Forests Pty. Ltd. only plants eucalypt seedling stock. Seedlings are grown in 42 per tray peat jiffypots with a root plug volume of approximately 100 millilitres. At the time of planting they are ideally between 0.2 and 0.3 metres tall.

Planting commences once the soil has become sufficiently moist, and site preparation has been completed (usually by the end of May). Planting is continued through to late August, but it is preferable to have finished earlier.

Seedlings are dispatched in a moist state from the nursery, in fully enclosed vehicles to prevent drying out. Once in the field they are stored in a convenient and sheltered location. If seedlings are not to be planted that day, they are stored in pens to protect them from the wind and browsing animals. At all stages the aim is to keep the jiffy pot moist.
On sites that have been fully prepared, planting is done with a modified spade. A hole is created and the seedling placed within.

Care is taken to ensure that the simazine surface coated soil does not contact seedling roots. Seedlings are planted into the centre of the cultivation line. Planting is into the side of any ridge to encourage deep roots to prevent windthrow and enhance access to soil moisture.

At least 2.5 centimetres of soil is required above the top of the jiffypot. On sandy soils, it is necessary to plant deeper into the layer of soil that does not dry in the summer, to prevent the jiffypot from drying. Any exposed part of the jiffypot will act as wick, and once dry, a jiffypot becomes hydrophobic and will not re - wet by any amount of rainfall.

On sites that have not been fully cultivated, seedlings are pit planted into the centre of the pre-prepared herbicide spots on ex-pasture sites. On scalped country, pit planting is in a line as labour moves across the slope. In both cases, the actual planting is done at the time of pit preparation.

Once the seedling has been planted, the area around is firmed to leave a vertical seedling with no air pockets in the soil below. At all times a Company representative is on site to maintain planting quality by continuous plot assessments of the correct stocking rate and planting technique.

12.3.2: BUNNINGS TREEFARMS

All planting stock is grown from seed by contract nurseries. The majority of seedlings are grown in 72 per tray peat jiffypots with a root plug volume of 60 millilitres. One contract nursery, producers 64 cell plastic tray stock (root plug volume of 70 millilitres). Seedlings are between 0.15 and 0.30 metres in height.

Planting commences once site preparation has been completed and the soil is sufficiently moist. This can be from May onwards through to August.

Seedlings are collected by a fully enclosed truck with a hydraulic ramp and mobile trollies that can be pre-filled at the nursery ready for collection. The trollies are then off-loaded in the field, easily unloaded and then put back in the truck and taken away. One full truck load consists of nine trollies each with 84 trays of seedlings. Each tray has a maximum of 72 seedlings giving a maximum total load of 54 432 trees. There is no maintenance of seedlings once in the field, as planting soon follows.

All hand planting is done using Pottiputki planting tubes and as many ex-pasture sites as possible are machine planted. The seedlings are planted into the rip line or in rows on broadcast prepared sites, with 2.5 to 3.0 centimetres of soil above the jiffypot to prevent drying out.

12.3.3: DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

CALM only plants seedlings. Presently they are investigating options of container size and type to produce the best possible seedling root system. Once that has been achieved, a seedling should be capable of rapid growth after planting. Their standard container is the 72 per tray jiffypot. Due to the results of field trials, copper impregnated paint coated 64 cell plastic trays (root plug volume of 70 millilitres) are in favour. The seedlings supplied are between 0.2 and 0.3 metres in height.

Planting commences once the soil is sufficiently moist and is aimed to be finished as soon as possible. Due to the diversity of sites, special considerations are given to specific site problems. On sites prone to water logging, planting should be as early as possible to avoid problems of poor access. Sites prone to summer drought, should be planted as early as possible to allow seedling roots to develop to give greater access to soil moisture. Areas prone to high rainfall should be planted after low rainfall sites have been completed. Sites characterized by heavy textured loams should be planted after all more sandy soils have been completed (extracted from Bradshaw (1990)).

Machine planting is into pre-prepared rip lines. On sites that have been ridged, planting is by hand using Pottiputki planting tubes. All jiffypots are planted moist and below the surface of the soil. The soil around the jiffypot is firmed in to remove any air pockets and to leave the tree in an upright position.

12.4: THE PEOPLES REPUBLIC OF THE CONGO

The majority of planting stock is clonal. Martin (1987) presents full details of the methods used to prepare cuttings in the Congo. Planting of cuttings commences from January to February and goes through to May. Seedlings are planted only in the wet season (November to April).

All planting is done by labour using garden hoes or a special planting tool. Labour works in pairs, with one digging the hole and the other planting the tree. Planting is into a pre-placed portion of granular fertilizer. When planting cuttings, they are planted to below the stub (from the initial plant material).

All trees are watered in with an insecticide solution to prevent termite attack. This was necessary on the grasslands of stage one as termites eat the roots of any planted trees.

12.5: FRANCE

12.5.1: AFOCEL

All planting stock used by AFOCEL is clonal, in an attempt to provide uniform frost resistance. Cuttings are grown in 196 millilitre "containers" made of synthetic cloth cut into tubes and filled with potting media.

Planting commences once the danger of the heaviest frosts has eased. The frost period commences in autumn (last half of November) and continues through to late spring (the end of March).

In a usual year, planting is from March to the end of June, or September through to October. It is preferred to plant in spring as this allows time for growth through summer to produce trees with a better chance of surviving the following frost season. Planting is by hand.

12.6: PORTUGAL

12.6.1: CELBI

As part of the D95 Project, Celbi is investigating the use of clonal techniques, but at present seedlings are planted. All seedlings are raised in paper pots. The size of the pot depends upon the season of planting; spring 62 millilitre containers and winter 71 millilitre containers.

Seedlings are dispatched overnight, travelling up to 400 kilometres to be onsite the following morning. The aim is to reduce any transport stress. A full load consists of 50 000 seedlings, which takes 15 to 25 minutes to load and has a total weight of 5 to 6 tonnes.

Planting commences after the first rains of winter. In non-frost areas, planting is usually from March through to May (spring). In areas prone to frost, planting is from October through to January (winter). The paper pots are ripped and removed prior to planting by hand.

12.6.2: EMPORSIL

The majority of EMPORSIL'S planting stock are seedlings. For the 1990 crop they have been directed to produce up to 1 000 000 cuttings. If it can be achieved (unlikely), it will be the first large scale production of cuttings in Portugal (and of cuttings of <u>E.globulus</u> subsp. <u>globulus</u>).

All seedlings are raised in moulded plastic containers. Each seedling grows in an individual 110 millilitre cell. Their container system allows infilling with a fully developed seedling, to give 100 percent full trays on dispatching from the nursery..

Trays of plants are stacked into frames and loaded into trucks. Planting is by hand. The seedling trays are put into baskets and carried into the field. Seedlings are easily removed from the containers prior to planting.

12.6.3: PORTUCEL

All of Portucel's planting stock are seedlings. They also have a programme to develop clonal material, but as yet it is still on a research scale. Seedlings are produced in plastic bags by the field staff with a series of small nurseries for each operational area. Planting is by hand.

12.7: SOUTH AFRICA

12.7.1: HANS MERENSKY HOLDINGS (PTY.) LTD.

Seedlings are routinely planted. Experimentation with clonal stock is underway, but is not to an operational scale. The main delay is because of poor root structure. All seedlings are produced in a 110 millilitre individual plastic cell container. These are suspended in plastic rack trays in the nursery.

Planting continues all year round in the Tzaneen region. The only seasonal variation is that the majority of trees are planted in the wet summer months. Planting is by hand. Where full site preparation has not been possible, pit planting is used. On fully prepared sites, planting is done using a hoe and is to the same depths as for pit planting. Cuttings are planted, to a depth that ensures that the dead stub of the original stem material is covered.

12.7.2: HL AND H MINING TIMBERS

HL and H Mining Timbers was stated to be a clonal company and are at present in a transitional phase from seedlings to cuttings (commencing in 1983). In 1989 50:50 seedlings to cuttings were planted. They are aiming for 80% cuttings by 1992.

All planting stock is produced in 110 millilitre individual plastic cell containers.

Planting commences only after 15 millimetres of rain. Planting usually continues from September through to April. Winter (dry season) planting after rainfall has been thrilled and was found to be successful. This will help spread out the planting season and ease pressure from all other operations.

Planting is by hand using pit planting techniques or into fully prepared ground using a hoe. Planting is to a depth of 80 millimetres of soil over the top of the root plug, covering the lower two leaves and the original stem stub (in the case of cuttings).

12.7.3: ICFR

The pit planting technique presented in figure 9.1 is as specified by the ICFR. In a series of trials into other aspects of site preparation, they incorporated planting technique. It was found that pit planting should only be done into strip sprayed areas to allow the tree to get the most benefit from this inadequate method of site preparation. In which case, a poor root system developed, but the tree survived (Boden (1989)). On R2 sites there was no difference in tree growth when planting was between the rows of stumps compared with planting with-in the rows of stumps (Boden (1989)).

12.7.4: MONDI FORESTS

Mondi is the leader in the production of clonal planting stock in South Africa. For 1990, 99% of the planting stock in the Zululand area will be clonal. In the Transvaal area more seedlings are used. All plants are produced in styrofoam trays with varying soil plug sizes (48 to 110 + millilitres in volume). Trays are coated with copper impregnated paint to prevent root penetration. On dispatch from the nursery, plants are 0.15 to 0.2 metres in height.

All planting is by hand. In the Zululand area planting only stops during the hot summer months (November to February). In the Transvaal and other areas planting is all year round. All planting is done into the pre-prepared pits.

The foam trays of plants are carried into the field and the stock removed prior to planting. A 0.2 x 0.2 metre mud puddle is created in the pre-prepared pit using one litre of water and then planting into the middle of the mud. After planting the trees receive a further litre of water.

In Zululand the soil surface heats up to a temperature that will cause seedling death, so planting is to a depth below the level of soil warming. It also requires less root growth to access soil moisture.

12.7.5: NTE LIMITED

Only seedlings are planted by NTE LIMITED. As with other South African companies, they have a clonal programme, but the future of their programme is in doubt due to the more complete amalgamation with Mondi. It is likely that Mondi will develop suitable clones for NTE LIMITED.

All seedlings are grown by contract nurseries (Mondi as the main contractor). Their planting stock is produced in the same containers as Mondi and the seedlings are between 0.15 and 0.20 metres in height.

Planting is best carried out from April through to May. This allows the tree to develop a root system prior to the dry months. With such an advantage, the tree can out compete any floral competition that develops after the autumn rains.

All planting is by hand using a modified puddle/pit planting technique. Once the tree has been planted into the mud puddle, a layer of dry top soil is spread over the surface to prevent the mud drying rapidly.

12.7.6: SAPPI FORESTS

Sappi has made the decision not to pursue the avenue of developing clonal planting stock until the best genetic base has been developed. Even once that has occurred, they still doubt as to whether cuttings are the best option. One of the main concerns is the threat of disease.

Sappi commenced operations with a range of small nurseries managed at a local level. Now they have developed a centralized approach with a small number of large nurseries, (one in each of the three regions).

Previously styrofoam block container trays, dipped into a copper solution were used. Now they have changed to plastic cell block trays. Still they are not convinced that plastic trays are the best due to the potential for root caging. They see root structure as one of the most important components of a seedling. Seedling height varies according to the season of planting, ranging from 0.07 to 0.2 metres.

The stated aim of planting is "quality rather than quantity". One essential factor is good supervision. Continuous supervision and detailed spot checks are needed to ensure the use of correct technique. A maximum of 15 to 20 labourers are permitted in any one planting gang. When working with labour, it is essential that the gang works on a face to enable close supervision and it ensures that the work pace is kept constant. At no time does Sappi permit the use of individual task work.

In Natal, Transvaal and Melmoth the best time to plant is September through to January. The earlier the planting the greater chance a tree will grow to a height where frost is not a threat. Trees should not be planted to early due to frost. The first areas to be planted should be those which are prone to frost. If trees are planted in February, they grow slower, respond less to fertilizer and suffer greater mortality. In the Zululand coastal area, the best time to plant is in the cool months from March through to September.

Wherever possible, trees are water planted. A planting hole is opened with a mattock (blade width of no more than 80 millimetres) and one half to one litre of water is poured into the hole. The seedling is then planted into the hole to a suitable depth, withdrawing the mattock and then firming the soil around the seedling, to ensure that no air pockets remain. Where a plantation is to be established in the Highveld termites will eat the roots. Therefore when planting, seedlings are watered in with a clodane (insecticide) solution. In Zululand sands, the seedling root plug is first firmed into the bottom of the hole and then at least two litres of water are applied. The amount of water is a set minimum regardless of the rainfall.

12.8: DISCUSSION

Two options exist (in theory) as to the type of planting stock; either seedling or clonal. The above statement was qualified as in some cases the species under development have proven difficult to grow from cuttings. Under Australian conditions it is questionable whether the high cost of cutting production (labour, glass houses and mother plant beds/houses) would be justified. As well, our main species have not been operational propagated as cuttings.

At this point it is pertinent to discuss the desirable characteristics of eucalypt planting stock. Two points must be considered. Firstly root system structure and secondly the condition of the stem and leaves.

A complete and health root system must be present. A primary tap root, with a mass of secondary roots is required. All roots must be separate (no intertwining) and with good vertical (no "J" rooting) as well as lateral development. All roots must be capable of rapid colonization of the surrounding soil after planted.

The leaves and stems must be hardened to allow resistance to desiccation or light frost damage. A full compliment of healthy leaves with a single dominant apical growth tip will ensure strong apical growth. In general planting, stock height should be between 0.2 and 0.3 metres, to allow planting to a greater depth.

Container size and nursery practices will dictate the root quality. Any description of containers can be divided into four topics; material used, size, shape, and internal design.

Peat, paper, plastic, synthetic cloth and polystyrene foam are all used. Peat and the synthetic fabric pots allow the plant roots to grow through, where as the other three materials do not. Once outside the peat or synthetic pot, roots must be inhibited from spiralling around the plastic containing tray. In the case of plastic cell and foam block trays, a copper layer (paint or impregnation) will prevent root spiralling or caging. Paper pots cannot been treated with copper paint and therefore can cause spiralling and caging.

The size (volume) of containers varied greatly. There has always been a question of root:shoot ratio, but it has been suggested that it may be the influence of the quality of the root system rather than the quantity (Personal Communication 2). Before the advent of copper paint, if a container was not of adequate size root binding would result. With the use of (copper) painting a root system will develop laterally and stop at the container wall. Further root growth will develop until the soil plug is a mass of roots, not intertwined, but waiting till the copper source is removed.

If greater depth than width containers are used, (as in South Africa), a dominant tap root develops. A tap root is important where sites prone to water stress are planted, as root development to depth will be essential to access soil moisture.

The use of root trainers can cause root caging. Plant roots will grow to the edge of the cell and then grow around at the same level until they hit a root trainer. If the trainer works, the roots will then grown downwards, resulting in a cage of intermingled roots along the surface of the container.

Plastic cell and foam trays could be dispatched from the nursery with 100 percent stocking. Peat and paper pots have to be dispatched without infilling making transport less efficient.

Separation in the field of both peat and paper pots becomes an additional expense. In terms of lost production it is estimated as the need for four additional labourers to separate seedlings per 15 planters. The same would be true for machine planting as peat or paper pots would have to be separated prior to commencement of work.

The best container system observed was the one used by EMPORSIL. It is plastic cell design (with root trainers that would be replaced by copper paint). It has a root plug depth of 90 millimetres and a cell volume of 110 millilitres. A sample was brought back to Australia for testing.

The season of planting is very much dependent upon local conditions. If due to the scale of a companies operations planting is required all year round, it could be done with puddle planting. The overall aim is always to plant after the commencement of rainfall to ensure maximum tree survival.

There are special site characteristics that will influence when to plant. Frost, heating of the soil in summer, poor access in winter, and a very sharp transition from wet to dry soil conditions with the change of season will give priority to areas at certain times of the year. If a company's estate contains a mixture of sites, it will be necessary to assign priority to the sequence of planting.

On sites prone to frost, planting should be delayed till the threat of frost has eased, but such delay should not be too long, as the aim is to allow the planted tree to grow to sufficient height to be above the danger zone before the next frost season.

Where soils are prone to heating or drying out over summer, planting should be as early as possible after the commencement of rainfall. In extreme cases where summer rainfall and heating of the soil combine, planting is best delayed till the cooler, but still moist autumn months.

If due to water logging a site cannot be readily accessed after rain, it should be planted as soon as possible after the season breaks. Tree roots will not be damaged on ridged sites as they will be above the water logged zone.
Planting stock quality can be greatly reduced by poor management outside the nursery. All vehicles used to transport seedlings must be fully enclosed to prevent wind desiccation. A trolley system is desirable. These can be pre loaded in the nursery allowing a rapid turn around time. Once in the field, the trollies can be off-loaded by a hydraulic ramp, the trays removed and the trollies re-loaded. At least two sets of trollies would be required, but the savings in time would soon be recovered. If cuttings are planted they must have at least the original stem stub buried. On sites that are prone to surface soil heating or desiccation, planting should be to the depth of permanently moist soil. If the soil profile drys out to a great depth, planting should be as deep as possible in the hope that the roots will explore the soil to the depth of permanent soil moisture prior to the next dry season.

Great variation was encountered in planting technique. Generally the aim was to ensure that the top of the root plug was not exposed to the air to prevent the root plug drying out, especially where jiffypots are used. The depth of planting reflected the individual site characteristics combined with the effects of site preparation.

The position of planting is best over the line of cultivation. There is a loss of benefit from deep ripping if planting is between the rip lines. There is no benefit in planting between residual stumps of a R1 crop. On ridges it is best to plant on the side of the ridge, as this will promote root development into solid soil for added wind firmness.

At planting, a hole is required to be prepared. Any spade or hoe can be used with containerised stock. The only requirement is that residual herbicide coated soil be prevented from falling into the hole. Specialised planting tools such as the Pottiputki can be used, but if the same effect can be achieved on a site with a spade it may be a cheaper option.

Planting stock is placed in the formed hole to the desired depth. The plant is maintained in an upright position and the surface soil is best lightly firmed rather than "healed in". When healing in a plant, there is a chance that it may damage the root system. Only as a last resort should a site be pit planted. Figure 9.1 describes the technique in detail. Only on sites with a proven termite problem would there be the need to "water" in with insecticide.

13.0: STOCKING, ESPACEMENT AND INFILLING

13.1: SUMMARY

Selection of a stocking rate will be a function of the site, the end products and the proposed management regimes for a given species. Generally, as site quality decreases so does the number of stems per hectare of a given species, that will grow through to rotation. Management practices will determine the end product within the bounds of an adequate initial stocking rate. Machine access between tree rows is important to allow mechanical maintenance.

Infilling within the same planting season was seen as essential to ensure that the plantation was fully stocked, to maximise site production.

13.2: INTRODUCTION

The number of trees planted per hectare will influence the management options and requirements to sustain a healthy and viable plantation. A set stocking can be achieved with variable between row and within row espacement. To ensure the desired stocking rates are achieved, it maybe necessary to replace dead trees. Infilling and the timing of infilling are both important.

It is the aim of this section to detail the stocking rates, planting espacement and the process of infilling observed in the organisations visited. Espacement will be presented as the distance between rows x distance within rows.

13.3: AUSTRALIA

13.3.1: APM FORESTS PTY. LTD.

INITIAL STOCKING: 1000 STEMS PER HECTARE (3.3 X 3.0 OR 3.6 X 2.8 METRES)

Stocking rates are the same across all sites. In steeper country, the espacement is varied to give the desired stocking rates in a plain perspective. Inter - row machine access is required for maintenance works. On flat ground, were machine access is desirable, the option of wider between row spacing is taken.

Plots are put in to check on the stocking rates at planting to provide immediate feedback on stocking and planting quality. After planting has finished, survival is checked. Infilling then takes place as required. At nine months a survival count is taken which becomes the recorded initial stocking for the plantation. Infilling the following year only takes place in failed patches.

13.3.2: BUNNINGS TREEFARMS

INITIAL STOCKING: 1250 STEMS PER HECTARE (4.0 X 2.0 METRES) - ROUTINE SITES

INITIAL STOCKING: 1700 STEMS PER HECTARE (3.3 X 1.75 METRES)- HIGH QUALITY SITES WITH GOOD RAINFALL

Routine sites are planted at 1250 stems per hectare, but on higher quality site they are planting at 1700 stems per hectare. Four metres between rows allows machine access. On high quality sites, they alternate between 2.0 x 3.0 metres for two rows and then a wider gap of 4.0 x 2.0 metres to give an average stocking of 1527 stems per hectare (with good machine access).

It was stated that actual stocking rates on high quality sites varied up to 1905 stems per hectare. Therefore, Bunnings Treefarms are developing an assessment and check procedure to maintain the desired stocking rates.

13.3.3: DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

INITIAL STOCKING: 1667 STEMS PER HECTARE (3.0 X 2.0 METRES)- PRESENT STANDARD

INITIAL STOCKING: 1428 STEMS PER HECTARE (3.5 X 2.0 METRES) - COASTAL AREAS

CALM has established a series of espacement trials. Espacement ratios from 1:1 to 1:2 and espacements from 2.0 x 1.0 metres through to 4.0 x 4.0 metres were included. As CALM plantings are based on agricultural land, between row espacements of 5.0 metres are under investigation to allow inter - row round hay bale production.

13.4: THE PEOPLES REPUBLIC OF THE CONGO

INITIAL STOCKING: 1000 STEMS PER HECTARE (4.0 X 2.5 METRES)

The CTFT and the ENGREF gave different stocking rates for the Congo operations. The rate listed above is from the CTFT, were as the ENGREF stated that plantings were at 500 stems per hectare.

13.5: FRANCE

13.5.1: AFOCEL

INITIAL STOCKING: 1250 STEMS PER HECTARE (4.0 X 2.0 METRES)

A between row distance of 4.0 metres allows machine access. Lower quality sites have a stocking rate of between 1000 and 900 stems per hectare.

13.6: PORTUGAL

13.6.1: CELBI

INITIAL STOCKING: 1300 STEMS PER HECTARE (4.0 X 1.9 METRES - TERRACE WIDTH OF FOUR METRES)- DRIER SOUTHERN SITES

INITIAL STOCKING: 1600 STEMS PER HECTARE (3.0 X 2.0 METRES)- MOIST NORTHERN SITES

With the development of different silvicultural regimes, stocking and espacement have varied greatly. Initially planting was at 1111 or 1667 stems per hectare (3.0 x 3.0 and 3.0 x 2.0 metres respectively). At present they aim to reduce spacing to suppress floral competition growth, but still allow machine access.

13.6.2: EMPORSIL

INITIAL STOCKING: 1250 STEMS PER HECTARE (4.0 X 2.0 METRES)- DRY INTERIOR

INITIAL STOCKING: 1667 STEMS PER HECTARE (3.0 X 2.0 METRES)- COASTAL AREAS WITH HIGH RELATIVE HUMIDITY AND RAINFALL

As operations move onto lower quality sites (poor soils, lower rainfall and less relative humidity), stocking is reduced. Machine access between rows of trees is required. Any large areas of failed plantings are replanted.

13.6.3: PORTUCEL

INITIAL STOCKING: 833 STEMS PER HECTARE (4.0 X 3.0 METRES)

Terraces are built 4.0 metres wide and the trees are planted at 3.0 metres intervals.

13.7: SOUTH AFRICA

13.7.1: HANS MERENSKY HOLDINGS (PTY.) LTD.

INITIAL STOCKING: 1111 STEMS PER HECTARE (3.0 X 3.0 METRES)

A between row distance of 2.7 metres is used on ripped sites. They aim for a square spacing. A reduced stocking of 816 stems per hectare (3.5 x 3.5 metres) has been thrilled, but it was found to degrade wood quality.

As all plantations are thinned from an early age, machine access is adequate after the first thinning.

13.7.2: HL AND H MINING TIMBERS

INITIAL STOCKING: 1543 STEMS PER HECTARE (3.6 X 1.8 METRES)- OPERATIONAL PRESCRIPTION

INITIAL STOCKING: 1667 STEMS PER HECTARE (3.0 X 2.0 METRES)- RESEARCH PRESCRIPTION

During planting, work gangs are roped together to give perfect espacement, with pegs placed to give alignment reference points. The two planting espacements reflect the different consideration of operations and research. With operations it is to allow more economic harvesting and for research, it is to effect a more rapid and complete canopy closure to suppress floral competition.

13.7.3: ICFR

The ICFR has been investigating plantation espacement in terms of biological and merchantable volume production. Merchantable volume has been defined based on product diversity and piece size.

It has been found that stocking rates and espacement will depend upon; species, climate, site quality, management objectives, silvicultural techniques, harvesting methods and rotation length. The different stockings and espacements will influence; canopy closure, competition, tree growth rate, wood production, end product diversity, juvenile wood content, silvicultural operations, mechanisation and equipment, establishment and maintenance costs, harvesting (method and cost), and rotation length.

Stocking rates of 833 (3.0 x 4.0 metres) through to 2222 (3.0 x 1.5 metres) per hectare have been tested. They still question whether or not the upper limits of stocking and production are being adequately thrilled, especially for <u>E.grandis</u> grown on a short rotation (Coetzee (1989)).

The self thinning nature of eucalypts is well recognised and was described for natural stands by Jacobs (1955). The ICFR have investigated the effect of initial stocking levels on natural mortality. They found that when growth competition reached or exceeded certain levels of intensity, suppression and mortality increased. It was more so under the influence of a very dry spring. The level of mortality within the range of espacements thrilled was found to be constant at 25 percent. This was over a rotation of 10 years (Schonau (1974)). Schonau and Coetzee (1989) concluded that mortality due to initial espacement was a function of age, species, and site characteristics (both inherent and occasional).

The main effect of initial espacement was on plantation productivity (Schonau (1974)). It was stated that higher stocking rates produced the greatest biological volume (to a stem diameter of 5.0 centimetres). In merchantable terms, were a log is defined down to a small end diameter of 12.5 centimetres, higher stocking rates did not increase volume production. Coetzee (1986) showed that for an average site the total volume to 5.0 centimetre small end diameter increased from 1100 to 1700 stems per hectare, with the differences increasing with age.

Rotation length was found to influence the relationship between increasing biological volume production and the initial stocking rate. For a drier site in Zululand, Bredenkamp (1987) found that maximum total volume production occurred between 1800 and 2000 stems per hectare. As rotation length increased, the maximum volume decreased for the above stocking rates.

13.7.4: MONDI FORESTS

INITIAL STOCKING: 1332 STEMS PER HECTARE (3.0 X 2.5 METRES)- ROUTINE PULPWOOD PRESCRIPTION IN ZULULAND

INITIAL STOCKING: 1111 STEMS PER HECTARE (3.0 X 3.0 METRES)- ROUTINE SAWLOG PRESCRIPTION IN THE TRANSVAAL

Initial espacement depends upon the intended product and site conditions. In the high rainfall environment of Zululand, higher stockings rates can be carried in order to maximise fibre production. As the production of sawlogs requires several thinnings and is in the Transvaal, lower initial stocking rates are required.

After a site has been planted, it is inspected for survival. Where the mortality rate is greater than 25%, infilling is required. This is done as soon as possible, as rapid growth rates of the initial plantings will soon out compete any infilled trees.

13.7.5: NTE LIMITED

INITIAL STOCKING: 1667 STEMS PER HECTARE (3.0 X 2.0 METRES)- STANDARD ACROSS ALL SITES

Rather than change the initial espacement between sites, NTE LIMITED has a standard prescription. This allows all company machinery to be interchangeable across all sites. This may change in the future as Mondi has a greater influence.

13.7.6: SAPPI FORESTS

INITIAL STOCKING: 1667 STEMS PER HECTARE (3.0 X 2.0 METRES)- NATAL

INITIAL STOCKING: 1562 STEMS PER HECTARE (3.2 X 2.0 METRES)- TRANSVAAL AREA ON FLAT SITES (LESS THAN 15 DEGREES) OR AFTER DE - STUMPING

INITIAL STOCKING: 1736 STEMS PER HECTARE (2.4 X 2.4 METRES)- TRANSVAAL AREA, ALL OTHER SITES

INITIAL STOCKING: 1667 STEMS PER HECTARE (3.0 X 2.0 METRES)- PIET RETIEF AREA

INITIAL STOCKING: 1372 STEMS PER HECTARE (2.7 X 2.7 METRES)- ZULULAND COASTAL AREAS

INITIAL STOCKING: 1736 STEMS PER HECTARE (3.2 X 1.8 METRES)- ZULULAND/ MELMOTH AREA FLAT SITES (LESS THAN 15 DEGREES) OR AFTER DE - STUMPING

INITIAL STOCKING: 1736 STEMS PER HECTARE (2.4 X 2.4 METRES)- ZULULAND OTHER AREAS

Sappi's range of prescriptions reflects their recognition of site variability. Machine access is not a great consideration as most maintenance programmes are labour based. As well, only billet wood is to be produced.

Sappi is very definite as to their prescription for any infilling operations. Newly planted areas are to be inspected with in four weeks of planting. Greater than 10 percent death, requires infilling to proceed immediately. They specify use of the same species and if possible the same stock number. If not the same stock number, the seedlings planted must be the same size.

A compartment or large areas within a compartment that has a mortality of 40 percent or more by the following growing season, should not be infilled, but replanted.

13.8: DISCUSSION

The initial espacements of operational eucalypt plantations visited ranged from 833 to 1736 stems per hectare, reflecting site conditions and the silvicultural regimes to achieve the objectives of management.

The following trends exist in the allocation of stocking rates. As site quality increased, so does the initial stocking rates. As the projected rotation length increased, initial stocking rates decreased (if it was intended to thin a plantation, the initial stocking rate could be higher).

In discussing volume production at the different stocking rates, piece size specifications are required. Higher stocking rates will produce more volume, in smaller and potentially unmerchantable piece size classes. It was stated that regardless of the initial stocking rates, as rotation length increases, natural mortalities increased. The stated constant natural mortality rate of 25 percent (Schonau (1974)) may correlate to the self fertilized trees, which Eldridge (1974) and Hodgson (1976)) estimated as 28 and 30 percent of an open pollinated populations of E.regnans and E.grandis respectively.

The importance of infilling was of interest. The prescriptions stated generally required infilling in the same season of planting to avoid the infilled trees lagging behind the initial plantings. The actual time period within which infilling can take place will depend upon on the local environment. Where a coppice crop was to be grown, the timing of infilling was not as critical as it was mainly to ensure maximum stocking at rotation. But if the rotation was too long, late infilled trees would self thin, defeating the purpose. If large patches of plantation failed, re-planting the following planting season was seen as an option.

Initial espacement will influence the cost of establishment. As the between row distance increases for the same stocking rates, the distance travelled by any machine will decrease making establishment cheaper. The overall increase in cost of establishment due to higher stocking rates must be recouped by increased production of a range of products recovered at clearfalling.

14.0: FERTILIZER

14.1: SUMMARY

Increased growth on a given site can be achieved by the addition of fertilizer. The response is dependant upon site, species and the level of site preparation. Response will be greatest with full site preparation. Floral competition control is necessary to ensure that the planted tree receives the greatest fertilization. Deep ripping and ploughing will promote the development of a complete root system, but adequate phosphorous is also required. It is only through a complete root system that the maximum uptake of fertilizer can take place.

Spot application of granular, rather than compressed pill fertilizer is preferred. The spot is to be under the soil surface at a safe (at least 20 centimetres) distance so as to not burn the tree roots. Fertilizer formulation is to be site and species specific, but generally is NPK. The amount fertilizer applied is also site and species specific.

14.2: INTRODUCTION

Rapid initial growth enables the planted trees to capture a site and beat any floral competition. Eucalypts are capable of rapid initial growth under the right conditions (as created by complete site preparation). Initial growth can be increased by the addition of fertilizer.

It is the aim of this section to detail fertilizer type and method of application to eucalypt plantations.

14.3: AUSTRALIA

14.3.1: APM FORESTS PTY. LTD.

Initial work with fertilizers regimes for eucalypts showed the potential hazard of incorrect technique. Therefore they introduced compressed 21 gram pills of nitrogen, potassium and phosphorous (N:P:K). Subsequent trials have developed safe prescriptions for granular fertilizer and now 100 grams of NPK is applied to each tree.

Fertilizer is applied using a spade slit 20 centimetres away from the seedling parallel with the slope. The fertilizer is placed into the hole and covered with three centimetres of soil. On steep sites 21 gram pills are still used at planting so as to avoid the need for a second pass across the site.

14.3.2: BUNNINGS TREEFARMS

One hundred grams of granular NP fertilizer (17.5:7.6 with 600 ppm zinc and 16% sulphur) is applied within one month of planting. It is placed three centimetres underground using a Pottiputki planting tool. Placement is at least 15 to 30 centimetres away (uphill) from the seedling. Compressed pill form fertilizer has been thrilled, but found to be of no additional benefit for the extra cost.

14.3.3: DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

On poor pasture sites with residual phosphorous below 15ppm, CALM apply 50 grams of granular diammonium phosphate per seedling. On better pasture sites with a residual phosphorous level of above 15 ppm, 50 grams of granular NPK is given to each seedling. In both cases, the fertilizer is buried 15 to 20 centimetres from the base of the seedling with a planting spear or Pottiputki planting tool two weeks after planting (Bradshaw (1990)).

14.4: THE PEOPLES REPUBLIC OF THE CONGO

Granular fertilizer (NPK) is applied by machine in a spot prior to planting. The granules are left on the surface (with high clay content soil). Planting is then into the fertilizer spot.

14.5: FRANCE

14.5.1: AFOCEL

At present they are developing their fertilizer prescriptions. Granular phosphorous and potassium (PK 1:1) fertilizer can either be applied before planting and ploughed in, or post planting (100 gram spot per cutting).

14.6: PORTUGAL

14.6.1: CELBI

Granular fertilizer application can be at planting or in a separate operation. In one trial trees received 200 grams of NPK per seedling. The effect of fertilizer is under investigation as part of the D95 Programme.

14.6.2: EMPORSIL

The original method of fertilization was to apply 150 grams of NPK (7:21:21) to the soil surface post planting. Now 30 grams of Osmocote (NPK, 11:22:9) is placed into the planting hole. Prior to the initial broadcast ploughing, phosphorous is broadcast across the site to promote rapid initial seedling root growth. The end result is an increased and more even tree growth.

14.7: SOUTH AFRICA

14.7.1: HANS MERENSKY HOLDINGS (PTY.) LTD.

At planting each tree receives 150 grams of granular NPK (2:3:2) applied in a band or spot on the surface of the soil.

14.7.2: HL AND H MINING TIMBERS

Each seedling receives 100 grams of NPK (2:3:2 26 percent active) post planting. Placement is two to three centimetres under ground in two 50 gram pockets at 30 centimetres on either side of the seedling. Further research is aimed to produce site specific fertilizer regimes.

14.7.3: ICFR

Extensive work has been done into the fertilizer requirements of eucalypt plantations. A general conclusion was that fertilizer regimes should complement not only the species planted, but the method of site preparation. In combination with the other site preparation operations, fertilizer was said to dominate the response. The greatest response was when combined with ripping. Site preparation gives the planted tree the ability to make use of any applied fertilizer. Adequate floral competition control was seen as essential to the successful use of applied fertilizer.

The different fertilizer formulations reflect site and species requirements. The following are their recommended fertilizer regimes. On fully prepared sites, apply 100 grams of ammoniated super phosphate. If a site with high organics has been ripped only or has been pit planted, apply 100 grams of NPK (2:3:2). With the same site preparation on low organic soils, apply 100 grams of NPK (2:3:1). On the sandy soils of Zululand, apply 40 grams of diammonium phosphate.

Individual tree spot application was seen as the best option. Care must be taken with high nitrogen fertilizers as they can burn tree roots. Therefore, fertilizers with 10 grams plus of nitrogen should never be placed less than 20 centimetres from base of the planted tree. Where a site has been ripped, fertilizer is best split into two equal portions and placed in a pocket in the rip lines at least 20 centimetres away from the base of the tree.

14.7.4: MONDI FORESTS

The fertilizer regime followed by Mondi depends upon the site. In the Transvaal each tree receives at planting 100 grams of granular NPK (2:3:2). Placement is in a spade slit adjacent to the tree. In Zululand, 25 grams of super phosphate is mixed into the puddle during the planting process, followed by a post planting application of limestone ammonium nitrate (which is 28 percent nitrogen).

14.7.5: NTE LIMITED

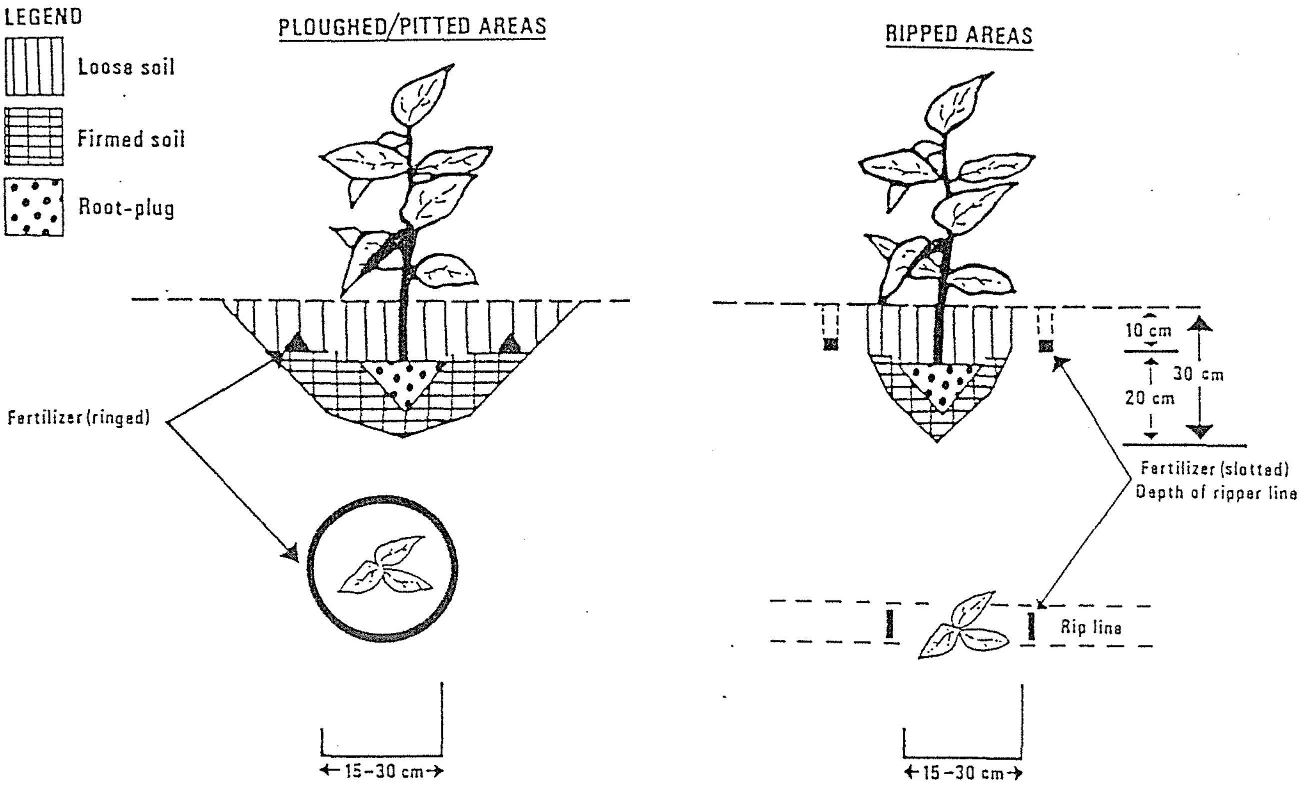
At planting, each tree receives 100 grams of NPK (2:3:2) fertilizer.

14.7.6: SAPPI FORESTS

Sappi's silviculture manual lists the essential steps for successful fertilization of planted eucalypts. The first step is to ensure that there has been adequate floral competition control within 20 to 25 centimetres of where the fertilizer is to be placed. The second step requires fertilizer to be applied immediately after planting.

Fertilizer is placed five to ten centimetres below the soil surface (figure 14.1), to allow it to add to the soil moisture (the source of plant access and uptake). It also protects the fertilizer from degrading, disturbance, surface runoff and drying out.

FIGURE 14.1: SAPPI FORESTS SILVICULTURE MANUAL (1989) FERTILIZER PLACEMENT PRESCRIPTION



If a re - application is required, or if the fertilizer is applied late, it is placed in two slots 10 centimetres deep, 25 centimetres from either side of the tree. Any ring placement below the soil surface may result in root burning and tree death.

On fully cultivated sites, 100 grams of granular ammoniated superphosphate per tree is to be applied. Such sites in Zululand require 100 grams of granular NPK (4:1:1 30 percent nitrogen) applied three weeks after planting (at the time of infilling). Those site that previously grew acacia species require 120 grams of granular superphosphate (10.5 percent phosphate) per seedling.

Those sites that have been ripped or pitted require 100 grams of NPK (3:2:1 25 percent active) granular fertilizer per seedling. If a site has a high organic component, 100 grams of granular NPK (2:3:2 22 percent active) is applied per tree.

14.8: DISCUSSION

The addition of fertilizer to planted eucalypts returns an economic growth response. The degree of response is dependant upon the intensity of the other site preparation components. Full site preparation will give the greatest response and the least response is with pit planting. In order to ensure that the planted tree gains access to the applied fertilizer, adequate floral competition control is required.

The uptake of any applied fertilizer is through the planted trees' root system, absorbing minerals and nutrients from the soil water. Therefore to ensure maximum access to the fertilizer, it should be covered by at least three centimetres of soil. Surface application of fertilizer may result in fertilizer loss due to runoff or wind erosion. Spot application of granular fertilizer was the most common method. Such application would ensure that the planted tree, rather than floral competition obtained the most benefit. To prevent root damage and death due to burning, fertilizer should be applied at least 20 centimetres (on the contour), away from the planted tree.

Broadcast application of fertilizer and subsequent ploughing in maybe an option on some site, especially were a soil is deficient in phosphorous.

The formulation of fertilizers varied with local site conditions. Generally nitrogen, phosphorous and potassium were added in varying ratios. Soil survey information, combined with the individual requirements of a given species will determine the required nutrients. Consideration must be given to the availability dynamics of the applied nutrients. For example, a soil with a high clay content will quickly bind any added phosphorous and therefore the fertilizer applied needs to address such a reaction.

15.0: PLANTATION MAINTENANCE

15.1: SUMMARY

It has been found that where a plantation canopy is incomplete, maintenance is required to remove any other species that develop in direct competition with the planted trees.

The degree of maintenance required to remove floral competition can be minimised. A strip application of contact and residual herbicides at establishment which leaves a strip of vegetation which can then be ploughed over the first or second summer. Provided that the species planted can rapidly grow to crown closure, a site can be captured with minimal maintenance.

Competition may develop after thinning from coppice and other species on the site. Both require controlling. Mechanical methods may suffice, if not broadcast spraying or wick wiping with a knock down herbicide may be required.

Introduction of sheep to a plantation not only provides a rental return, but gives a much more complete control over competing species (provided that the species are palatable). As well the sheep grazing will reduce the fire risk and return nutrients to the soil by the deposition of dung.

15.2: INTRODUCTION

Within the period following establishment and prior to crown closure, a site cannot be considered as captured. Light still reaches the ground and other competing species can develop. Such competition may reduce plantation growth rates by consuming some of the sites limited resources.

It is the aim of any maintenance programme to reduce the level of floral competition. The degree of competition development will be determined by the previous land use and more importantly the degree of site preparation. It is the aim of this section to detail the post establishment maintenance programmes and relate them back to the initial site preparation techniques.

15.3: AUSTRALIA

15.3.1: APM FORESTS PTY. LTD.

APM Forests Pty. Ltd. has long used inter-row chopper rollers in the maintenance of pine plantations. Similar inter-row works are now being carried out in eucalypt plantations, using heavy duty slashers behind small crawler tractors on ex - scrub sites. This enables works to be carried out on limited side slopes were trailing chopper rollers would otherwise slide into the planted trees. On ex-pasture sites, the inter-row grass strips are rotary hoed during the first summer to reduce water competition. In both cases a successful strip spraying of residual herbicide leaves only a 1.3 to 1.6 metre wide strip of regenerated competition that requires treatment.

Chemical methods (inter-row and complete coverage) are under consideration. Regimes have been developed, but they have not been justified based on economical or environmental considerations. Sheep are introduced to graze out grass and noxious weeds. Goats are used on a more limited scale at much later stages of plantation development.

15.3.2: BUNNINGS TREEFARMS

By the time of the autumn break following planting, the trees are 1.2 metres tall. Sheep can then be introduced to ex - pasture sites. Sheep keep the grass down low to reduce fire risk and the level of competition. After crown closure there is very little growth under the plantations, but sheep can still graze road and edge areas. No mechanical works are carried out.

On ex-bush sites (grey sands), later age fertilizer is required. Thin tree crowns give limited canopy closure, allowing light into the plantation. Floral competition growth is prolific and is inter-row disc cultivated. Broadcast application of 180 kilograms per hectare of super phosphate then follows.

15.3.3: DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

On ex-pasture sites sheep are introduced after a few months to reduces pasture competition and fire risk over the first summer. The exact timing is a function of tree growth as sheep may trample the trees.

Inter-row application of herbicides with directional nozzles has been thrilled at age 13 months. Feathering was observed were glyphosate was used (as described in section 10.7.4). A trial was established using a wick wiper to determine the benefit of complete floral competition control. The results will be used to determine the cost / benefit constraints for complete floral competition control.

Later age fertilizer is under consideration.

15.4: THE PEOPLES REPUBLIC OF THE CONGO

Prior to crown closure (for the first two years), plantations are hand weeded around the trees and inter-row disc ploughed. The aim is to reduce competition for moisture. After crown closure there is very little growth on the plantation floor.

15.5: FRANCE

15.5.1: AFOCEL

On all sites, inter-row cultivation is used to remove both grass and scrub competition. In some cases inter-row mowing is carried out. Agricultural tractors are used with normal agricultural implements.

15.6: PORTUGAL

15.6.1: CELBI

The aim of any maintenance work is to reduce competition for water by other floral species on the site. One option is to increase stocking rates, but it restricts machine access. On some sites they hand hoe around each trees, but it can result in the removal of soil from the base of tree making it unstable. Therefore, they push soil up against the tree to counter the effect.

Inter-row ploughing is done to remove floral competition, for the first two years. Care must be taken to avoid damage to the tree roots. The end result is reduced competition and fire risk.

15.6.2: EMPORSIL

EMPORSIL research has shown that trees require floral competition free conditions on ex - pasture sites for the first two to three years. It can be achieved by hand hoeing around each seedling and inter-row ploughing. Hand hoeing was required up to three times in the first year and ploughing prior to the fire season. Both competition and fire risk are reduced.

Ploughing is to 0.30 to 0.40 metres depth with a ridge thrown towards the planting line. Investigations have shown that 80 to 90 percent of active tree roots are in the first 0.4 to 0.5 metres of soil. Therefore the depth of cultivation was destroying the tree root system.

With the use of herbicides to control initial floral competition, EMPORSIL has avoided the need for hand hoeing. New prescriptions for inter-row ploughing have been developed to avoid tree root damage. Inter-row spraying with glyphosate was thrilled and was found to kill the planted trees. Due to the uneven ground conditions, mowing of inter-row strips has not been considered possible.

15.6.3: PORTUCEL

During the first year, floral competition growth underneath plantations is removed by hand hoeing and ploughing.

15.7: SOUTH AFRICA

Several species have become noxious weeds in South Africa. These include <u>Solanium</u> <u>mauritianum</u> (bug weed) and <u>Lantana</u> <u>camara</u> (lantana). <u>S.mauritianum</u> was reported to be growing in Queensland and is potentially a threat to Australia if not controlled.

15.7.1: HANS MERENSKY HOLDINGS (PTY.) LTD.

Their aim is to keep plantations free of other floral competition species until crown closure. Under local conditions crown closure is complete after one year.

If a site is burnt as part of site preparation, peanuts are grown inter-row by the local villagers in 0.25 hectare plots. The rules of the lease include that the lessee must keep 0.4 to 0.6 metres away from the planted trees and there is to be no pruning of the lower branches of the trees. The area must be kept free of all other floral species. The site must be left bare once the crop has been harvested. If the rules are not followed, the lessee is banned from a lease in the following season. The Company aims to help the villagers by supplying genetically improved peanut seed in the future.

Back pack application of herbicides to control inter-row floral competition is an option.

Contractors are used to slash out all other floral competition two months after first thinning, by which time all surviving stumps have coppiced. Any coppice development is removed and coppice poles are sold for CCA treatment (for use as hut roofing poles). Live stumps are poisoned with triclopyr and diesel. After each thinning, similar operations ensure that by the end of the rotation sites are clean of all coppice (some ground cover is left to encourage native animals).

15.7.2: HL AND H MINING TIMBERS

The aim of the maintenance programme is to keep floral competition to a minimum. If a pre-plant spraying was not possible, sites are post plant sprayed with glyphosate and using a tree shield. In some instances a total spray with glyphosate is carried out using a rickshaw. Up to two complete sprayings maybe carried out before crown closure. Hand slashing is as an option.

Inter-row discing is only allowed once by Company policy. It must be carried out before trees are one metre high and is only to 0.1 metres depth up to the tree base. In some cases despite Company policy it is done up to three times before crown closure.

Hand slashing between coppice rotations removes scrub to allow the coppice to develop free of floral competition.

15.7.3: ICFR

Long term research by the Wattle Research Institute has shown that for all species it was necessary to keep sites free of floral competition prior to canopy closure. The method to achieve such a goal was dependant upon the degree of initial site preparation. Hand hoeing around the tree base, followed by inter-row rotary hoeing is an option in the absence of residual herbicides. Inter-row glyphosate application was also seen as an option.

15.7.4: MONDI FORESTS

The principle of total floral competition control up to crown closure is achieved by a range of methods, depending upon site conditions, site preparation and previous land use. In the Zululand area, plantations are hand hoed up to five times in the first year. Where possible sites are disced.

Glyphosate is applied with a rickshaw to some sites in the absence of labour. It was stated (section 10.7.4), that Mondi has observed and tested glyphosate's effect on E.grandis.

In the Transvaal stumps are treated with glyphosate after thinning. Application is by the faller or an assistant. The aim is to prevent coppice from developing as it competes with the retained stems. In some instance a complete understorey spray operation or hand slashing is undertaken.

15.7.5: NTE LIMITED

Several methods of floral competition control are used prior to crown closure (usually at two years). Glyphosate and paraquat are applied using a rickshaw (taking 16 man hour per hectare). Application of 11 litres of mixture per hectare is considered optimal with micro herbi spray heads, to give 0.475 to 0.700 kilograms per hectare of active ingredient (glyphosate). The aim is to check competing species growth rather than effect a kill, to prevent soil erosion.

Inter-row discing is carried out on flat sites, but only before trees reach one metre in height (to prevent tree root damage).

15.7.6: SAPPI FORESTS

Floral competition control up to canopy closure is seen as critical, with the method site dependant. The objective as stated by their silvicultural manual is to kill the competition. Operations take place both before crown closure and prior to clearfalling.

In the Highveld grass species are the main competition. The options are to hand weed (around the trees or the entire plantation), spray, mechanical slashing or mechanical inter-row cultivation to a maximum depth of 40 millimetres. Treatment in frost prone areas is critical as the retardation in growth is enough to leave the trees susceptible in the next frost season.

In the Lowveld all site are hand slashed prior to spraying for woody competition control. It was stated that it is important not to remove the lower branches of the tree, as this reduces the tree's photosynthetic potential. On sites prone to erosion after hand hoeing, goats are used to graze out the competing species. Goats may trample the planted trees, but find them unpalatable. Therefore great care is required in the management and supervision of the goat herd. The goats dung is said to fertilize the site.

15.8: DISCUSSION:

The overall philosophy of plantation maintenance appears to be one of floral competition control during periods of incomplete canopy closure (from time of establishment to canopy closure and after thinning). The species of eucalypt involved under given site conditions will dictate the time to canopy closure. For example E.regnans has a very sparse crown and never really completely develops a closed canopy. Species such as E.nitens, E.globulus subsp. globulus and E.grandis all develop closed canopies.

The degree of site preparation will influence the maintenance required to control floral competition development. The use of contact herbicides will relieve the need for around the tree hoeing for only a short period. Figure 10.1 presented the different levels of initial floral competition control. If only contact herbicides are used, the area sprayed will soon be recolonized by floral competition, after which around the tree hoeing is required. The use of residual herbicides will remove the need for manual "around the tree treatments", leaving only the inter - row strip to be treated. The planted tree's canopy development over the residual herbicide treated ground should control re - colonization by other species.

Inter - row strip spraying is an option, but it requires special attention to the protection of the tree crop. Safe herbicides can be used, but a rickshaw type applicator would increase the degree of protection. Consideration of cost and any adverse environmental effects must be made in order to justify such an operation. Inter - row cultivation is a cheap and less damaging option provided that the plough or rotary hoe pattern does not promote erosion. A very shallow depth of cultivation is preferable so as to not damage tree roots. Such operations should be carried out prior to the development of tree roots into the inter - row strip, using tree height as an index of root development. Any index would be dependant upon a species / site interaction.

If a plantation is to be thinned, much of the understorey will be damaged by machine activity. A post thinning operation would require less work and be able to treat any coppice development (species dependant).

Sheep should be introduced once there is little chance of damage to the planted crop. Regular checks should be made to ensure that the sheep do not bark strip the planted trees. Adequate fencing will be required, but the cost can be returned in rent for grazing. The removal of a need to control some species of noxious weed and the reduction of fire danger are additional benefits. As well any vegetation consumed will pass through the sheep and return the nutrients to the soil.

16.0: FIRE PROTECTION

16.1: SUMMARY

Fire threat is a common characteristic of the areas into which eucalypts are planted. Preparation, detection and rapid (and effective) initial attack were the key points to fire protection of eucalypt plantation estates visited.

Strategic fire breaks and maintenance of plantations in an understorey free condition were key to the success of fire fighting. Effective fire detection systems that made best use of the resources available were critical to rapid initial attack. Rapid initial attack by whatever means available will reduce damage. Aerial systems were in favour due to their effectiveness.

16.2: INTRODUCTION

Australia's flora has evolved in the presence of fire. It has not evolved a resistance to fire, but rather mechanisms for dealing with the result of fire. When not killed by fire, eucalypts suffer from a lack of water uptake or drought due to crown loss. A prolific flush of accessory buds results restoring the crown and therefore the uptake of water.

A site's fire regime is composed of two factors; frequency and intensity. By the influence of management, both can be modified for the natural forest. In plantations, fire can be both a useful tool and a destructive force depending on conditions. It is the aim of this section to detail fire protection measures encountered in the organisations visited.

16.3: AUSTRALIA

16.3.1: APM FORESTS PTY. LTD.

Fire is a constant and real threat to APM Forests Pty. Ltd. plantations. Ignition sources vary with arson and power lines as frequent causes. Other causes include accidental ignition by machinery, lightning and escaped recreational fires (BBQ and camp fires). Fire detection and suppression is in conjunction with the State Electricity Commission, Department of Conservation and Environment and the Country Fire Authority.

Fire losses have been minimised by rapid detection and response. Aerial detection on most summer days (weather permitting), combined with ground observation permits the rapid dispatch of crews. A fleet of 13 fire tankers and various mobile plant (bulldozers and motor graders) combined with a trained crew are used in fire fighting. In recent years helicopter fire bombing has been used with great success. Preparation of mineral earth fire breaks and grass slashing helps in fire suppression. Road access is ensured by roadside slashing and grading.

16.3.2: BUNNINGS TREEFARMS

Most fire detection and suppression is in conjunction with the Department of Conservation and Land Management, and the Bushfires Board of Western Australia. Presently, due to the small number of permanent employees, Bunnings Treefarms only has two fire tankers and a number of slip-on units for company utilities. A standby system has been set up for company employees and staff. No use is made of aerial fire bombing.

Under the Bush Fire Act of 1954, fire breaks are required by the various Shires. The initial preparation is by ploughing to get a flat surface, after which they are annually sprayed with glyphosate and sulfometuron methyl.

16.3.3: DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

Fires started by natural causes or arson are a constant threat to CALM's native forests and plantations. Detection is by aircraft, towers and ground patrols. Highly trained and experienced crews, with modern equipment are available for fire fighting.

Control burning of native forest has long been practised, but as yet it is not carried out under eucalypt plantations. Both chemical and mechanical fire breaks are prepared on an annual basis. The actual width will depend upon local government requirements.

16.4: THE PEOPLES REPUBLIC OF THE CONGO

During the dry season, the grass cover under and around the plantations becomes very dry and is a potential fuel for wild fires. Inter-row maintenance work and external fire breaks are prepared along roadsides to reduces the threat. They also help with plantation access by allowing roads to dry through better air circulation and light onto the road surface during the wet season.

16.5: FRANCE

16.5.1: AFOCEL

Over summer there is the possibility of fire. Fire breaks are prepared prior to summer and plantations are inter-row cultivated. Aerial bombing of fires is common.

16.6: PORTUGAL

Throughout Portugal there exists opposition to eucalypt plantations. Over the very dry summer months, it is not uncommon for large losses due to arson. Volunteer fire fighting units complement the fire fighting resources of the companies growing eucalypts, who in turn contribute funds to the volunteer units. Overall, one of the greatest hindrances to fire fighting is poor access to plantations.

16.6.1: CELBI

In 1989 1000 hectares of plantation were burnt, which amounts to two percent of Celbi's plantation estate. In 1989, 5000 hectares of private plantations were burnt in areas adjacent.

Celbi takes the following measures to protect it's plantation estate from fire. All plantations have good access and trees are kept well away from powerlines. Inter-row maintenance reduces fuel levels. A well equipped standby crew is available for fire fighting. Three helicopters are available to fight fires and to support aerial detection.

16.6.2: EMPORSIL

Fire protection works include good access development and maintaining plantations free of understorey.

16.6.3: PORTUCEL

Fire breaks are ploughed after the last rains of winter to avoid erosion. Fire detection is from the air using fixed wing aircraft. The local aeroclub provides pilots free of charge and the Company funds the aircraft. Aerial and ground based fire fighting is used.

16.7: SOUTH AFRICA

16.7.1: HANS MERENSKY HOLDINGS (PTY.) LTD.

In the Tzaneen area fire is not a great problem due to the climate, however most threat occurs in the dry winter months. The most common causes of fire are arson, bee keepers and lightning. Towers are used to detect fires. The cost of manning the towers is split with other local organisations. All fire breaks are slashed by hand and control burns are used in some areas to reduce the threat.

Tankers and slip on fire units are used in fire suppression. Fire suppression operations are shared with the other local forestry companies.

16.7.2: HL AND H MINING TIMBERS

Arson and accidental ignition are the most common cause of fires. Bee keepers use smoke rags while collecting honey and often cause wild fires. Therefore the Company is attempting to educate the surrounding populations.

Fire detection is from towers and spotter planes. Suppression is by local farmers who are part of a fire committee, equipped by the Company.

16.7.3: MONDI FORESTS

In the past a row of eucalypts were planted within pine plantations as fire breaks. The opposite effect resulted with the eucalypt belts acting as wicks through the rest of the plantation. Fires maybe started either deliberately, by accident, or by lightning. Fire detection is mainly from towers. In the Highveld, aerial fire suppression is with fixed wing aircraft.

16.7.4: NTE LIMITED

Fire is a big threat to Company plantations. Mobile fire units use trailer tanks and slip on utility units.

16.7.5: SAPPI FORESTS

Fire is a major threat to Company plantations. Fires are either by accident, arson or from natural causes. Losses in the Eastern Transvaal area have been significant with over 5000 hectares of plantations burnt in one fire (a number of other companies plantations were burnt along with those of Sappi to make up the 5000 hectares).

Fire detection is from fire towers and by aircraft. Fire fighting is carried out using both ground units and aircraft. Fire breaks in the Highveld are prepared by strip spraying grass lands with glyphosate, allowing the grass to dry and then burning the strip.

16.8: DISCUSSION

The vulnerability of plantations to destruction by fire is an ever present threat. The degree of threat can be related to the local environment. However, management options can reduce the transformation from threat to event.

Keeping the plantation floor clear of vegetation, not only reduces competition, but reduces the rate of spread and intensity of any fire event. Slashing, ploughing and grazing are the best options, with grazing the most beneficial in that it will give an economic return as well as complete coverage (provided that the vegetation is palatable to stock). Adequate and well maintained fire breaks were a common factor in plantation management.

Early detection and the rapid suppression of any fire will minimise damage. The detection systems encountered ranged from ground based (vehicle patrols and tower surveillance) through to aerial patrols. Aerial patrols are expensive, but they are the most effective (weather permitting). Pilots, can sometimes be obtained for no cost from training schools in return for payment of aircraft hire.

A range of fire fighting equipment was encountered. Initial attack by aerial systems appeared to be favoured were funds allowed. In South Africa, fixed wing aircraft were preferred and very effective where a large number of equipped airstrips were available in the Highveld. Helicopters were more in favour were such infrastructure was not available. Ground crew equipment varied, as did the structure of fire fighting crews. Wherever possible, companies supported local rural fire brigades with funds and equipment as a supplement or replacement of their own resources.

17.0: PESTS AND DISEASES

17.1: SUMMARY

Disease and insect attack are generally associated with stressed trees. Several cases were observed. As eucalypts are planted on more marginal sites, stress will increase followed by greater susceptibility to attack by otherwise passive agents.

Of all the insect pests mentioned, Phoracantha semipunctata Fabricus is of greatest concern. Two examples of attack on eucalypt plantations are known. If unthinned pulpwood rotations are planned, they may have to be shortened to a point before stress allows attack, or be planted at wider espacements. Apart from exclusion of sawn products by the boring of the larval stage, pulp yield will be reduced and chemical consumption increased by the stimulation of kino production.

Better species matching to site, wider initial espacement and thinning could all be used to reduce tree stress and therefore reduce the potential of pest and disease attack.

17.2: INTRODUCTION

Associated with eucalypts are a diverse insect fauna, including leaf miners, leaf skeletonizers and a range of insects that harvest and consume eucalypt foliage. Insect populations vary, with peaks resulting in severe defoliation. For example in south west Western Australia there was severe insect attack on E.rudis Endl. in 1986 and 1987. Other insects consume the woody bole of standing trees. For example the termite Porotermes adamsoni Froggatt attack on E.regnans is common in alpine areas of Victoria.

It is the aim of this section to present the information collected on insect attack and any pathogens encountered as a problem in eucalypt plantations.

17.3: AUSTRALIA

17.3.1: APM FORESTS PTY. LTD.

As yet there has been no significant outbreaks of disease. However, where plantation remain unthinned at later ages (approximately 17 years) severe stress results. It is not uncommon in both E.globulus subsp. globulus and E.regnans plantations to see red kino stains exuded onto the outer bark. The effect is most noticeable were species have been planted off site. The bark stain appears to be coming from holes made in the bark by Phoracantha semipunctata Fabricus (long horned beetle). On inspection of several E.globulus subsp. globulus, there had been extensive damage to the cambial layer, with the larvae boring into the heartwood. Thinning to remove such affected trees is aimed to control the insect by removing the next generation of adults and by reducing individual tree stress.

17.3.2: BUNNINGS TREEFARMS

The main insect pest on planted trees is the spring beetle. Normally it eats grass and lives underground. Once spring arrives, the beetle becomes active and emerges to graze seedlings almost to a state of defoliation. One method of reducing the threat of the beetle, is to retain an inter-row strip on which it can feed.

P.semipunctata has been observed on stressed planted eucalypts.

Phytophthora cinnamomi Rands is well documented in Western Australia. Therefore, initial and future selected species are known to be resistant to P.cinnamomi. Resistance has been determined by glasshouse and field experiments.

Several, otherwise healthy E.globulus subsp. globulus were observed to have the beginnings of stem cankers or bark lesions. There appeared to be no real effect on plantation development.

17.3.3: DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

Insect attack is one of the major causes of plantation failures. If trees fail to grow rapidly through the first spring, they can be defoliated and killed by spring beetle attack. Grass cover in the inter-row strips is retained as an alternate food source. The African Black Beetle is a recent pest. It kills seedlings by ring barking below the soil surface. Attempts have been made at control by applying Marshall Saseon Granules.

P.semipunctata has attacked drought stressed E.globulus subsp. globulus (aged 14 years). The site had been visited several times in the past and was well known to the author. Great changes in the health of the stand were observed. Abbott (1985) gave details of the Phoracantha spp. attack in Western Australia, with the main concern as the attack of fallen trees.

Infestations of the Psyllids spp. (lerps) are common and are not detrimental to the planted trees.

17.4: THE PEOPLES REPUBLIC OF THE CONGO

Termites are a problem on the grass land areas and cuttings are watered in with insecticide. Helopeltis bergrothi is an insect parasite on juvenile plantations. Helicopter spraying has been used to control insect pests.

There is recognition of the danger in having such a narrow genetic base with their clonal programme. Attempts are being made to broaden the base to prevent disease epidemics.

17.5: PORTUGAL

A common threat to Portuguese eucalypt plantations is P.semipunctata. It arrived, or more likely was noticed in the early 1980s and has had the greatest impact in dry areas (stressed plantations). Higher stocking rates and therefore greater water stress are associated with infestations. It was difficult to get an actual quantification of the attacks.

17.5.1: CELBI

P.semipunctata has been observed and is of concern. Dipcilla spp. (sugar aphids) occur on eucalypt growth tips and have been shown by research not to be a problem.

Armillaria spp. have been noted. They occur on dead wood and it is thought that they may colonize dead wood sections of live trees. Old stumps are seen as the source of the fungi and are removed or covered with soil. Branch stubs are thought to be another potential entrance point for fungal attack.

17.5.2: EMPORSIL

P.semipunctata is of concern and a research programme is investigating the insect's life cycle. Pheromone traps are one envisaged method of control. At present any host tree to P.semipunctata is culled. Psyllids spp. have also been observed, but are not considered a threat.

Research is underway into both pathogenic and beneficial fungi with the aim to introduce the beneficial fungi to exclude the pathogens.

17.5.3: PORTUCEL

Areas prone to P.semipunctata attack have been identified as those inducing plantation water stress and are hot / dry or cold / frost sites. E.viminalis was stated as being prone to insect attack in the southern areas, but not in the north.

17.6: SOUTH AFRICA

17.6.1: HANS MERENSKY HOLDINGS (PTY.) LTD.

No disease problems have arisen, however they recognise the need for disease resistant clones.

17.6.2: HL AND H MINING TIMBERS

As they have embarked upon a clonal path, HL and H aim to exclude disease susceptible clones. They have a policy of 30 hectare maximum mono clonal plantings, with 30 clones to give 900 hectares of plantation before a clone is repeated.

E.globulus subsp. globulus and E.viminalis are not planted due to destruction by Gonipterus scutellatus Gyllenhal (snout beetles, introduced to South Africa from Australia in the last century). E.smithii and E.macarthurii are attacked to a limited extent.

Mycosphaerella spp. attacks the juvenile foliage of E.nitens, therefore N.S.W. provenances are planted due to their rapid transition to adult foliage. Black leaf spot will kill E.nitens under humid conditions, as will white leaf spot on E.grandis. A

E.nitens X E.grandis clone has shown resistance to both diseases.

17.6.3: ICFR

The ICFR recognises that as greater emphasis is placed on clonal stock, with planting on marginal sites, disease will become a significant threat. They have also found that shallow planting and pushing plants into the ground results in deformed roots. Stress increases, wind firmness decreases and the chance of disease is greater.

Phaeoseptoria eucalypti (a leaf spot pathogen) defoliates stressed trees. Research aims to find effective chemical control methods and to determine species susceptibility. The climatic conditions with the greatest danger of attack are under investigation.

17.6.4: MONDI FORESTS

As Mondi has a clonal base, disease resistance must be considered. They specify a maximum of 25 hectares be planted in a mono - clonal block. In the Zululand area, they have observed clones with variable susceptibility to Phytophthora spp. and stem cankers. Seedling stock are 40 percent effected by cankers which slow and in some cases halt tree growth.

17.6.5: NTE LIMITED

Monocalypts are not planted due to P.cinnamomi attack on water logged sites, (excluding E.smithii from some sites).

17.6.6: SAPPI FORESTS

Macrotermies spp. (termites) attack tree roots in natural grass lands. They normally eat grass roots, but with complete site preparation only seedling roots remain. One solution is to retain inter-row grass strips. Seedlings are watered in with insecticide. E.dunnii are attacked, whereas E.macarthurii are not. Termites remain a threat till canopy closure.

Ex - wattle sites are high in nitrogen and are associated with P.cinnamomi and insect attack, therefore seedlings are planted with insecticides. The overall effect of P.cinnamomi is dependant on species / site interactions.

A hail stone prone belt with a five year cycle of bad storms has been identified. If a tree is subjected to hail damage, fungal attack soon follows. Such belts and susceptible species are avoided.

17.7: DISCUSSION

Tree stress is a factor common to both disease and insect attack. It is caused by growing species off site, over stocking and delayed thinnings. The attacking agent can either be indigenous or introduced.

In the organisations visited, selection of resistant genetic material was the main method to combat disease. Selection of species, provenances, families and clones were all observed. Of the species planted, E.globulus subsp. globulus appeared to be suffering the most. Other members of the same Pryor and Johnson (1971) grouping (table 7.1) were shown to be prevalent to disease and insect attack.

Such an observation is most likely due to extensive plantings of E.globulus subsp. globulus, allowing an agent to evolve the ability to utilize such a created niche. As plantation forestry is forced onto more marginal sites, stress is common. Once trees are stressed disease resistance is reduced. A combination of the two creates a disease problem.

Planting of clones presents an increased disease risk. Those companies that have gone "clonal" have developed a policy of a maximum mono clonal plantings of 25 to 30 hectares. Selection of disease resistance in clones is seen as a priority.

P.semipunctata naturally attack recently felled logs or dead and dying trees. In Western Australia it is a significant pest of E.marginata Donn ex Smith (jarrah) (Clarke and Ellis (1989)). The insect attacks the sapwood of the host tree, after which it bores into the heartwood to pupate. Initial cambial and sapwood damage was observed on standing E.globulus subsp. globulus in W.A. and was found to be associated with increased kino production. The boring of the larvae will exclude any attacked tree from sawn timber production. The increased kino may make an otherwise excellent pulping species less desirable due to increased chemical consumption and reduced pulp yield associated with kino (Higgins (1978)).

A host of potential insect pests and diseases are present in Australia. Currently plantations are being forced onto more marginal sites due to land cost. Rainfall isohyets of as low as 600 millimetres are being used to define the extent of planting. The chance of drought is high. With intermittent patches of native forest, there must be a ready source of P.semipunctata (and a host of other threats). Under stressed conditions, planted eucalypts (especially E.globulus subsp. globulus) will become prone to attack. In the absence of attack, trees may otherwise recover from drought. If sites are not thinned (ie a pulpwood rotation) stress will be greater. Species / site matching will help to minimise tree stress. If a longer rotation length is desired, wider initial espacement or thinning will be required to minimise tree stress and therefore insect or pathogen attack.

18.0: THINNING AND PRUNING

18.1: SUMMARY

The inherent self thinning nature of eucalypts, combined with susceptibility to insect and disease attack of stressed trees dictates that only short rotations are possible. Therefore thinning of eucalypt plantations is carried out in order to allow longer rotations to produce bigger tree sizes and therefore greater value products.

The overall production of a plantation is not greatly influenced by thinning as it will capture those trees which would otherwise self thin. Therefore if the production for a given site is known, a theoretical thinning regime can be developed. This will act only as a guide, but in the absence of any real data due to the lack of experience in Australia it has great potential.

Pruning was only carried out on those species that failed to eject the occluded branches. It was seen as necessary to maximise the volume of clear wood on trees destined to be saw or peeler logs. In some instances it was done as a fire protection measure. Only dead branches were removed to prevent reduction in the stands photosynthetic potential.

18.2: INTRODUCTION

The initial stocking rate for one naturally regenerated stand of E.regnans was 199 000 seedlings per hectare, but by age 11 years it had reduced to 2820 stems per hectare (Opie et al (1978)). While seedlings are small, part of such a reduction is due to browsing animals. After which natural mortality causes self thinning. Jacobs (1955) detailed self thinning and stand dynamics of natural regeneration based on crown shyness as postulated by Lane-Poole (1936).

In section 13 the effects of initial stocking rate on natural mortality were discussed. With longer rotations aimed to increase individual tree size, more intense management will be required. It is the aim of this section to present thinning and pruning regimes encountered with the organisations visited.

18.3: AUSTRALIA

18.3.1: APM FORESTS PTY. LTD.

Presently APM Forests Pty. Ltd. is thinning some areas of plantation. Apart from supplying pulpwood, the aim of the thinnings is to allow the plantations to continue healthy and vigorous growth. Stressed plantations of E.globulus subsp. globulus are being released and trees effected by P.semipunctata are removed. Rather than clearfall plantations, thinning is seen as a strategic option to promote stand increment while still expanding the plantation estate.

As yet regimes are under development with permanent plots to determine the effects of various thinning intensities. The current operations are based on third row outrow with the removal of suppressed individual in the retained rows. Second thinnings are envisaged. All operations are machine based, with mechanical de-barking. No pruning is carried out.

18.3.2: BUNNINGS TREEFARMS

Little work has been done on thinning eucalypt plantations. However, in 1985 due to projected difficulties in marketing P.radiata first thinnings, trial mixed pine / eucalypt (E.globulus subsp. globulus) compartments were established (the eucalypts as the proposed third and fifth row outrows). Inspection of one site showed it to be an interesting option.

A trial was conducted into pruning with the aim to supply essential oils. The different percentages of crown removal did effect tree growth in the short term, but they soon recovered.

18.3.3: DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

CALM commercially thins regrowth E.diversicolor F.Muell at age 50 years (plus) and have recently commenced thinning 20 year old regrowth. As yet no plantations have been thinned. Mixed plantings of E.globulus subsp. globulus and E.diversicolor were established in a 1989 trial. The aim is to use the E.globulus subsp. globulus component as a nurse crop to promote strong apical growth and self pruning, after which it will be thinned for pulpwood to leave the E.diversicolor crop to grow on for sawlogs.

18.4: PORTUGAL

18.4.1: CELBI

E.globulus subsp. globulus does self prune, but usually fails to fully occlude the branches. On dry and windy sites, the retained dead branches are bashed off for fire protection. The effect was questionable. On sites that had been terraced, the top side branches are pruned to allow machine access. They aim to prune the bottom one third of the total tree height.

18.5: SOUTH AFRICA

18.5.1: HANS MERENSKY HOLDINGS (PTY.) LTD.

An intensive thinning regime (as presented in table 18.1) is used to grow high quality sawlogs. Included is pruning to maximise clearwood and restrict the knotty core to 10 centimetres diameter. All thinnings are from below (removing the smallest and poor formed trees) with marking and check plots to ensure the correct espacement.

After first thinnings the retained trees are pruned. No live branches are removed as it has been shown to reduce tree growth. By age three trees are ten metres tall and have 12 centimetres diameter at breast height. A second pruning of dead branches takes place before the second thinning.

TABLE 18.1: HANS MERENSKY HOLDING PTY. LTD. THINNING REGIME

OPERATION:	AGE (YEARS):	STOCKING (STEMS PER HECTARE): BEFORE:	AFTER:	PRODUCT:
T1	2.5	1100	700*	P
T2	5.0	700	450	P,M
T3	8.0	450	300	P,M,S
CF	20.0	300	0	P,M,S

T- Thinning, CF- Clear Falling
P- Hut Poles, M- Mining Timber, S- Sawlogs
*- Prune to 7 metres and at age 4.0 to 4.5, prune to 10 metres

All operations are carried out with hand falling followed by hand extraction at T1, four wheel drive tractor or mule extraction at T2 and four wheel drive tractor extraction from subsequent operations.

18.5.2: ICFR

Schonau and Coetzee (1989) recommended that E.grandis be thinned as presented in table 18.2 based on the results of a long term thinning trial in Natal. The trial investigated thinning regime variables as stated by Van Laar (1984) and included; method, intensity, age of commencement and frequency.

TABLE 18.2: ICFR THINNING REGIME FOR E.GRANDIS IN NATAL

OPERATION:	AGE (YEARS):	STOCKING (STEM PER HECTARE): BEFORE:	AFTER:
T1	4	1333	750
T2	6	750	500
T3	8	500	350
T4	12	350	250
CF	20	250	0

Based on the Natal trial, Schonau and Coetzee (1989) concluded that to grow sawlogs or other valuable crops, a mean annual increment (MAI) of 20 and 30 cubic metres per hectare per year are required at ages 20 and 10 years respectively. T1 (first thinnings) should be early and heavy enough to remove all suppressed and poor form trees even though spacing is considered of great importance. The commencement of T1 will depend upon the value of the timber, mean tree size, markets and the relative cost of the exercise.

Subsequent thinnings should be up to age 12 and be lighter to prevent epicormic shoot development which would otherwise reduce the percentage of clear wood production. The frequency of thinning should aim to prevent the formation of crooked stems and live crown reduction.

18.5.3: MONDI FORESTS

In the Transvaal, Mondi aim to grow trees with a diameter breast height over bark (DBHOB) of 30 centimetres at age 24 years for sawlog recovery. Their aim is achieved by thinning and pruning as shown by table 18.3. The regime presented is the objective, but practical limitations may cause alterations. Pruning is by bashing and only removes the dead, but not fully occluded branches.

TABLE 18.3: MONDI FORESTS THINNING AND PRUNING REGIME

OPERATION:	AGE (YEARS):	STOCKING (STEMS PER HECTARE): BEFORE:	AFTER:	PRODUCT:
T1 *	4	1100	750	W,P
T2	7	750	500	W,P
T3	14	500	325	M,PP
T4 +	18	325	250	M,PP
CF	20 - 24	250	0	S,M,PP

W - waste, P - poles, M - Mining Timber, PP - Pulp and S - Sawlogs
+ - Maybe left out due to operational limitations.
* - Pruning commences before T1 and is to 4.5 and 6.7 metres at age 3 and 4 respectively.

18.5.4: SAPPI FORESTS

Eucalypts are only bashed or pruned to two metres above ground for fire protection.

18.6.0: DISCUSSION

Thinning can be defined as the removal of individual living trees from a stand before clearfalling or natural regeneration (Van Laar (1984)). A qualification of the above definition is that thinning removes trees that would otherwise die due to competition. The overall result is to achieve the objectives of plantation management.

It was stated in South Africa that thinning is only warranted where the aim is to produce sawlogs, veneer logs or transmission poles and that it was not considered an option for pulpwood, mining timber or firewood production. Before a thinning programme can be designed, the desired size and product type at clearfalling must be specified. The regime will be a function of growth rate (site and establishment) and rotation length.

In the Australia situation, the above must be qualified with the aims of specific management problems. If a longer rotation is desired to ensure strategic resource objectives (as is the case with APM Forests Pty. Ltd.), thinning is essential to ensure adequate stand hygiene and continued growth. As well, it captures the increment that would otherwise be lost due to natural mortalities.

It is then clear that thinning is an integral part and function of all previous factors of the silviculture of a stand, as they influence the development of individual tree competition. Competition in the South African situation commences at age 6 for E.grandis. Therefore beyond that age trees will die and production will be lost. T1 may then be uncommercial depending on the local situation, as will the nature of subsequent thinning. The overall aim is to reduce the stand to the final stocking as soon as possible to allow as uniform as possible growth rates under the fluctuations in climatic conditions.

It was shown by Schonau and Coetzee (1989) that MAI was not influenced by the intensity, frequency, commencement age, and final stocking, except were a 50 percent thinnings at two year intervals commenced before age six years. DBHOB and height increment are not significantly influenced by thinning. Height and MAI are a product of the site rather than management. However, it was stated that standing volume at age 20 years will be considerably decreased by heavy thinnings at long intervals. Overall, any thinning regime will be controlled by species / site interactions. Factors such as wind firmness and the commencement of self thinning must be taken into consideration.

Therefore for a given site, we can design a theoretical thinning regime by working around total volume production (volume of standing live trees at rotation plus the volume of natural mortalities) and the desired tree size at rotation. In the real situation, self thinning will dictate the bounds to which stocking rates can be manipulated.

Pruning was only seen as a benefit where clear wood was required in the final product or as a fire protection measure. Therefore it commenced as early as possible after T1, but only removed dead branches (so as to not reduce photosynthetic production).

The degree of self pruning is species specific under silvicultural and site conditions. It is a characteristic of some species to self prune, but fail to occlude the branches, and it is those branches that are removed. In terms of tree health, dead branches have been naturally sealed, and therefore the potential for pathogen entrance through the stubs is reduced.

19.0: CLEARFALLING; ROTATION, PRODUCTION AND PRODUCTS

19.1: SUMMARY

The decision to clearfall a plantation is dependant upon growth rate and the market specified log sizes. Site quality and silvicultural practices will dictate growth rate. Processing requirements and end use will dictate log size. As log size requirement increases, so will the required rotation length. As rotation length increases, so does the need for more intense management (including thinnings).

Even with rotations of 10 years in Australia it maybe necessary to thin in order to maintain stand hygiene and prevent pathogen and insect attack. The other option is to reduce rotation lengths or increase initial espacement. At present the growth rates achieved in Australian plantations are average to better than average when compared to the operations of the countries visited (table 19.1).

TABLE 19.1: SUMMARY OF MAI (CUBIC METRES PER HECTARE PER ANNUM), ROTATION AND PRODUCTS

ORGANISATION:		ROTATION:	MAI:	PRODUCTS:
AUST.	APMF*	30+	10 - 30	PP
	BTF	15	20	PP
		10	20+	PP
	CALM	12	15	PP
		8	35	PP
CONGO	ENGREF/CTFT*	7	15 - 20	PP
FRANCE	AFOCEL	10	20	PP
PORTUGAL	CELBI *	10	15	PP
	EMPORSIL *	12	17.5	PP
	PORTUCEL *	10	17	PP
S.AFRICA	HMH *	20	25	P,PP,M,S
	HL & H *	9	17.5	M,PP
	MONDI *	8 - 12	50	PP
		20	17.5	P,PP,M,S
	NTE *	10	30	PP
		10	11	PP
	SAPPI*	6 - 8	30	PP,M
		6 - 8	20	PP,M

* - ACTUALS
P - HUT POLES
PP - PULPWOOD
M - MINING TIMBERS
S - SAWLOGS

19.2: INTRODUCTION

Eucalypts will grow through developmental stages prior to eventual death. The longevity of eucalypts is species dependant for any given site. Factors such as fire, drought, wind or disease may cause premature death. The products recovered from a natural stand will depend on the developmental stage at which harvesting takes place. The same is true for plantations.

A combination of age, establishment technique and management will dictate plantation characteristics at the time of any operation.

Such factors have been discussed in previous sections. It is the aim of this section to detail rotation length, production and products for the various organisations visited.

19.3: AUSTRALIA

19.3.1: APM FORESTS PTY. LTD.

The proposed rotation length for eucalypt plantations is still under investigation. In the case of E.regnans, rotations in excess of 30 years are possible, provided that the stands are thinned. A mean annual increment (MAI) of 30 cubic metres per hectare per annum has been achieved on better sites, yielding with a 30 year rotation 900 cubic metres per hectare total (thinnings plus clearfall yield). Rotation lengths for E.globulus subsp. globulus plantations are in a similar stage of development. An MAI of approximately 10 cubic metres per hectare per annum has been achieved with the early plantations (currently age 18 years). In both cases, clearfalling will yield only pulpwood, as there is not a commercial outlet for plantation grown eucalypt sawlogs.

Clearfalling is expected to be machine based in most cases, with motor manual falling and machine extraction in special instances (such as steep country).

19.3.2: BUNNINGS TREEFARMS

A rotation length of 15 years is planned for routine sites with an MAI of 20 cubic metres per hectare per annum. Such sites are expected to yield 300 cubic metres per hectare of pulpwood. On sites with higher MAI (some sites are producing up to 40 cubic metres per hectare per annum at age 8 to 9 years), rotation lengths of 10 years are planned to yield approximately 400 cubic metres per hectare. Initial tests on the sawing of plantation grown eucalypt have been carried out, but as yet it is not a commercial option. Clearfalling is expected to be machine based.

19.3.3: DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

Rotation lengths are planned to vary according to site productivity. It has been predicted that an MAI of between 15 and 35 cubic metres per hectare per annum can be expected. Therefore rotation lengths of between 8 and 12 years are planned to give clearfall yields of between 180 and 280 cubic metres of pulpwood per hectare. Sawlog production is under consideration from mixed species plantations.

Clearfalling is expected to be machine based in larger plantations, but in small plantations or farm woodlots, it will most likely make use of the farmer's own tractor and chainsaw.

19.4: THE PEOPLES REPUBLIC OF THE CONGO

For the first phase of the project, a rotation length of 7 years is expected with an MAI of 15 to 20 cubic metres per hectare per annum. Production is expected to increase to 20 plus cubic metres per hectare per annum for stage two. At clearfalling the trees are 20 to 30 metres tall and are recovered down to a small end diameter of six to seven centimetres, producing between 105 and 140 cubic metres per hectare.

Pulpwood is recovered in 2.5 metre billets for the European market as there is not a pulpmill in the Congo. Poles (some for treatment) are recovered in 8.0 to 14.0 metre lengths. The residues are collected by local villagers for fire wood. Sawing of plantation grown logs has been thrilled, but was not successful.

Motor manual falling and cross cutting of billets is done by locally employed labour. Billets are hand stacked in the field and extracted by tractor.

19.5: FRANCE

19.5.1: AFOCEL

A 10 year rotation is planned with a projected MAI of 20 cubic metres per hectare per annum to give a yield 200 cubic metres of pulpwood per hectare. Clearfalling is expected to be by machine and motor manual operations with cross cutting into two metre long billets. Debarking is to be done in the plantation. Billets are to be extracted to the side of the road for collection and transport to the pulpmill.

19.6: PORTUGAL

19.6.1: ALHERS LINDLEY LDA.

In the past clearfalling was done by individual Company crews. Due to poor productivity (poor machine maintenance leading to breakdowns) it has moved across to contractors. 2.2 metre billets are cut, as it is the largest piece size that can be manually handled, as well as being the width of a truck tray. Therefore, ALHERS LINDLEY LDA. is attempting to introduce specialist machinery.

NORCAR machines were selected as they suited the Portuguese situation. They have low ground pressures and on the sandy soils of Portugal would create minimal compaction. Processing would be at the stump to retain organics onsite. Due to the fragmented nature of Portuguese plantations, frequent machine shifts are required. Due to it's size, the NORCAR system can be road registered for ease of movement. It can recover pulpwood down to 5.0 centimetres small end diameter.

19.6.2: CELBI

A 10 year rotation is standard, but it can be increased if plantation growth rates warrant. Currently an MAI of 10 to 22 (average 15) cubic metres per hectare per annum is achieved, with an average of 150 cubic metres per hectare of pulpwood recovered at clearfalling. The D95 project aims to increase the average MAI to approximately 30 cubic metres per hectare per annum.

Harvesting is mostly motor manual. The mill can handle any billet size, but with an increase in machine harvesting, piece size will become critical. Debarking is by hand in the field to retain organics onsite. In some instances the bark is left on and taken to the pulpmill to act as a boiler fuel for electricity generation. Presently 2.9 cubic metres of wood are required to produce one tonne of pulp. Sawlogs are not recovered, however harvesting residues are collected from some site to fuel brick kilns.

19.6.3: EMPORSIL

A 12 year rotation with an MAI of 15 to 20 cubic metres per hectare per annum produces 180 to 240 cubic metres per hectare of pulpwood. A 14 year rotation is used on drier sites near Spain. It is hoped to increase MAI of better coastal sites to 25 to 30 cubic metres per hectare per annum.

Clearfalling is by motor manual methods. Billets are cut and hand debarked. Debarking is best in winter due to reduced drought stress. No sawlogs are recovered.

19.6.4: PORTUCEL

A 10 year rotation with an MAI of 17 cubic metres per hectare per annum produces 170 cubic metres of pulpwood per hectare at clearfalling. Clearfalling is by motor manual methods, with sniggling to the roadside. If billets are to go straight to the pulpmill, they are not debarked. If billets are to be debarked, it is done in the field after which they are left to dry, which allows any attached dirt to fall off. No sawlogs are recovered.

19.7: SOUTH AFRICA

19.7.1: HANS MERENSKY HOLDINGS (PTY.) LTD.

Rotation length is set by the age at which a stand attains an average diameter at breast height over bark (DBHOB) of 38 centimetres (usually with a height of 40 metres), and occurs around age 20 years. They are attempting to introduce an inventory system to refine harvesting allocation. An average MAI of 25 cubic metres per hectare per annum is achieved. Prior to clearfalling, stands have all the understorey slashed, with coppice from thinned tree stumps recovered as payment (it is pressure treated for hut poles).

Clearfalling is by motor manual methods. The bark is cut at stump level on the standing tree and stripped upwards. The tree is then fallen. Sawlogs are extracted and transported on the same day to the sawmill. Mining timbers are cut and left for four weeks to allow drying down to the required moisture content. Pulpwood is not recovered from the Tzaneen operations due to location. After all merchantable material has been removed, local villagers are allowed to collect fire wood.

19.7.2: HL AND H MINING TIMBERS

Rotation length is dictated by the time taken to reach an average

DBHOB of 20 centimetres. With seedling stock it takes approximately nine years. It is anticipated that clonal plantations will be ready by age 4 to 6 years. Clonal plantations will have greater uniformity and therefore more trees with the desired DBHOB, giving greater mining timber recovery per tree. With seedling stock, an average MAI of 17.5 cubic metres per hectare per annum is achieved. It is claimed that by the use of clonal stock MAI can be increased to 28 cubic metres per hectare per annum.

Clearfalling is by motor manual methods. Prior to falling the bark is cut around at the stump and stripped upwards. A 10 centimetre height stump is left depending upon how many coppice crops have preceded. Logs are cross cut into mining timber and pulpwood (1:1 ratio by volume). Mining timber is twice as valuable as pulpwood. Billets are left in the field to dry for five weeks, after which they are sorted and stacked at roadside. Transport to railway yards is by truck, with rail transport to the processing centre. Table 19.2 presents a breakdown of the two products. Mining timbers are double chipper cantered (two edges) for preparation into slabs (90 percent) or left round as mine props (10 percent). Some props are encased with metal for extra strength (30 percent) and others are treated with flame retardant (30 percent).

TABLE 19.2: PRODUCT BREAKDOWN FOR HL AND H MINING TIMBERS

	PULP:	MINING TIMBER:
LENGTH (METRES)	2.4	2.4
DIAMETER (CENTIMETRES)	DOWN TO 3.0	14.0 TO 24.0
PRODUCTION (CUBIC METRES)	1 460 000	1 460 000

Mining timber specifications are very strict. Storage and handling practices aim to minimise splitting. The timber must have a specific gravity of 420 to 450 kilograms per cubic metre, providing compression and load bearing strength. In South Africa, for every kilogram of gold produced, 2.5 tonnes of eucalypt mining timbers have been consumed.

19.7.3: MONDI FORESTS

In the Zululand area, only pulpwood is produced. An 8.0 to 12.0 year rotation is applied, with clearfalling once they achieve a standing merchantable volume of 420 cubic metres per hectare. An average MAI of 50 cubic metres per hectare per annum is standard with seedlings, but improvement is anticipated by the use of clonal stock.

In the Transvaal, sawlog rotations are applied. Clearfalling is scheduled once a stand attains a mean DBHOB of 30 centimetres (with a height of 30 to 40 metres). It usually results by age 20 years. Their average MAI is 17 to 18 cubic metres per hectare per annum. It is hoped to increase the average MAI to 35 cubic metres per hectare per annum by the use of clonal planting stock. Table 19.3 presents the average product breakdown for a 20 year old stand in the Sabie area. There is no set end use for any one plantation in the Transvaal (unlike the Zululand operations).

TABLE 19.3: AVERAGE STANDING PRODUCT BREAKDOWN (CUBIC METRES PER HECTARE) FOR THE SABIE AREA

SAWLOGS	266
PULPWOOD	44
WASTE	44
TOTAL	354

Clearfalling is by motor manual methods with extraction of tree lengths by a skidder. Products are sorted and loaded accordingly. Pulp and mining timbers (if any) are left to dry on the landing. A Bell Infield Logger is used for loading trucks. At clearfalling stumps are killed by spraying with glyphosate.

19.7.4: NTE LIMITED

Rotation length is usually 10 years, however they are now trying achieve the best overall delivered wood costs by balancing growth rate variation with distances to Mondi's pulpmills. The average MAI varies with site preparation technique. Full site preparation will produce 30 cubic metres per hectare per annum, where as pit planting will only give an MAI of 11 cubic metres per hectare per annum.

Clearfalling is by motor manual methods, with cross cutting into 2.4 metre billets. The wood is left for six weeks to dry before transport to the pulpmill. No sawlogs are produced.

19.7.5: SAPPI FORESTS

A rotation length of six to eight years, produces an average MAI 20 (Highveld) and up to 30 (Lowveld) cubic metres per hectare per annum. Pulpwood and mining timbers are recovered. Clearfalling is by motor manual methods, with the bark cut at stump level and stripped up before falling. The fallen trees are cross cut into 2.4 metre billets. In the Transvaal, they are stacked in the field to allow drying for four to six weeks. After which they are extracted by grapple skidder. In Natal cross cut billets are moved to a central depot as soon as possible to prevent coppice damage.

19.8: DISCUSSION

Rotation length is usually specified in terms of time, however in several instances it was defined in a more qualified manner by the age at which certain stand parameters had developed to a specified size. A specification of the development of a certain DBHOB, or standing volume was most common. In such instances, the Company had determined exactly what it was aiming to produce to match market and processing requirements.

Great variation in rotation length was noted, with the range encountered in actual use (compared with projected rotations with genetically improved planting stock) from six years for Sappi in the Lowveld through to 30 years plus for APM Forests Pty. Ltd..

A general rule was that if the aim of production was a larger piece size (ie sawlogs), a longer rotation was required. However to achieve a longer rotation, thinning must be used to capture potential mortalities prior to self thinning and to reduce water stress and therefore the chance of pathogen attack. It also retained the best trees to accrue increment.

In the Australian situation, if rotations of greater than 10 years are planned, it may be necessary to include a thinning prescription to maintain stand hygiene.

Site, species and silviculture will dictate the production rate at clearfalling. As such, MAI ranged from 10 (Celbi) through to 50 (Mondi) cubic metres per hectare per annum. It has been shown that site preparation dictates tree growth for the first two to three years, after which it is controlled by site factors (Boden (1990)). However, if during the first two or three years, a tree has developed a complete and vigorous root system, subsequent growth will be at the maximum capable for that site. Even on poorer sites and in the absence of the benefits of a tree improvement programme, good site preparation can increase production.

In comparative terms to the countries visited, Australia's eucalypt plantation growth rates are average to better than average (table 19.1). It has always been the habit to make comparisons to the better growth rates overseas (ie the best for Brazil), when the average MAI for most countries is less than that of Australian eucalypt plantations.

The products recovered at clearfalling were shown to be a function of the available markets. It is more the case that the plantations evolved in response to market demands. There is always the option that a tree maybe processed in any number of ways. However, as products become more specialized (log size and wood properties requirements), the chance for substitution becomes limited. For example a sawlog in South Africa could be either sawn or pulped, but a pulpwood billet could not be put through the present sawmills. In the end, log utilization is determined by a balance between economics and the demand for raw materials by the industry which created the plantation.

20.0: SAWLOGS AND SAWN PRODUCTS

20.1: SUMMARY

Australian eucalypt plantations would be able to grow South African size sawlogs. We have adequate growth rates (table 19.1) and it would be possible to derive suitable thinning regimes. However, processing characteristics would be different, as the South African industry has selected and genetically improved species to optimise sawing behaviour.

Similar, if not the same sawmilling technology as used for processing P.radiata could be applied to plantation grown eucalypts. Species specific drying schedules for different local environments would be required to maximise recovery. It would then become a marketing exercise to adjust consumer demands.

20.2: INTRODUCTION

Australia's timber industry has traditionally been supplied large diameter logs from which to recover sawn products. In the late 1960`s a mid point diameter of 0.5 metres was considered as a small log, as most logs had a mid point diameter of at least 0.6 metres, with 1.40 to 2.50 metres not uncommon (Page (1978)). Based on such log sizes and processing characteristics, sawmilling technology developed accordingly. However, log size has declined as areas of old growth forests are either removed from production or cut out.

The option of sawn product recovery from plantation (and regrowth) grown eucalypts has gathered momentum in Australia with research programmes such as The Young Eucalypt Project. A Department of CALM internal paper presented favourable results for a sawmilling trial of plantation grown E.globulus subsp. globulus (Thomson and Hanks (1990)).

It is the aim of this section to detail routine operational production of sawn products recovered from plantation grown eucalypts. Both plantation silvicultural practices and the processing required to recover sawn products are to be discussed.

20.3: SOUTH AFRICA

20.3.1: THE DEPARTMENT OF ENVIRONMENTAL AFFAIRS

Although Departmental plantations were not visited, it was at the J.D.M. Keet Forestry Research Station that a basic factor of sawn timber recovery was explained. Between 1961-62 they commenced breeding E.grandis for sawlog production. Tree selections were undertaken in the Eastern Transvaal based on volume, stem form, crown form, branching (self pruning) and timber properties. Van Wyk (1977) presented details of their programme.

One aim of the breeding programme was to minimise log end splitting after falling. Such a trait was found to be genetically controlled and could be selected for once the ortet (selected individual in the field) had been fallen. It was acknowledged that log handling practices will also dictate splitting characteristics. Photographs 20.1 and 20.2 present a typical poor sawlog and good sawlog end splitting respectively.

Scions were collected from the selected trees and grafted to form a seed orchard and culled based on progeny trials. The seed orchard is still in use today, but due to present interest in clonal forestry, the seed orchard programme has been scaled down.

Currently, two types of seed are supplied, based on the intended end use. Short rotation seed is best used in the production of pulp and mining timbers and should not be used for sawlog production. Long rotation seed can be used in a short rotation, but the primary use is for sawlog production.

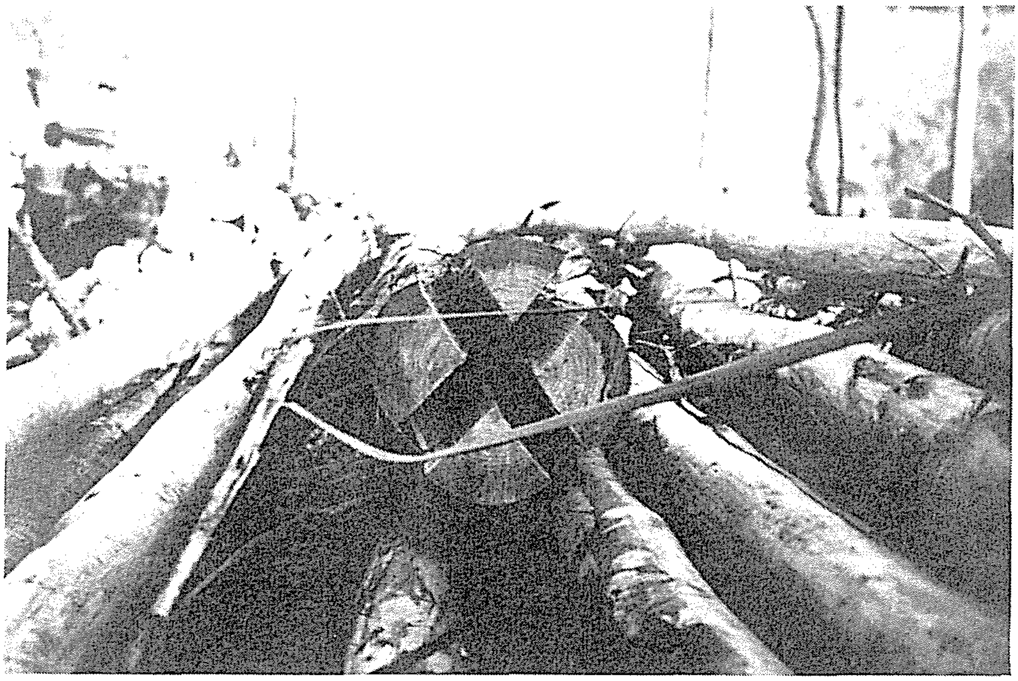
20.3.2: HANS MERENSKY HOLDINGS (PTY.) LTD.

The silvicultural practices that result in the production of sawlog material have been presented in the previous sections. They include the use of long rotation seed, and an intense thinning and pruning regime to produce the desired log size.

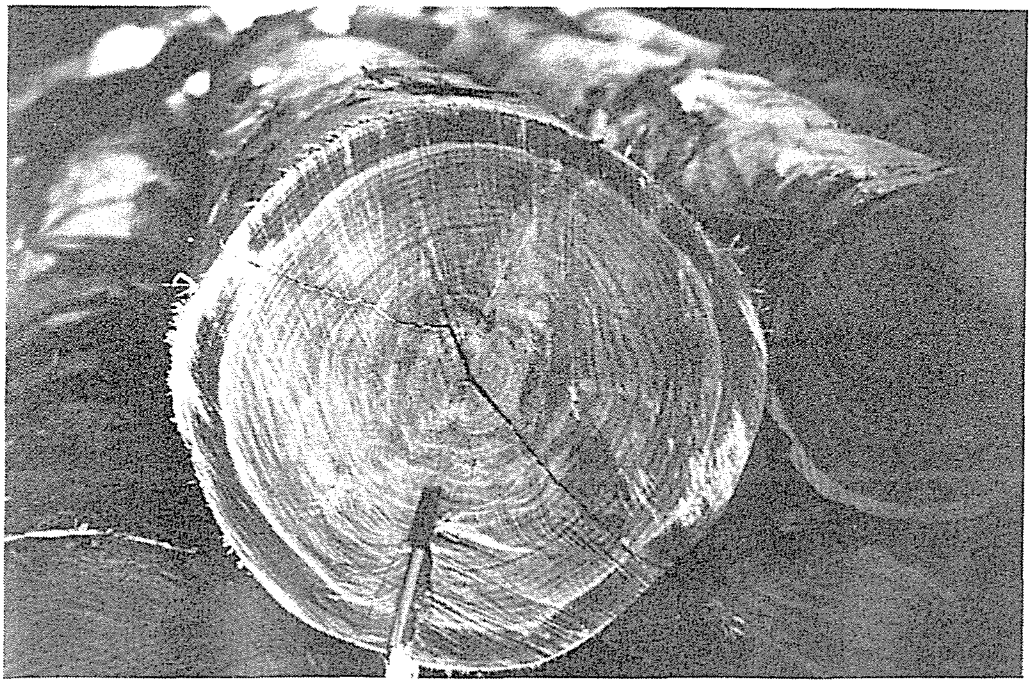
Once logs are delivered from the plantation, they are divided into two classes; class A, 19.0 to 29.0 centimetres and class B, 31.0 to 55.0 centimetres small end diameter. Subsequent breakdown is by gang saws with the cutting pattern based on the two size classes (figure 20.1).

Four grades of sawn product are recovered from any one log. Table 20.1 presents the recovery of each product. Overall they achieve a 50 percent pre kiln drying recovery, with a recovery of 40 to 43 percent recovery after kiln drying.

The juvenile wood core is subject to collapse, but is accepted by the mining timber market. All mining timber products are sold after air drying. Square chocks and wedges (for mine use) are cut from the core wood section, with 90 percent going as wedges. Gum planks for mine works are also cut from the core section. The market value of such timber is so high that there is no need to recover the edge clear wood. The knotty core section (wood grown prior to T1 and pruning) is cut to size for lamination into beams. High quality timber is recovered in slabs of various thicknesses: 25 to 38 millimetres for furniture grades, and other uses up to 50 millimetres. The length of timber cut is dependant upon market demands and is usually 4.4 metres (but can be up to 4.8 metres).



PHOTOGRAPH 20.1: POOR SAWLOG END SPLITTING

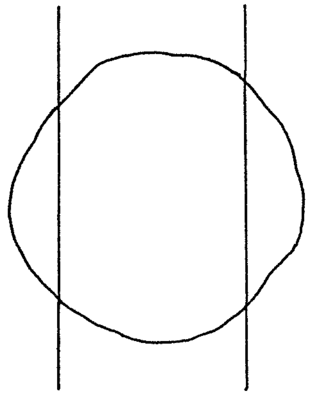


PHOTOGRAPH 20.2: ACCEPTABLE SAWLOG END SPLITTING

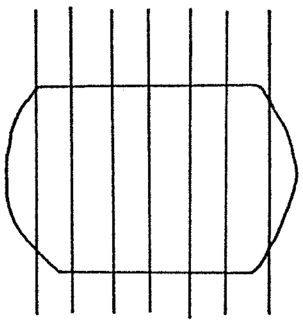
FIGURE 20.1: BREAKDOWN PATTERNS BASED ON SMALL END DIAMETER CLASSES

CLASS A: 19.0 TO 29.0 CENTIMETRES SMALL END DIAMETER

FIRST CUT



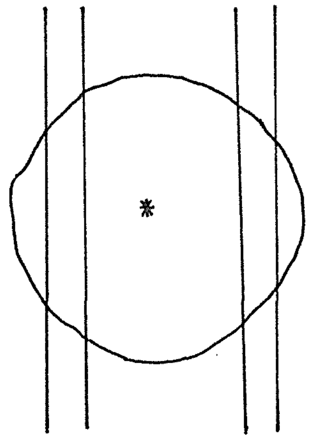
SECOND CUT



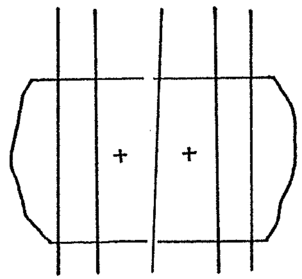
NOTE: ALL SECTIONS ARE RE - SAWN INTO DIFFERENT PRODUCT GRADES

CLASS B: 31.0 TO 55.0 CENTIMETRES SMALL END DIAMETER

FIRST CUT



SECOND CUT



* MID SECTION WIDTH IS 60 % OF THE LOG DIAMETER

\+ THE CENTRAL PORTION GOES TO MINING TIMBERS (CHOCKS) AND THE REMAINDER IS CUT INTO SAWN PRODUCTS

TABLE 20.1: SAWN PRODUCT RECOVERY

PRODUCT:	PRE KILN (%):	POST KILN (%):
CLEARWOOD	13.00	10.40
SEMI CLEARWOOD	3.75	3.00
KNOTTY GRADE	8.25	6.60
MINING TIMBERS*	25.00	25.00

* - Sawn mining timbers are not kiln dried

All other sawn products (apart from mining timbers) are air dried prior to kiln drying. 25, 38 and 50 millimetre thickness boards take 5, 9 and 14 months respectively to air dry down to 30 percent moisture content. Efforts are being made to decrease air drying time.

Kiln drying takes 5, 8 and 12 days for 25, 38 and 50 millimetre thickness boards respectively. Kiln drying takes the sawn timber down to 25 percent (from the commencement moisture content of 30 percent) using air conditions of 55 and 48 degrees celsius dry and wet bulb temperatures respectively. The final moisture content and dry/wet bulb temperature gradient is dependant upon the log characteristics. Overall the kiln drying process is slow to prevent collapse.

20.3.3: MONDI FORESTS

Overall the silvicultural practices used by Mondi to grow sawlogs are similar to those of HANS MERENSKY HOLDINGS LIMITED (PTY.) LTD.. Their sawlogs have small end diameter of 18.0 to 40.0 centimetres (with a maximum of 48.0 centimetres). They achieve a 37 percent recovery of sawn products, and they sell the sawdust generated to arms manufacturers for polishing ammunition. Gang saws are used for log breakdown (figure 20.2). A total of 16.6 and 20.4 percent of each log (overall) is recovered as clearwood and knotty core respectively. 25, 38 and 50 millimetre thickness boards are cut.

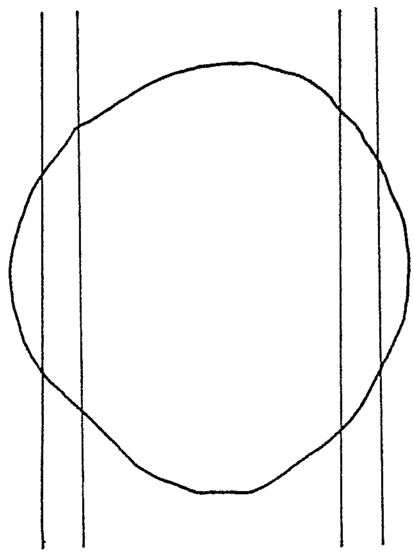
At present one mill in the Graskop (Eastern Transvaal) area cuts both pine and eucalypt with a daily cut of 200 cubic metres. They alternate the species cut with no change to the sawmill or sawing technique. They plan to switch to 100 percent eucalypt in the near future, with a daily cut of 170 cubic metres.

All sawn products are air dried prior to kiln drying. A temperature gradient of 85 and 50 degrees celsius dry bulb and wet bulb temperatures respectively is introduced in increments till the desired moisture content is reached.

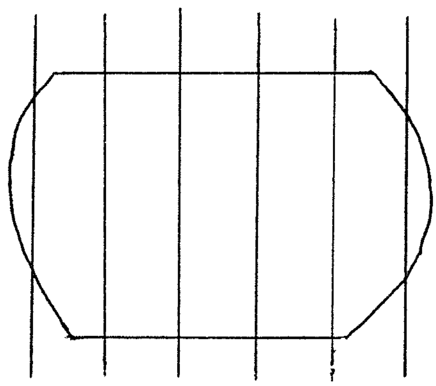
Presently Mondi is having problems with both sawlogs and sawn products splitting. They are trying to resolve the problem by the selection of better genetic material, reduction of the time between clearfalling and delivery (at present it can take up to three days) and by cutting 6.5 metre logs to allow degrade and still recover

FIGURE 20.2: GANG SAWING PATTERNS (ALL LOG SIZES)

FIRST CUT



SECOND CUT



4.5 metre lengths of sawn product. Another option under investigation is to debark at the mill.

20.4: DISCUSSION

Prior to the commencement of any discussion, a definition of a sawlog must be addressed. A sawlog is logically a log from which sawn products are recovered, but any log can be cut to recover some sawn products. Therefore qualification must be applied to the definition. Consideration must be given to both quality and quantity of sawn product recovery. However, sawn product recovery percentage is a function of log quality and sawmilling technology within the constraint of market demands. A suitable definition is that a sawlog is a log of certain physical attributes, able to be processed by the available technology into sawn products as demanded by the market.

Based on the above definition, it is not possible to look at "sawlog" silvicultural practices in isolation of processing technology and market forces.

Sawlog size material as processed in South Africa could easily be grown by the three Australian organisations included in this study. As shown by table 20.2, MAI requirements are easily achieved by Australian plantations. Thinning regimes as applied in South Africa (see section 18) are possible with T1 potentially non commercial. It would not be wise to lower stocking rates to avoid T1 till a merchantable tree size has been reached, as it would reduce the selection potential and increase the time till canopy closure allowing floral competition to develop. As well it would reduce self pruning. The nature of subsequent thinnings would depend upon markets for the piece size produced and the machinery available. Thinning will also prevent water stress and therefore the chance of disease and insect attack, and allow the required longer rotations. Pruning maybe done as a maintenance operation at T1.

The production of (South African size) sawlog material is feasible, but at what cost? It is not possible to compare labour costs due to differences in wages and labour productivity. Advances in eucalypt silviculture in Australia have reduced labour requirements. For example, one of Australia`s biggest advantage is the use of effective residual herbicides, which reduce (remove) the need for hand weeding of plantations.

Sawlog size material can be produced, but can it be processed by existing technology? The ability to process will be a function of log sawing characteristics and the sawmill itself. Certain handling practices such as rapid transport and processing can help reduce log degrade and increase recovery percentage. The sawmills inspected had technology not unlike many of Australia's modern P.radiata sawmills. Drying schedules would be required to be developed, taking into account the different climatic conditions at each sawmill.

TABLE 20.2: A COMPARISON OF SOUTH AFRICAN SAWLOG PLANTATION PRODUCTION WITH AUSTRALIAN PLANTATIONS (PRIMARILY GROWN FOR PULPWOOD)

	HMH	MONDI	APMF	BTF	CALM
STOCKING	1100	1111	1000	1250	1667
MAI	25	17 - 18	UP TO 30	20	15 - 35
ROTATION	20	20 - 24	30	15	8 - 12

NOTE - Stocking is stems per hectare at establishment
- MAI as a sum of production throughout the rotation
- Rotation in years

The key difference appeared to be the species and degree of genetic improvement to grow trees with enhanced sawing properties. The effect of the different species is important, but E.globulus subsp. globulus and E.regnans must have some potential. If such species are grown in plantation, pulpwood could be recovered from thinning operations and sawmill residue chips, as a by-product of high grade sawn timber production.

The final aspect of sawlog and sawn timber production is the market. Consumer preferences will change and it may be possible to influence the public through marketing strategies. Changes in preference for different colour and structural characteristics can be expected. Colour can be easily modified for any uniform sawn product. Secondary processing into laminated beams would be an option to satisfy desired structural (mechanical) characteristics.

21.0: COPPICE MANAGEMENT REGIMES

21.1: SUMMARY

Although it removes the need to re-establish a plantation, coppicing when done correctly is an expensive option. At least a one, if not a two staged reduction of the number of shoots per stool is required to ensure suitable piece size at rotation. It is also necessary to ensure that merchantable MAI is maximised. In some areas the potential gains from using genetically improved planting stock outweighs the few benefits of a coppice rotation. Where longer rotations and desired end products (ie sawlogs) demand thinnings, stumps must be killed in order to confine growth to the selected stems. Therefore, coppicing can only be used with short rotation crops such as pulpwood.

21.2: INTRODUCTION

Coppice and coppice with standards is a management technique that has been applied since neolithic times (4000 B.C.), to European broadleaf forests (Crowther and Evans (1986)). Early Australian foresters found that some eucalypts also possessed the ability to regenerate from the cut stump. Jacobs (1955) stated that, "European experience with coppice with standards gives useful leads for the treatment and improvement of eucalypt forests of poor quality".

Coppicing of some eucalypts has been exploited in overseas countries as a means of producing subsequent rotations after clear falling. It is the aim of this section to detail the techniques required to coppice plantation grown eucalypts.

21.3: AUSTRALIA

21.3.1: BUNNINGS TREEFARMS

There has been no operational scale coppicing. Limited trials have been undertaken to determine the requirements for coppicing E.globulus subsp globulus. One trial in an area with a mean annual rainfall of 700 millimetres has shown falling season effect on the survival of stools (stumps). The initial stand survival rate was 80 to 95 percent (three stratified sections) and after clear falling, with a stool survival rate of 80 to 90 percent a change in stocking from 625 (at planting), to 562 (at clearfalling), resulting in 506 (stool stocking) stems per hectare.

Operationally Bunnings Treefarms are proposing two to three coppice crops.

21.3.2: DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

A number of coppice crops are proposed by CALM, but as yet they have not fully tested and developed management techniques.

21.4: THE PEOPLES REPUBLIC OF THE CONGO

Coppicing is applied, with two coppice rotations after the initial cutting crop. Over the first two years after clearfalling the initial crop, the number of shoots per stool are reduced every six months till only one shoot remaining.

21.5: FRANCE

21.5.1: AFOCEL

As yet they have not gone through a full rotation, but they propose two coppice rotations.

21.6: PORTUGAL

21.6.1: CELBI

All CELBI plantations are coppiced, with three coppice rotations after the initial seedling crop. They achieve an increase in yield of 20 percent over the initial seedling rotation (an increase in overall MAI from 15 to 18 cubic metres per hectare per annum). Once clonal material is operationally available, they will replace all seedling stands and then apply coppice rotations.

The number of shoots left after reduction is dependant upon stool diameter (table 21.1). Stool height is normally 0.1 to 0.2 metres.

TABLE 21.1: STOOL DIAMETER AND NUMBER OF SHOOTS RETAINED

STOOL DIAMETER: (CENTIMETRES)	NUMBER OF SHOOTS:
< 20	1
20 - 30	2
30 - 40	3
> 40	SHOOTS ARE SEPARATED BY 20 CENTIMETRES IN CIRCUMFERENCE

21.6.2: EMPORSIL

Two to three coppice crops are grown, with a 20 percent increase in production over the initial seedling crop (an increase in MAI from 17.5 to 21.0 cubic metres per hectare per annum). They report no seasonal influence on stool survival.

After two years the number of shoots per stool is reduced to two or three. At this stage, the apical dominance of the retained shoots ensures that no secondary accessory bud development (feathering) occurs.

21.6.3: PORTUCEL

At two to three years after clearfalling, the number of shoots per stool is reduced to two to four.

21.7: SOUTH AFRICA

21.7.1: HL AND H MINING TIMBERS

Originally all plantations were coppiced up to five times (average of three coppice rotations), but if by clone / site matching production can be increased by 25 percent, a site will be replanted and then coppiced. The acceptable survival rate for the initial crop is 90 percent at clearfalling. Stool survival (as a percentage of the initial stocking rate) is 72 percent.

A typical stool is 0.1 to 0.2 metres in height (depending upon the number of coppice rotations). At age 14 to 20 months, shoot reduction is to two per stool (300 to 400 stools can be treated per day by labour). Any feathering that develops after shoot reduction is sprayed with paraquat. At age 28 to 38 months the number of stems is further reduced to one per stool (provided that there is not an adjacent gap). The strongest and lowest attached shoots are selected for wind firmness. The aim is to effect canopy closure as soon as possible to suppress floral competition development.

21.7.2: ICFR

The ICFR has undertaken several trials into the coppice management. The following was compiled from observations in the field, discussions with ICFR staff and published ICFR papers.

The condition of the initial tree crop was found to have a significant influence on any coppice rotation, with good survival and uniformity of growth (and therefore uniformity of stool size) as the most important factors. Infilling of the initial crop within one month of planting would ensure the minimum required survival of 95 percent.

Stubbings and Schonau (1980) stated that harvesting the initial crop dictates the quality of the coppice crop, as stool mortality is greatest during the dry months of the year. Chainsaw felling is preferred to felling with an axe, as it gives a smooth surface, better stool height control, reduces damage to the cambial layer and reduces bark separation. All are important to maximise stool survival by reducing the chance of fungal attack and desiccation. On falling, the bark of standing trees should be cut one metre above the ground and stripped up to prevent damage to the stool. The stool must not be covered with slash as it will cause coppice shoot defect. Any fuel reduction burning was found to kill the stools.

Shoot selection for retention is regarded as important, with the first reduction to commencing once the dominant shoots are three to four metres in height. The initial reduction is down to two to three shoots per stool. The second reduction takes place once the retained stems have reached a height of seven to eight metres and is down to one or two stems. Only dominant or those shoots on the windward side are selected. They should have good form and be well attached at the lowest point on the stool. If two shoots are to be retained, they should be well matched with no more than one

centimetre difference in diameter. The two shoots should be as wide apart as possible. Shoot reduction is avoided during periods of strong winds, to allow time for wind firmness to develop.
The final number of shoots per stool and therefore stems per hectare can either be matched to the original stocking rates or to a set number of shoots per stool. If a set number of shoots per stool is specified it must allow for greater retention adjacent to gaps to maintain site productivity.

21.7.3: MONDI FORESTS

The option of a coppice rotation is dependant upon the aims of production. If a sawlog silvicultural system is in place, at thinning all stumps are killed to avoid coppice competition with the selected trees. Only pulpwood (with mining timbers) are produced on a coppice basis.

When using a coppice based silvicultural system, at 18 months the number of shoots per stool is reduced to three to four. At 36 months the number of shoots per stool is reduced to two. Such a system will be applied once all plantations have been converted to clones matched to each site. One site visited had been coppiced seven times the since the 1940's and had over 200 tonnes per hectare of stumps, which made the task of re-planting rather difficult.

21.7.4: NTE LIMITED

Previously all plantations were coppiced, but with tree improvement programmes, better genetic stock can now be planted out instead of coppicing. Traditionally two coppice crops were grown, but it was reported that a 10 percent decline in production was experienced between rotations after the initial coppicing (attributed to stool death and general loss of site productivity). After clearfalling and shoot growth to four metres in height, the number of shoots are reduced to 1500 stems per hectare (the original planted stocking rate was 1667 stems per hectare).

21.7.5: SAPPI FORESTS

Better genetic stock is being used to replace existing plantations on clearfalling wherever possible. However, some sites are still coppiced. When a plantation is to be coppiced, the initial crop is fallen by motor manual methods to leave a stump of 0.1 metre in height. Subsequent coppice development is thinned twice. In the Transvaal, Natal and Melmoth areas, once the dominant shoots have reached three to four metres in height, they are reduced down to three shoots per stool to prevent feathering. Once the retained stems have reached a height of seven metres, one or two stems are selected for retention, depending upon the number of viable stools per hectare. Two stems per stool are retained adjacent to any dead stools and around the edge of the plantation. If two stems per stool are to be retained, selection is for equal stems rather than the biggest stems.

Feathering is removed by spraying with glyphosate at 0.26 kilograms of active ingredient per 100 litres of mixture (0.52 kilograms AI per 100 litre will kill the stumps). A brush cutter is not an acceptable means of thinning shoots or removing feathering.

21.8.0: DISCUSSION

Coppice on eucalypts originates from the mass of accessory buds that lay dormant under the bark at the tree's base. The clusters of buds are referred to as the lignotuber. Other accessory buds are present at each point were a leaf petiole has been attached at any stage during the life of the tree. Hormones produced by the apical tip suppress accessory bud development until the tree is damaged (fire or wind) or harvested. Not all members of the genus have the ability to coppice from the stump, the major exceptions are the members of the monocalyptus group.

It is often assumed that a coppice rotation will produce a "free" crop of wood. That is true, but if merchantable wood production and maintaining MAI are the objective, detailed management is required. The following must be taken into consideration.

Coppicing is only an option in the absence of thinning and is therefore only applicable to short rotation regimes. To manage a coppice crop beneath a thinned stand would divert increment away from the selected stems.

To produce a coppice crop, chainsaw (either motor manual or machine falling heads) falling is preferred as it allows a stump height of 0.1 metres to be maintained and minimises bark damage (and therefore stool death). All slash must be cleared from on top of the stool. Extraction machinery must not damage the stumps. Harvesting will be locally limited to favourable seasons to minimise stool mortality (Blake (1983)).

The initial plethora of coppice shoots must be reduced. Rather than considering the age at which shoot reduction commences, it is better to consider a determinant physical attribute. In South Africa, shoot reduction commences once a dominant shoot height of three to four metres is attained. A second reduction is carried out at a shoot height of seven metres.

The number of stems retained maybe expressed on an individual stool basis or as a number of stems per hectare. In Portugal it was usual to reduce down to two to three stems per stool in one operation, whereas in South Africa it was more usual to thin down to one stem per stool in two stages. Piece size, can only be maintained by retaining one shoot per stool. Only shoots well attached to the base of the stool should be selected to enhance stability. Feathering will result in a loss of increment from the selected stems to inferior stems. Therefore, a corrective operation maybe required. The use of low concentration herbicide mixtures would be the best approach.

Fertilizer application have been shown in South Africa to be of no benefit to coppice crops (Stubbings and Schonau (1980)).

Assuming that increment has been maintained, if two stems per stool have been retained, average tree size will be halved. At rotation, coppice will have to be hand fallen, as mechanical harvesting is not possible due to the small gap between stems. If processing is based on a linear feed system, costs will be increased due to the smaller piece size. Again, stools must be protected during harvesting.

It is difficult to economically analyse coppicing. At every point in a coppice rotation there is additional cost compared to a seedling crop. If shoot reduction down to one shoot is in two stages and feathering results, three passes by labour will be required treating each stump individually. Mechanical treatment maybe possible, but it must be noted that coppice shoots are easily knocked off the stool. Additional harvesting costs of the first rotation must be included, as well as increased harvesting costs due to reduced piece size.

The decision not to coppice is common in South Africa as they develop genetically superior plants, matched to specific site types and advanced silvicultural techniques. The expected yield (both volume and wood quality) outweighs the cost of re-establishment. If a species first flowers at age five years, during the time required for a seedling crop with one coppice rotation, four generations of genetic improvement would have been possible.

In Australia we are establishing eucalypt plantations from mostly wild seed (section 7). We have only recently begun to explore species and provenance options, parallel with increased understanding species site requirements. Land for future plantation development (due to economic constraints) will be more often of marginal quality with poor soils and low rainfall (section 5). Silvicultural systems to maximise production from such sites must be developed. Therefore, coppicing when realistically viewed considering the inputs required and the advances (silvicultural and genetic) forfeited, is presently not an option for Australian eucalypt plantations. In some specialised instances small private woodlots could be coppiced for local use. For example a coppice firewood crop of <u>E.camaldulensis</u> or posts and rails made from <u>E.cladocalyx</u> F.Muell coppice. Limited research into coppicing is required to allow an economic evaluation.

22.0: ACRONYMS AND ABBREVIATIONS

AFOCEL	Association Foret - Cellulose
APM	Australian Paper Manufacturers
BTF	Bunnings Treefarms
CALM	Western Australian Department of Conservation and Environment
CELBI	Celulose Beira Industrial, S.A.
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CTFT	Centre Technique Forestier Tropical
DCE	Victorian Department of Conservation and Environment
EMPORSIL	Empresa Portuguesa de Silvicultura Lda
ENGREF	Ecole Nationale du Genie Rural, Des Eaux et de Forets
FAO	Food and Agricultural Organization of The United Nations
GIS	Geographic Information System
HL & H	Hunt, Lechers and Hepburn Mining Timbers
HMH	Hans Merensky Holdings (Pty) Ltd
ICFR	The Institute for Commercial Forestry Research
NAP	National Afforestation Programme
NTE	Natal Tanning Extracts Ltd
OFI	Oxford Forestry Institute
PORTUCEL	Empresa de Celulose e Papel de Portugal E.P.
R1	First Rotation
R2	Second Rotation
SAMTMA	South African Mining Timber Manufacturers Association
SOPORCEL	Sociedade Portuguesa de Celulose, (S.A.)
WACAP	WA Chip and Pulp Company
WRI	Wattle Research Institute

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Personal Communication 1 Gary Inions Research Forester Dept of CALM

Personal Communication 2 Gavin Ellis Research Forester Dept of CALM

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