REVIEW OF PINUS PINASTER PLANTATIONS GROWN IN THE MIDWEST OF WESTERN AUSTRALIA

2 February 2006

SCOPE OF THE REVIEW

This review relates to an area in the Midwest cell north of a line east/west of Beverley that is affected by drought. The scope includes:

1. Determination of the extent of drought deaths;
2. Factors that predispose *P. pinaster* to drought;
3. The appropriateness of current genotypes of *P. pinaster* as a commercial species in this zone;
4. Silvicultural regimes necessary to grow *P. pinaster* successfully;
5. Financial implications of alternative silvicultural regimes to grow *P. pinaster* on drought-prone sites;
6. Assess the environmental (hydrological) effectiveness of *P. pinaster;*
7. Assess the economics for growing *P. pinaster* in the Midwest cell;
8. Identification of gaps in knowledge.

BACKGROUND – Gavin Butcher

- Long-term resource for local industry (Replacement of Gnangara Mound plantations)
- Industry support ($1m/annum) – Don't know if fibre can be grown outside the Midwest cell **2**
- Silvicultural regimes
- How much has been spent - $10 000 000 = 10,000 hectares **3**
- Treasury perceptions **4**
- Supply obligations/perceptions (sawlogs & LVL) **5**
- Current PaPs **6**
- Legal obligations
- Managing areas that have been heaped and not producing **7**
- Environmental benefits **8**
- NRM commitments (NAP) **9**
- Importance of the program to FPC commitments (commercial and environmental) **10**
- Political embarrassment? **11**

The plantations of *Pinus pinaster* commenced on the sandy soils to the north of Perth in the 1920's, however the major part of its growth occurred in the 1970's and 80's. Until 1989 when the medium density fibreboard plant was established in Welshpool the level of timber production from the plantation was minimal. This had been unable to effectively thin the plantations and significant drought deaths had occurred in the dry years of the late 70's. Non-commercial thinning of stands was practiced until the markets became established. Pinetec increased the demand for small sawlogs for pallets and packaging and progressively expanded through the 1990's, and a laminated veneer lumber plant was established in 2004 using the mature logs.

As these industries have become established on the resource from the first rotation the prospects of a second rotation on the same sites has become more difficult. The presence of the ground water in Gnangara progressively became more important, to the extent that it represented up to 40% of the resource for the city. Along with the difficulty in managing this plantation adjacent to a large population and the restrictions on using chemicals on a water production area resulted in a decision in 1996 to grow the next rotation of the plantation on farmland rather than as a second rotation at Gnangara.

Cabinet approval was obtained for a target of a minimum of 20,000 hectares of pine plantation to replace Gnangara and thereby sustain the industries that had been developed. These new plantations were to be funded from asset sales and interest savings, however these were not realised at the level anticipated and borrowings were sought to sustain the plantations.

The plantations on farmland were established through Profits a Prendre whereby the land title remains with the landowner and CALM/FPC secures the right to use the land for the period of the rotation and the shares the benefits of the commercial crop. Originally this was based on a share of the crop value, but as this did not secure large areas of land there has been increasing demand for cash payments as a part of the mix. These agreements place certain obligations on the Commission in relation to harvesting and clean up of the plantation. They all contain a force majeur clause which deals with the issues related to unexpected events such as fire, which could mitigate FPC's responsibilities.
FPC has a target of establishing sufficient plantations to sustain the existing industries. The area of plantation required will depend on where these plantations are placed. Plantation growth on farmland in the higher rainfall areas could be expected to achieve growth rates of 10 – 14 m3 per hectare per year. If that is the case a minimum annual planting program of 1,000 hectares per year would be sufficient. However much of the land planted in the first few years may not achieve this growth rate. It was assumed in discussions with Treasury that each hectare would at least yield 100 m3 of wood suitable for LVL manufacture. This gave an annual target of 1,600 hectares.

Plantation silviculture on farmland has proved a number of different problems when compared to that applied on the Gnangara Mound. Lack of markets as described above lead to a low planting stocking and non-commercial thinning regime on the Mound, however on farmland the problems were initially quite different. The plantations had a surplus of water (due to lack of competition) and nutrients (due to fertilizer used in agriculture) and grew quite vigorously, have there are far more agricultural pests to be controlled. Soon however the form of the trees on farmland was apparently of significantly poorer form. As a result some stands were planted at even higher stocking in an endeavour to control branching.

The desire to use plantations as a means of contributing to water table control and in the management of the State's salinity risk, has been long part of the program. While the Midwest region has not exhibited significant salinity on much of the area planted with *Pinus pinaster*, it has extensive rising ground water and risk of flooding. FPC has sought to develop relationships with a range of community-based natural resource management groups and garner their support for government funding to assist in the development of these plantations. As access to land has become more expensive the economic viability of the investment has become less justifiable on commercial grounds, and increasingly reliant on ancillary benefits related to the environment and the regional social benefits which arise. Many earlier plantings therefore sought to explore the limits of the plantation opportunity, by going into relatively low rainfall, high evaporation areas, and seeking to integrated trees with existing farm practices.

The occurrence of significant deaths in some stands over 2004 and 2005 has required a review of the options for the development of these plantations. Firstly as to where and how this species can be successfully grown in this region. Secondly as to the option for alternative plantation species in the areas which have failed with *P.pinaster.*

Most simply this review is intended to determine the causes of the problem and what can be done to avoid it happening again. For this there is a focus on the knowledge of the ecology of this species within the region. Ultimately the FPC needs to be able to determine whether its original plans for a sustainable plantation industry in this region are sustainable. In the short term it needs to be able to deal with the current problems of what to do with the damaged plantations and where it can sustain the program. This needs to be done in a manner which is thorough and rigorous, to ensure it has the scientific credibility for future investment. Equally there needs to be a program of communication which will provide other key interests (community groups, farmers, NRM) with an understanding of the issues and FPC's proposals for their resolution.

RISK ASSESSMENT – Ray Fremlin

Risk context

The FPC has established 9,500 hectares of *P. pinaster* plantation in the Midwest cell and there are plans to establish a further 9,500 hectares between 2006 and 2010.

Plantations of *P. pinaster* in the Midwest cell planted between 1998 and 2001 are suffering from drought and/or heat stress. The manifestations of this include reduced growth of trees, scattered deaths and the total collapse of significant areas of plantation. Down-stream impacts of this situation include disruption to the supply chain, inability to achieve production targets, inability to provide stated environmental benefits, reduced industry activity, economic losses and long-term negative impacts on the FPC's reputation.

The risks associated with continuing this program are assessed in this section.

Performance indicators and targets of the FPC Midwest Cell program

Goal: t*o develop the FPC's tree farm and plantation business providing forest products and environmental services at scales relevant to market opportunities and environmental needs.*

Strategy: *to establish viable tree farm estates within the Midwest cell to enable sustainable development of regional timber processing industries and to deliver significant regional environmental services.*

Objectives:

1. A *tree farm estate of a scale that will support a competitive processing industry in the quickest feasible timeframe.*
2. *Maximise contribution to salinity and watertable control consistent with regional NRM strategies.*

Targets:

1. *Actual expenditure not to exceed approved funding;*
2. *Funds secured and areas established in each year;*

3. *Midwest planting targets (hectares):*

2006	State/NAP	1500
	Private	0
	Total	1500
2007	State/NAP	1500
	Private	500
	Total	2000
2008	State/NAP	1500
	Private	500
	Total	2000
2009	State/NAP	500
	Private	1000
	Total	2000
2010	State/NAP	500
	Private	1500
	Total	2000
Grand total		**9500**

4. *Less than 10% of the planted estate requires infilling each year;*
5. *100% of EMS incidents are closed on time*;
6. *Industry development plans completed for all planting regions in 2005/06, in consultation with community, industry and government stakeholders*;
7. *Monitoring program for watertables in tree farms established in 2005, with annual reporting of impact*;
8. *Annual review of investment in and reporting on research programs to align with strategic directions.*

Extent of the project or activity in time and location Gavin Butcher

Critical dependencies Gavin Butcher

Treasury/State government

Commonwealth government/ NRM groups

Landowners

State government agencies

Timber industry

Extent and comprehensiveness of the risk management activities

Activity: Develop a tree farm estate of a scale that will support a competitive processing industry in the quickest feasible timeframe

Risk	Risk category	Likelihood	Consequence	Significance	Risk treatment	Adequacy of existing Controls	Responsibility for risk management
i. Plantations will operate at a loss ;	Economic loss	5	4	20	None	Inadequate	EM F&A
	Reputation and Image	5	5	25	None	Inadequate	Executive
	Performance	5	5	25	None	Inadequate	EM Operations
ii. Existing plantations will fail	Economic loss	5	5	25	This Review	Inadequate	EM Operations
	Interruption to services	4	4	16	This Review?	Inadequate	EM Operations
	Environment	3	4	12	?	Inadequate	Executive
	Reputation and Image	4	5	20	This Review	Inadequate	EM F&A
	Performance	5	5	25	This Review	Inadequate	EM Operations
iii. New plantations will fail	Economic loss	3	4	12	Site evaluation modified to account for drought	Adequate	EM Operations
	Interruption to services	4	5	20	Breeding program focuses on the identification and deployment of drought tolerant species and genotypes	Adequate	EM Operations
	Environment	3	4	12	Reviewing Gnangara Mound	Inadequate	Executive

					decision		
	Reputation and image	5	5	25	This review?	Inadequate	EM F&A
	Performance	5	5	25	This Review	Inadequate	EM Operations
iv. Treasury will not support investment in FPC projects	Economic loss	3	5	15	Treasury approached for support for tax-payer funded projects to develop new systems for smei-arid zones	Inadequate	GM
v. Associated activities will suffer losses, e.g. the Nursery	Economic loss	5	3	15	Nursery Business Plan concentrates on diversification of business.	Adequate	Manager OSB
	Performance	4	3	12	PPC structure modified to provide greater emphasis on R&D	Adequate	EM BD
vi. FPC projects will not attract investment	Economic loss	5	5	25	This Review?	Inadequate	EM BD
	Interruption to services	5	4	20	None	Inadequate	EM Operations
	Environmental	5	5	25	Proposal for alternative plant species investigation	Inadequate	EM Operations
	Reputation & image	3	5	15	None	Inadequate	EM F&A
vii. Governments will lose confidence in the FPC	Economic loss	3	5	15	None	Inadequate	EM F&A
	Environmental	5	5	25	None	Inadequate	EM Operations
	Reputation & image	3	5	15	None	Inadequate	EM F&A
viii. Loss of community support	Reputation & image	4	4	16	None	Inadequate	EM F&A
	Performance	5	5	25	None	Inadequate	Executive

Activity: Maximise contribution to salinity and watertable control consistent with regional NRM strategies							
i. Timber will be sourced from regimes that do not provide environmental benefits .	Economic loss Environmental	3 5	3 4	9 20	None None	Inadequate Inadequate	Executive Executive
ii. NAP/Commonwealth funding will cease	Economic loss Performance	4 4	5 5	20 20	? ?	? ?	Executive
iii. Value of land amelioration will not be realised	Reputation & image Performance	4 3	5 4	20 12	None None	Inadequate Inadequate	Executive EM Operations
iv. Environmental benefits will not be realised in original timeframe	Reputation &image Performance	5 3	5 5	25 15	Monitoring of environmental performance Monitoring date will start to become available	Adequate Inadequate	EM Operations EM Operations
v. Perception that FPC activities do not improve the environment	Reputation & image	5	5	25	Monitoring of environmental performance	Inadequate	Executive
vi. Lose support of environmental NGOs	Reputation & image	3	5	15	None	Inadequate	Executive
vii. Loss of Government/Treasury financial/moral support	Economic loss Reputation & image	5 3	5 5	25 15	? ?	? ?	Executive Executive

	Performance	4	5	20	?	?	Executive
viii. Loss of community support	Reputation & image Performance	4 3	5 4	20 12	None None	Inadequate Inadequate	Executive EM BD

CURRENT DROUGHT STATUS - Mike Carter

Area of total collapse across all years.

Of the 10,000 ha of *Pinus pinaster* established in the Midwest plantation development area, 6,847 ha were established between 1998 and 2001.

Reductions in tree density have been detected by remote sensing analysis on approximately 400 of this 6,847 ha's, representing 6% of the plantation area. Deaths have not occurred in *P. pinaster* plantations of similar age between Esperance and Perth. A detailed listing of areas is provided in Appendix 1.

Area affected by drought across all years.

The area affected by drought of the P yrs 1998-2001 surveyed is 6 % or 410 hectares as at December 2005. Field observations in 2005/6 summer show no further loss to the plantation estate.

Geographic spread of drought death & severity

Tree deaths only occurred in *P. pinaster* plantations north of Beverley, despite being planted across the >400 mm rainfall zone from Moora-Katanning-Esperance.

Sharefarms in the Midwest plantation development area were grouped according to their location. The average reduction in density (%) estimated by remote sensing is presented in Figure 2. The areas with the most severe impact are concentrated in the north and eastern areas of the district.

A major feature of the climate of the south-west is that evaporation and mean maximum temperatures increase from south-to north and the length of growing season decreases. Thus the occurrence of deaths is strongly associated with climate.

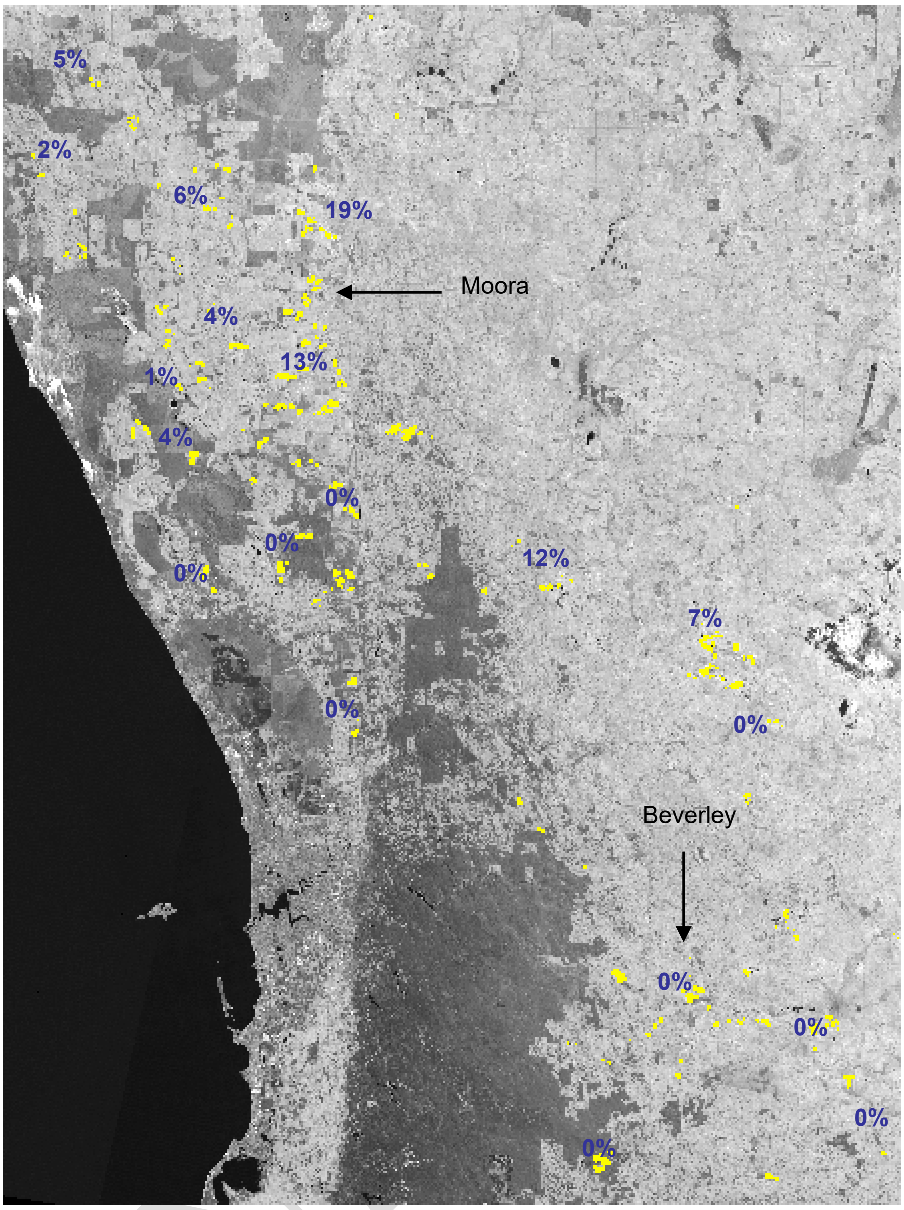


Figure 1 Severity of *P. pinaster* deaths. This Landsat image shows the average proportion of each property that has been affected by deaths. There is a clear regional trend, with few deaths in the south.

A Climate Wetness Index (CWI) was developed. This is the ratio between rainfall and pan evaporation. The lower the index the higher the stress on the plantations, with Table 2 showing that deaths are concentrated in the areas with a lower climate wetness index. Table 2 also shows that those plantations (in red) that are planted in areas which are now no longer considered for plantation establishment.

Table 1 Reductions P 1998-P 2001 in *P. pinaster* plantation density (%).

Climate Wetness Index	Climate Point	Rainfall (10 Year Average) mm/year	Evaporation (10 Year Average) mm/year	Average Reduction in plantation density (%)
0.17	21	351	2073	7
0.18	4	397	2218	19
0.19	20	384	2074	12
0.23	1	504	2237	5
0.23	9	505	2141	13
0.24	2	548	2236	2
0.25	3	531	2124	6
0.26	7	561	2147	4
0.28	8	606	2124	1
0.29	11	621	2137	4

Key Red indicates outside current target zone
Black indicates within current target zone

Reductions in density observed within the current plantation development zone mostly occur in the area immediately south of Moora (climate point 9 in Table 2). It can be seen from the CWI value that this area experiences a harsher climate than the other points that are within the development zone.

Although the average reduction in density at climate point 9 is only 13 % the range observed is between 0 and 41%. It should be noted that these reductions tend not to be spread out evenly across the plantation and occur as localised in patches. This indicates that site conditions may also be contributing to the deaths.

The reductions observed at the other climate points within the current zone are less significant than those detected at climate point 9. The better survival was associated with the more moderate environmental conditions as indicated by the higher CWI.

Area not affected at this point in time that may be either susceptible or safe – categorise the risk

Previous episodes of drought deaths with other species suggest that more trees will die. Thus, further deaths are likely in plantations that are currently less than five years old. Drought deaths in other plantations eg *E. globulus* and *P. radiata* progressed over a number of years.

A major concern is the fact that the deaths in the plantation have occurred during a period of average rainfall. The have not been exposed to drought conditions that will inevitably occur i.e. significantly lower rainfall than average.

Summary by property by Planting year (See Appendix 2)

FACTORS THAT PREDISPOSE *P. PINASTER* TO DROUGHT DEATH - John McGrath

Physiology of *P. pinaster*

Stocking at time of death/competition

Climate

Site

Prognosis of the likelihood of the drought-affected area to extend outside the zone covered by this review

Physiology

Physiology of Drought Stress

Growth rate and Tree Form
Water plays a central role in plant growth. Not only do plants transpire water as part of their metabolic process they also store water. Over 50%of the total fresh weight of a tree consists of water, but the water concentration varies widely in different parts of the tree and with species, age, site and season (Kramer and Kozlowski 1979).
Therefore as plants grow their demand for water increases and the demand on the environment to supply it also increases.
Hence, rapid growth and the development of large foliar biomass will speed up this demand for water and also increase competition between trees.

Inherent Physiology
Plants differ widely in their stomatal response to drought stress. This variability is at least partly associated with the existence of drought adaptation strategies based on (1) drought avoidance, which is generally found in species with high sensitivity to drought, or (2) drought tolerance, which is found in species with lower stomatal responsiveness but displaying structural and functional adaptive traits such as osmoregulation, allowing the plant improved tolerance of reduced water status (Picon *et al*. 1996).

Soil Water Availability

Soil water potential decreases as soils dry. This reduces the driving force for the movement of water from soil to roots. Additionally the resistance to water movement through the soil increases because the larger pores are emptied first. The resistance to water absorption by roots increases due to the shrinkage of roots and soil resulting in a decrease in root-soil contact. Root permeability also decreases due to an increase in root suberization in drying soil. (Kramer and Boyer 1995).

These limiting effects of low soil water potential increase as atmospheric conditions favour high potential rates of transpiration. The practical significance of this is that on sunny days rapidly transpiring plants can often develop water deficits in moist soil, but in cool cloudy weather plants may show little stress even in a relatively dry soil (Kramer and Boyer 1995).

Predawn Leaf Water Potential and Homeostasis

Water Potential is a common physiological measurement used to assess the general water status of a plant. A value of zero indicates the absence of water stress, while increasingly negative values depict increasing severity of water stress.

It has been assumed that before sunrise plants will be in equilibrium with the soil's water potential, therefore making PDWP a more sensitive indicator of soil water availability. Hydrologic homeostasis is a physiological trait that allows plants to maintain their leaf water potential above a certain threshold level through stomatal control. Threshold levels will vary between species and are triggered by soil water availability and environmental conditions. Most plants can survive short periods of high water stress but will eventually die if it is prolonged. Again the degree and duration of water stress that eventually leads to drought death will vary between species. Water Stress Integral (calculated as water stress days), provides a measure of a plant's ability to withstand prolonged drought.

Soil Structure and Volume

There is evidence that the soil in the immediate vicinity of roots of actively transpiring plants often tends to become temporarily dry, increasing the resistance to water flow through the soil towards the plant root surfaces. This drying of soil around roots emphasizes the importance of root extension into previously unoccupied soil. It has been suggested that an increase in root depth is more important for postponing the onset of water stress than increasing root length density (cm of roots per cm^3 of soil) in the surface soil (Kramer and Boyer 1995). Therefore the importance of adequate soil depth, without impeding layers, for storing and accessing soil water is crucial to plant survival in drought conditions.

Physiological Traits of *Pinus pinaster*

To better understand the ecophysiology of *P. pinaster* in WA it is useful to understand the environment in which the genotypes currently planted here originated, and drought response findings from research around the world.

Range

Pinus pinaster (Maritime Pine) is native to S.W. Europe and N.W. Africa. In France, Algeria, Tunisia and Italy the distribution is mainly coastal, but in Portugal, Spain, Morocco and Corsica the tree grows from near the coast to far inland and high into the mountains, with marked differences in habit and rate of growth between the coastal

and inland forms. It thrives best in the mild and relatively moist climate of the southern Atlantic coast of France (the Landes of Gascony), the Atlantic coast of Portugal north of Lisbon and the north coast of Spain (Scott 1962). The absence of the species from the Mediterranean east of the Adriatic may be due to the climate there being too dry (Scott 1962).
In these areas where *P. pinaster* grows best the climate is wet and mild. Mean average rainfall in Landes France is between 700mm and 1200mm and even higher in the north of Spain. In the Leiria region of Portugal mean annual rainfall is 800mm and mean average temperatures are 13ºC – 15ºC (Scott 1962). It is interesting to note that when looking at suitable climates when introducing Atlantic provenances (Leirian and Landes) of *P. pinaster* into Western Australia Prescott and Lane-Poole (1947) considered the optimum locations to be around Collie, Donnybrook and Bridgetown, which are vastly different from the areas in which we are now trying to establish plantations. Later assessments by Hopkins (in Havel 1976), considered that the area of the Gnangara and Yanchep plantations to be the northern limit of pine planting based on the reliability of rainfall and suitable edaphic-topographic associations to concentrate and conserve water.

The Leirian strain dominates the plantations established in Western Australia. Of the various provenances it is among the fastest growing with reasonable form. It comes from an area that has moderately high rainfall (~800mm) and cool temperatures. It therefore has some of the least well developed drought avoidance adaptations and is also susceptible to frost damage. Frost susceptibility was not considered an obstacle to its development in WA as it has been grown in close proximity to the coast where frosts are infrequent and not severe. Moving the planting of this species inland may not cause problems, while the frost frequency is higher the severity is usually within acceptable limits (down to -8.0ºC).

In Western Australia *P. pinaster* has a reputation as a drought hardy species suitable for growing in the medium rainfall zone (400mm – 600mm) of Western Australia. It is however a drought avoiding species rather than a drought tolerant species as it;

- Displays a high stomatal sensitivity(responsiveness) to drought stress (or water deficit)
- Has decreasing CO_2 assimilation in response to drought which is associated with increasing water use efficiency. ;(Picon *et al*. 1996).

Martinez-Vilalta and Pinol (2002) showed through comparative $\delta^{13}C$ data that *P. pinaster* had higher water use efficiency than either *P. nigra* and *P. sylvestris*. Granier *et al*. (1990) showed that stomatal control (in response to vapour pressure deficit) in *P. pinaster* in Landes (France) limited the daily transpiration to a maximum of 3.5mm day^{-1}, well below the Penman Potential Evaporation (PET) for that site of 6.8 mm day^{-1} (0.51 of maximum) and below the average ratio of tree transpiration to PET of 0.55. This supports the classification by Picon *et al*. (1996) that it is a drought avoiding rather than a drought tolerant species.
It is however, known to tolerate considerable summer drought, although this feature varies greatly between the different provenances, with the inland Spain and Moroccan mountain provenances being the most adapted to dry conditions. Unfortunately the form and vigour of these provenances make them unsuitable for commercial plantation development.
Studies with 3 year-old seedlings from 5 provenances that differed in climatic conditions (Landes France, mean RF 1280mm Temp 13.5ºC, Tunisia RF 1044mm T

18°C, Leiria, Portugal RF 764mm, T 16°C, Porto Vecchio France RF 657mm, T 15.5°C, Morocco RF 650mm T ?) showed that there was significant differences in osmotic adjustment ,which contributes to drought resistance in woody plants, and a clear negative relationship between osmotic adjustment and annual rainfall at the geographical origins of the provenances such that trees originating from the Landes site (RF 1280mm) showed less capacity for osmotic adjustment than trees originating from Morocco (RF 650mm) (Nguyen- queyrens and Bouchet-Lannat 2003). They also stated that little is known about the adaptive processes involved that could serve as criteria for selection and breeding of more drought-tolerant genotypes.
Trials in New Zealand demonstrated that trees from different provenances reacted differently to stocking levels. They found the wide bushy crowns of the Atlantic coast provenances (Leirian and Landes) were apparently intolerant of competition and the best grown ones effectively thinned themselves. In other words competition for resources by these trees resulted in mortality. On the other hand the Corsican provenances retained close to their original stocking even though they are not noted as being particularly drought hardy (Knowles and Miller 1989).

A very valuable feature of *P. pinaster* is that it tolerates very poor infertile soils, especially sands, where few if any other useful timber trees will grow. It has a very low nutrient requirement for adequate growth.
P. pinaster is able to grow in a wide range of acidic soils changing its root system in relation to soil conditions. Soil pH does not influence lateral root initiation but it does have an impact on root length. In soils <3.5 pH and >6.5 pH root elongation is reduced (Arduini *et al*. 1998). As mentioned earlier root extension into previously unoccupied soil is an important factor in drought avoidance and therefore soil pH may have an influence in this process. Most soils in WA fall within the acceptable pH range except possibly some calcareous coastal sands, which may be higher than pH 6.5.

Long drought periods cause severe damage, especially to the Portuguese provenance, and this damage may continue after drought conditions end, possibly owing to the action of fungi that are not normally pathogenic (Scott 1962)
Manion (1981) has suggested that the multiplicity of factors which cause tree decline and death fall into three groups;

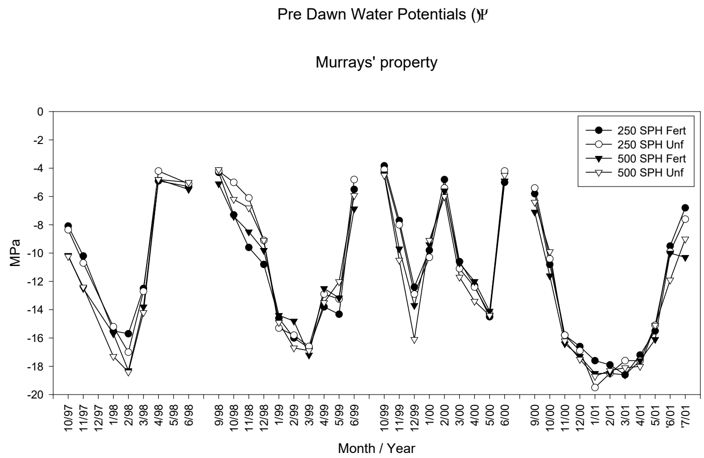
Predisposing Factors – long-term factors such as climate, soil type, aspect, landscape position, genotype, stand structure and stocking. These factors weaken trees growing in inappropriate locations.

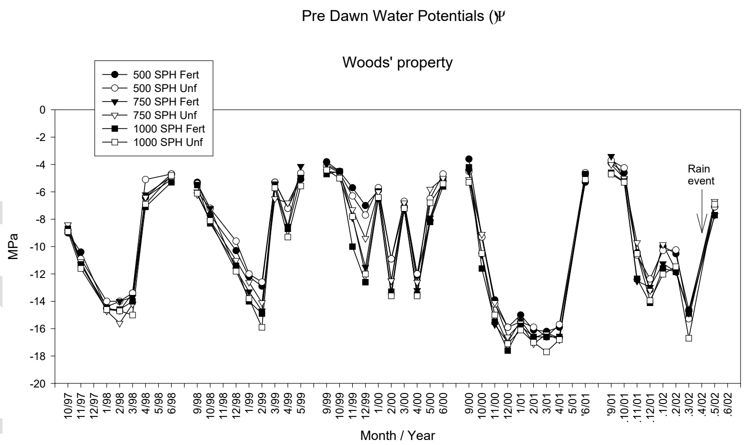
Inciting Factors – short-term factors such as drought, frost and insect defoliation which produce a sudden injury from which the tree has difficulty recovering.

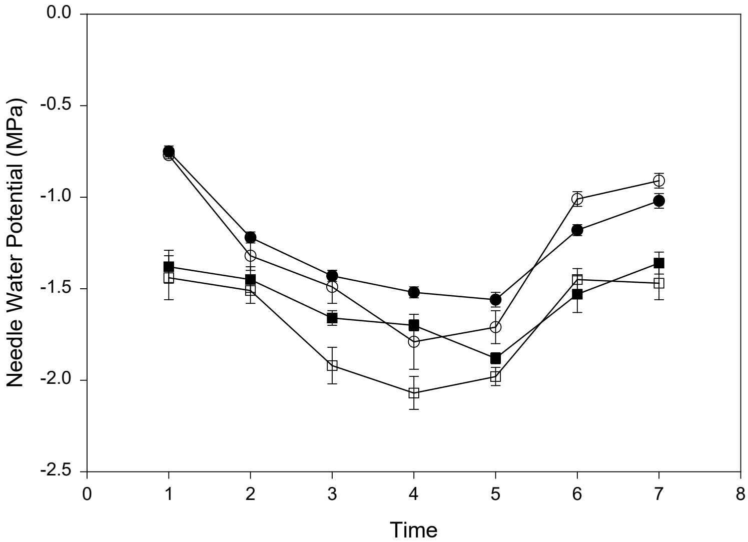
Contributing Factors – long-term factors such as secondary insect attack, cankers, and fungi which are able to invade only a weakened host. They are often very conspicuous but are best regarded as indicators of a severely stressed or dying tree.

Research Results from Western Australia

Evidence of hydraulic homeostasis was shown by Delzon *et al*. (2004) with a threshold level of -2.0 MPa and being independent of tree age and height. This is supported by data collected here in WA that shows mean pre-dawn water potentials remaining above -2.0 MPa. Extensive drought deaths occurred in 2000/01 at Murrays' plantation (right side of top figure) east of Wickepin. Although the threshold of -2.0 MPa was not breached it remained at or near this level for several months eventually leading to extensive mortality. The Water Stress Index (WSI) in relation to this collapse was greater than 500 MPa days. In the same year at Woods plantation near Dandaragan the duration of severe water stress was the same but the level was not as great leading to a WSI of approx 460 MPa



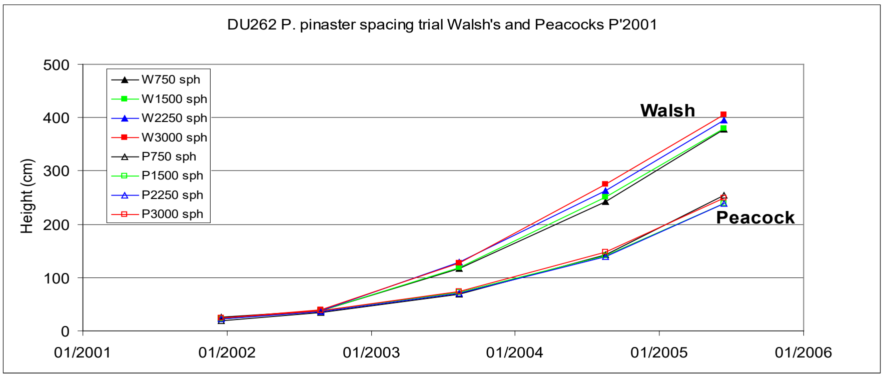


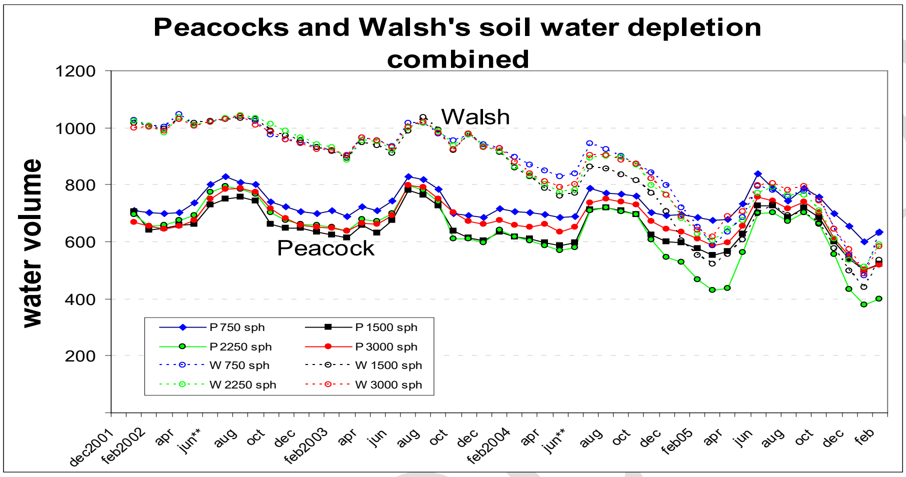


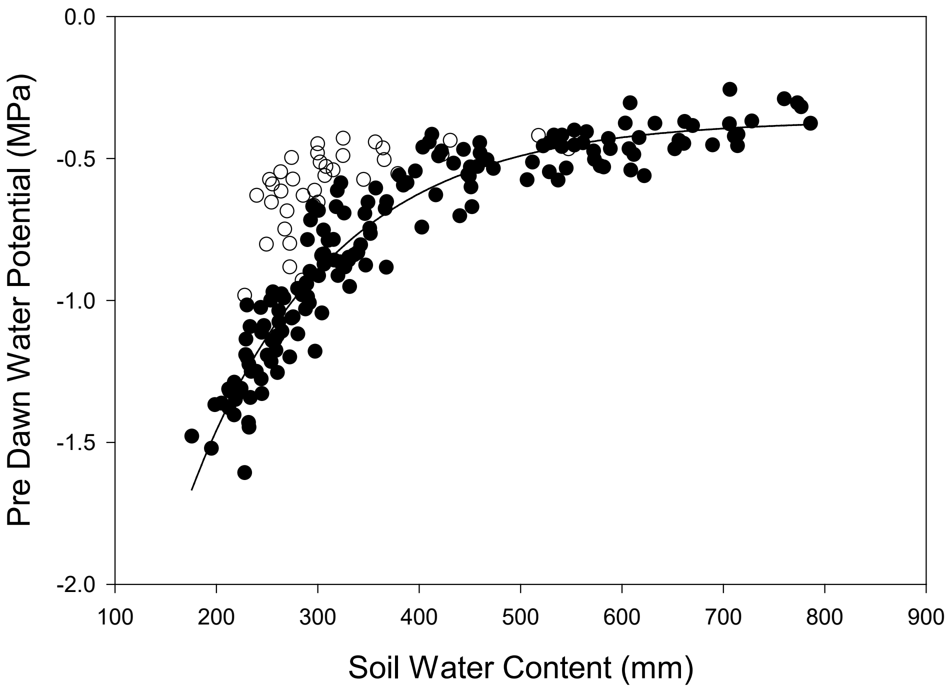
Maximum water stress in trees is experienced during the day and the standard measure is midday water potential. The figure above shows the diurnal range of leaf water potentials at the end of summer for two different stockings (250 and 750 stems/ha) of *P. pinaster* growing on the coastal plain at McLarty. The hydraulic homeostasis of -2.0 MPa appears to hold even under these late summer conditions.

Growth and soil water depletion by 4 year-old *P. pinaster* plantations north of Perth are shown in the following two figures. The trees were planted at 750, 1500, 2250 and 3000 stems per hectare (sph) and monthly soil water measurements have been collected since planting. Height growth has been measured annually. Peacocks is located east of Badgingarra, and high in the landscape. It is a deep coarse sand with water table below 6m and hence considered a dry site. Walsh's is located SW of Moora low in the landscape and adjacent to an uncleared swamp the soil is also a sand to loamy sand. At the time of establishment the water table was generally within 1 – 1.5m of the surface, and is considered a wet site. Long term average rainfall is the same for both sites at approx 550mm, however evaporation estimates indicate Peacocks to be approx 100 – 150mm higher than Walsh's.

Growth and biomass at Walsh's is nearly double that of Peacocks and can be attributed to the abundant supply of water near to the surface plus annual rainfall, while Peacocks has been surviving on what can be stored from annual rainfall alone. The mining of the abundant soil water by trees at Walshs in order to sustain their rapid growth is evident in the trace of soil water depletion shown in the lower figure. While the pattern at Peacocks is uniform in wetting and drying from winter to summer, with variation of approx 200mm each year (with the exception of the last year where 250-300mm have been extracted), Walshs shows a steady decline to a stage now where it has the same amount of water available as Peacocks. hence the trees at Walsh's having dried the soil profile out through their rapid growth are now relying on annual rainfall to supply water. Therefore the prospect of much larger trees at Walsh's having to survive on rainfall alone would indicate that, given a "normal" period of years ahead (age 5–6) will see extensive drought deaths in this plantation, particularly in the higher stocked plots.
Only in the past 18 months has there been any indication of the higher stocked areas using more water and drying the soil to a greater extent than the lowest stocked areas.


DU262 P. pinaster spacing trial Walsh's and Peacocks P'2001
Height (cm)
W750 sph
W1500 sph
W2250 sph
W3000 sph
P750 sph
P1500 sph
P2250 sph
P3000 sph
Walsh
Peacock
500
400
300
200
100
0
01/2001
01/2002
01/2003
01/2004
01/2005
01/2006


Peacocks and Walsh's soil water depletion combined
water volume
Walsh
Peacock
1200
1000
800
600
400
200
P 750 sph
P 1500 sph
P 2250 sph
P 3000 sph
W 750 sph
W 1500 sph
W 2250 sph
W 3000 sph
dec2001
feb2002
apr
jun**
aug
oct
dec
feb2003
apr
jun
aug
oct
dec
feb2004
apr
jun**
aug
oct
dec
feb05
apr
jun
aug
oct
dec
feb



The graph above clearly demonstrates the strong relationship between total soil water content to 8m (mm) and leaf water potential (MPa) for *P.pinaster* at McLarty plantation over a three year period. This indicates the importance of soil water availability in determining le level of drought stress experience by *P. pinaster*. Although *P. Pinaster* has some capacity to withstand summer droughts and possess adaptations that that make it effective at drought avoidance we have now taken the Leirian provenance well outside of its natural climatic range and therefore these tolerances are pushed to the limits and beyond. Exacerbating this alienation are the ex-farmland sites on which most of the new plantations have been established. These sites have artificially high soil water contents and generally raised fertility which favours rapid early growth. When this soil water is depleted and trees have to rely on annual rainfall alone, the larger canopies developed under the initially favorable water and nutrient supplies will likely predispose the trees to drought death even in "normal" years.
The extent to which other factors such as soil pH influence *P. pinaster* growth and drought avoidance in drier climates are not known, however given the generally acidic nature of WA soils this may not be an issue..

The focus of FPC's *P. pinaster* tree breeding since 1996 has been toward improved drought tolerance (avoidance) and improved stem form on farmland. The strategy to date in improving drought tolerance has concentrated on crossings within the Leirian provenance and the development of *P. pinaster* x *P. brutia* hybrids. Trial plantings have been established but are not yet old enough to conduct a thorough assessment. Trees in seed orchards have also been established and some seed is now becoming available. Unsuccessful (due to contract conditions) attempts have been made to collect genetic material from Leirian provenances grown on the coastal plain of Morrocco. The trees in this area seem to have adapted to a much lower rainfall than in its original range in Portugal. Incorporating this capacity into the current *P. pinaster* population may increase its capacity to withstand drought conditions.

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OPTIONS FOR THE MANAGEMENT OF PLANTATION AREAS SUBJECT TO DROUGHT RISK – John Mc Grath/Sean Sawyer

New areas

Collapsed areas

Areas with scattered drought deaths

Areas currently not drought affected but at risk

COST OF MANAGING PLANTATIONS AFFECTED BY DROUGHT – Sean Sawyer

Replanting with P. pinaster

Thinning

Pruning

Replanting with alternative species?

Funding sources (estimate: $6 – 8,000,000)

New areas

The zone identified as constituting an ongoing drought risk to the establishment and growth of *P. pinaster* represents an important land acquisition area for the FPC in terms of achieving its STF targets in the NACC region. The site type targeted for pinaster plantings (deep sands) is also important in terms of tackling issues of water table rise and soil stabilisation. These factors dictate that an alternative planting regime be developed for such site types in this zone.

Two main options are available in going forward on these sites:

1. Adjust *P. pinaster* silvicultural regime to manage drought risk (only in areas considered to be at drought risk but still within revised site selection and climate guidelines for *Pinus pinaster*
2. Adopt new species program with greater drought resistance.

Adjusted P. pinaster silvicultural regimes

It has been suggested that drought risk in *P pinaster* on these sites may be lessened by a combination of reduced establishment stocking, and reduced leaf area through non-commercial thinning and pruning. A potential schedule based on this approach is shown below.

Year	Operation	Estimated Cost
0	Plant 1200 spha	$1,665/ha
4 -6	Thin to waste to 750 spha and low prune to 2.5m	$1,250/ha
8-10	High prune 125 spha* to 5.7m	$ 250/ha
14	Thin to 250 spha (50m3/ha pulpwood)	
25	Thin to 125spha (50m3/ha LVL, 25m3/ha pulpwood))	
32	Clearfall (90m3/ha LVL, 45m3/ha pulpwood)	

* Only half of LVL harvest will be high pruned (Clearfall component)

There are obviously significant costs involved in the proposed culling and pruning operations as well as lost revenue from what were previously expected to be commercial thinnings. With increased costs solely the responsibility of the FPC, these factors will impact heavily on the economics of the pinaster program. A cursory evaluation of the impact of this regime on the economics of the NAP pinaster investment sees the expected IRR fall from a potential 10.2% down to 2.2% as a result of the increase in management costs in association with the loss of commercial product.

Reducing the first lift pruning commitment to the post commercial thinning LVL component only (250spha) would reduce costs by up to $500/ha and potentially lift IRR significantly (indicative comparison 3.6%), however the branch development typical to pinaster at low density is likely to reduce the recovery of industrial wood at T1 and the lack of control of leaf area may mean that drought risk remains an issue.

The opportunity exists to evaluate the issue of branching at lower stocking rates in the spacing and water use trials established in both the north and south of the pinaster establishment range. It is hoped this evaluation can be completed in the near future enabling better projection of future product yield.

Adopt new species program
While commercial options suitable for establishment and growth on deep sandy soils in the medium rainfall zone are limited, *Pinus brutia* is one which appears to offer some potential.

Trials of this species have encountered some difficulties in establishment, mainly as a result of nursery issues (seedling size), and early growth has been slow; however once established, development has been encouraging with trees displaying acceptable growth and good stem and branch form.

It is expected that over a full rotation *P. brutia* growth will be significantly slower than *P. pinaster* (in the range of 50% lower) however there are likely to be significant savings on the costs of stand management.

The good stem form displayed by the species in trial plantings should ensure that sufficient crop tree selection is available, even at lower establishment stocking, while the trees small branching habit should negate the requirement for pruning when growing for an LVL market.

A potential silvicultural regime for the growth of *P. brutia* in the medium rainfall zone is shown below.

Year	Operation	Estimated Cost
0	Plant 1000 spha	$1,590/ha
14-16	Thin to 250 – 300 spha (30-40m3/ha pulpwood)	
28 – 30	Thin to 125spha (40m3/ha LVL, 10m3/ha pulpwood)	
38 - 40	Clearfall (80m3/ha sawlog / LVL, 10m3/ha pulpwood)	

Even taking into account reduced yield (approx average 4m3/ha/yr) and a longer rotation cursory economic evaluation of the above regime indicates an IRR under the NAP project funding model of around 3.5 - 4%. However the greatest potential benefit to the FPC is in the reduction in financial risk with the majority of expenditure covered by the NAP establishment funding.

While the low input requirement of *Pinus brutia* looks attractive this is offset somewhat by the untried status of the species. Trial plantings are very much in their infancy so the longer term and broader scale performance is largely unknown. The market acceptance of *P brutia* timber is also largely untried although wood quality testing indicates that it should provide a direct substitute for pinaster in most applications.

An alternative to *P brutia* may be to utilise more drought tolerant provenances of *P pinaster*. The Corsican provenance of *P pinaster* is proven to have better osmotic adjustment than the Leirian strains which currently dominate WA plantings and also offer superior form although this is offset by significantly slower growth.

Collapsed areas

Collapsed areas represent a serious threat to FPC's reputation as a reliable provider of medium rainfall commercial revegetation programs. Many of these areas are highly visible and the management of them will be closely monitored by both participating landholders and future partners alike.

Two main options are available for the treatment of collapsed areas, the first being to remove the affected trees and return the planting area to an agricultural base while the second involves partial site clean up and replanting probably with an alternative species.

Clean–up and Surrender

Electing to surrender the failed area to the landholder will incur the cost of cleanup however that would be the full extent of the FPC's expenditure. The removal of dead trees is considered obligatory as the damage to the FPC's reputation from leaving these standing would be significant.

It is expected that the cleanup of collapsed areas to a condition suitable for a return to grazing and cultivation will cost in the vicinity of $600-$800/ha. While the full extent of stand collapse has not yet been quantified, it is estimated that approximately 400 hectares is drought affected to some extent, if half of this area is categorised as suffering from stand collapse the cost of cleanup will be in the range of $120,000-$160,000.

Clean-up and Replant

The FPC has effectively secured access to this land for 40 years via the provision of a participation payment. In most cases a minimum of 34 years of this term remains available to us. While in general the payment made to the landholder was not large (anticipated average approx $350 - $400/ha) the opportunity still remains to do something constructive with the secured access.

The risk associated with replanting pinaster is significant particularly as the proposed remedial regimes are untried. It is therefore preferred that alternative species be employed in the replant of any collapsed areas. Two species programs have been identified as being potentially suitable for the replanting of collapsed stands these being *Santalum spicatum* and *Pinus brutia*. While neither program could be considered a perfect answer to the situation at hand, *P. brutia* because of current establishment difficulties and spicatum because of site suitability issues, both offer some prospect of producing a commercial return.

It is unlikely that the replanting of these areas will be eligible for funding under the NAP program (as they are effectively not new plantings as required under the terms of this agreement) and they will therefore need to be funded from internal reserves.

Estimated direct costs for Year 1 and 2 replant of both species are shown below.
S. spicatum - $1,050/ha
P. brutia - $750/ha

When coupled with the cost of site cleanup and applied to the estimated total area of stand collapse the direct cost of replanting (assuming 50% brutia and 50% spicatum) can be expected to be in the vicinity of $300,000 - $340,000.

Recommendation
From an FPC perspective the reinvestment involved in the replant of these areas is unlikely to produce an attractive rate of return due to either site suitability issues or long haul distances. Therefore the FPC preference should be for the clean-up and surrender of these areas. However, while the FPC has the right under the terms of the PaP to make any exclusions it deems necessary from the original tree crop area such exclusions should be handled delicately given the infancy of our program and the potential for bad publicity. The treatment of each collapsed area should therefore be negotiated with the current landholder

While many landholders are likely to be satisfied with the return of the land in a neat and tidy state with their retention of participation payments and the option of recommencing farming operations, some may also begrudge the “stranding” of failed areas within plantation areas, particularly where larger cropshares were part of the contract conditions.

Where landholders express a desire for a replant of the collapsed area the decision on species selection should be based primarily on site type and to a lesser degree on haul distance. On better quality sites (coloured sands, loamy sands and sandy duplexes) and where haul distance to existing processing facilities exceeds 150km S. spicatum should be the selected species based on its potential for greater commercial return. On poorer quality sites (deeper sands) within 150km of existing processing facilities P brutia provides a more drought resistant softwood alternative.

Areas with scattered drought deaths

There are two main options for the management of areas currently exhibiting scattered drought death (<50% mortality).

1. Do nothing (allow drought to run it's course)
2. Take action reduce stand density.

It is recommended that areas suffering from scattered drought death are assessed for their level of drought risk. The risk rating for drought death should be determined as follows:

Risk = Likelihood x Consequence

The likelihood of drought is increased when a stand meets one or more of the following conditions.

- Drought deaths present in stand (residual stocking still greater than 750 stems/ha)
- Stocking rate greater than 1515 stems per ha
- Stand growing very rapidly, (evidence trees utilising stored soil water)
- High proportion of localised catchment planted to trees.
- Rainfall less than 400mm

The likelihood rating should be selected from the table below after consideration of these factors.

Likelihood

LEVEL	DESCRIPTOR
1	Rare
2	Unlikely
3	Moderate
4	Likely
5	Almost certain

The consequence rating for drought events is based on past observation. Recent drought deaths were strongly related to higher evaporation. Stands should be given a high rating (4) when average annual pan evaporation is greater than 2150 mm/year; this roughly translates to areas north of the Moore River.

Consequence

LEVEL	DESCRIPTOR
1	Less than 1800
2	1800-2000
3	2000-2150
4	2150-2200
5	Greater than 2200

Where risk rating (Likelihood x Consequence) is >10 it is recommended that stands are non-commercially thinned at age 5 to 7 to leave a residual stocking of between 600 and 900 spha dependant upon pan evaporation.

Suggested thinning schedules for two climatic categories are shown below.

Option 1 on pan evap greater than 2150mm/yr

Actual stocking (including E row)	1800 spha	1515spha
20 % (removed in E row/5th row)	360 spha	303spha
Trees in ‘bay’ to be selected from	1440	1212
Trees to be retained	600	600
Selection ratio	600/1440	600/1212
	5/12	5/10

Therefore, retain 5 trees in every 12 (in bay) if stocking 1800spha or 5 in 10 or 1 in 2 if stocking 1515spha

Option 2 on pan evap less than 2150mm/yr to Moore River to Beverley

Actual stocking (including E row)	1800 spha	1515spha
Trees to be retained	900	900
Selection ratio	900/1800	900/1515
	1/2	3/5

Therefore, retain 1 tree in every 2 if stocking 1800spha or 3 in 5 if stocking 1515spha

Culled plantations should be monitored for form and development in order to gauge the requirement for pruning however it is likely that such early thinning will encourage branch development making further treatment necessary in order to meet harvestability and product criteria.

A full rotation schedule and estimated operational costs is shown below.

Year	**Operation**	**Estimated Cost**
5-7	Thin to waste to 600 or 900 spha	\$500-\$750/ha
6-12	Monitor branch development Prune progressively (up to 5.7m for 125spha) when branch diameter exceeds 50mm	\$500-\$750/ha
14	Thin to 250 spha (50m3/ha pulpwood)	
25	Thin to 125spha (50m3/ha LVL, 25m3/ha pulpwood))	
32	Clearfall (90m3/ha LVL, 45m3/ha pulpwood)	

As for the schedule included for future plantings in drought risk areas, the cost of the proposed actions will be significant and they will also impact upon future harvest revenues. While the area affected by scattered drought has not yet been fully quantified, if half of the currently identified drought affected area is assessed in this category the full cost of treatment may amount to $300,000.

On sites where the assessed risk rating is< 10 it may be assumed that the final impact of drought is likely to be a “self thinning” of the stand rather than collapse. Stands in this category may be better managed via the “do nothing” approach as a similar outcome to the above treatment should result without the significant associated expenditure. The hazard associated with this approach is that thinning will be unmanaged and will not necessarily result in a uniform outcome and drought will also often affect the best trees first, effectively thinning the stand from above. Additionally dead and dying trees in a stand are predisposed to pathogen attack creating an environment likely to produce an increase in the population of such pests.

Areas currently not drought affected but at risk

Areas not currently affected by drought but at risk should be assessed and managed for the level of risk in line with the process above.

COST SUMMARY OF MANAGING PLANTATIONS AFFECTED BY DROUGHT – Sean Sawyer

Cleanup and Surrender

Estimated clean up costs	\$600 - \$800/ha
Estimated area requiring treatment	200ha
Estimated total cost	\$120,000 - \$160,000

Replanting with P. pinaster

Not recommended.

Replanting with alternative species

Estimated clean up costs	\$600 - \$800/ha
Replant S. spicatum (direct costs)	\$1,050/ha
P. brutia (direct costs)	\$750/ha
Estimated area	200 hectares
Estimated Total Cost	\$300,000 - \$340,000

Thinning and Pruning

Thinning and pruning of pinaster in stands affected by scattered drought death or at significant risk of drought.

Non – commercial thinning to 600 – 900 spha	\$500 - \$750/ha
Low pruning 250spha	\$300 - \$375/ha
High pruning 125shpa	\$250 - \$300/ha
Total	\$850 - \$1,425/ha
Estimated affected area	200 hectares scattered drought 1,500 hectares at significant risk
Estimated total cost	\$1,445,000 - \$2,422,500

Funding sources (estimate: \$1,865,000 – \$2,922,500)

ECONOMICS OF GROWING *P. PINASTER* ON DROUGHT-PRONE SITES - Mike McKelvie

	Target	Drought Prone
MAI (merchantable timber/year)	12	10
Rotation length	20	20
Stocking level	1515	1515
T1	600 (yr 12)	500 (yr 11)
T2	300 (yr 18)	300 (yr 17)
T3	180 (yr 24)	180 (y 23)
Establishment fee (y1 /2) approx	$2,300	$2,300
Maintenance fee (y2 -30) approx	$3,000	$3,000
Indicative land price / plantable ha	$4,000	$3,000
Annuity paid (4% of plantable ha)	$160/ha/yr	$120/ha/yr
Prices – as per current state agreements	LVL $35 IW $9.	LVL $35 IW $9.
Average haul distance to mill	120km	120km
Indicative revenue / ha	$8,100	$6,500
Target Real IRR	9% real	9% real
Indicative Real IRR	-0.6%	- 1.1%

Conclusion: The above table indicates that the economics of a 30 year rotation Pinaster plantation based on 1) land annuity payments and current land prices 2) current LVL log / Industrial Wood prices and 3) Establishment fee for service and 4) $100/ha/year maintenance and corporate overheads, would not meet cost of capital. Planting on drought prone sites would be marginally worse, assuming tree survival.

GAPS IN KNOWLEDGE John McGrath

Site evaluation/guidelines

Alternative species/genotypes

Options for other species for LVL

Effect of climate

Silviculture

LAI

SUMMARY/RECOMMENDATIONS

Appendix 1. (Mike Carter)
Detailed Listing of Density Reductions Recorded for P1998- P2001

Year	Area	Property	% Reduction in 2005	Min 2005 Reduction	Max 2005 Reduction	Total 2005 Reduction	Climate Point	% lo ob
1999	25.41	FITZGERALD	5%	1.32		1.32	1	
1998	27.99	KEMPTON	6%	1.30	0.25	1.55	1	
	53.40			**2.63**	**0.25**	**2.88**	**1 Total**	
2000	54.73	FLUCK	0%				2	
1999	29.35	MORCOMBE	6%	1.76	0.12	1.89	2	
1999	48.64	SUDHOLZ	1%	0.27		0.27	2	
	132.72			**2.03**	**0.12**	**2.16**	**2 Total**	
1998	114.15	ALIDALE (Richards)	8%	7.74	1.58	9.32	3	
2001	23.99	ALIDALE (Richards)	0%				3	
2000	34.67	DAVIES G & G	0%				3	
2001	116.80	DAVIES G & G	0%				3	
2001	46.82	LOVE	0%				3	
1998	44.11	NORCIA	37%	11.45	4.72	16.17	3	
2001	85.21	PEACOCK	0%				3	
	465.73			**19.19**	**6.30**	**25.49**	**3 Total**	
2001	37.65	BICKFORD	16%	3.98	1.99	5.96	4	
1999	22.21	STEFANELLI (MANNS)	54%	3.91	8.04	11.95	4	
2000	39.81	STEFANELLI (MANNS)	0%				4	
2001	70.24	STEFANELLI (MANNS)	1%	0.81		0.81	4	
1998	34.29	TONKIN B	17%	4.33	1.36	5.69	4	
1999	3.98	TONKIN B	6%	0.25		0.25	4	
2000	32.52	TONKIN B	14%	3.38	1.09	4.48	4	
2001	57.20	TONKIN B	3%	1.44		1.44	4	
1998	55.69	TONKIN C	30%	15.23	1.59	16.82	4	
1999	109.82	TONKIN C	36%	29.13	10.44	39.56	4	
2000	14.08	TONKIN C	31%	3.65	0.75	4.40	4	
1999	37.88	WARD	16%	5.71	0.44	6.15	4	
	515.37			**71.82**	**25.70**	**97.52**	**4 Total**	
1999	59.13	GLASFURD J	10%	4.14	1.72	5.86	7	
2000	96.72	GLASFURD J	0%	0.36		0.36	7	
2001	35.20	GLASFURD J	1%	0.18		0.18	7	
2000	40.16	GRIFFITHS	0%				7	
2001	21.31	GRIFFITHS	0%				7	
2000	63.80	McNEIL	1%	0.80	0.14	0.94	7	
2001	25.16	McNEIL	5%	0.40	0.81	1.21	7	
2000	84.76	MOLTONI	0%				7	
2001	67.32	MOLTONI	0%	0.12		0.12	7	
2000	91.57	TOMLINSON P	9%	6.06	1.74	7.80	7	
2001	30.50	TOMLINSON P	10%	2.12	1.00	3.12	7	
2001	74.89	WALSH	13%	3.93	5.84	9.77	7	
	690.51			**18.12**	**11.24**	**29.36**	**7 Total**	

Year	Area	Property	% Reduction in 2005	Min 2005 Reduction	Max 2005 Reduction	Total 2005 Reduction	Climate Point	% lo ob
2000	19.38	BROOKS	0%	0.08		0.08	8	
2001	131.31	BROOKS	0%	0.47		0.47	8	
1999	33.80	GLASFURD R	1%	0.40	0.05	0.44	8	
2000	62.17	GLASFURD R	1%	0.49		0.49	8	
2001	39.63	GLASFURD R	0%				8	
1999	31.56	MINTY	0%	0.04		0.04	8	
2000	47.78	MINTY	1%	0.23	0.06	0.28	8	
2001	32.07	MINTY	0%				8	
1998	18.99	TOMPALL NOMINEES	2%	0.45		0.45	8	
	416.69			**2.14**	**0.11**	**2.25**	**8 Total**	
1998	26.80	BENEDICTINE COMMUNITY	27%	2.71	4.55	7.26	9	
2000	64.29	CREAGH 2	8%	3.44	1.55	5.00	9	
2001	41.75	CREAGH 2	4%	1.39	0.18	1.57	9	
2000	47.26	FLEAY	12%	3.23	2.37	5.61	9	
2001	42.05	FLEAY	33%	8.04	5.82	13.86	9	
2000	55.35	MCGILLIVRAY	24%	5.76	7.36	13.12	9	
2001	95.11	MCGILLIVRAY	28%	17.70	8.93	26.63	9	
2001	24.54	MCKINLEY	0%				9	
1999	94.90	MILNER J	0%				9	
2000	208.78	MILNER J	5%	5.33	5.14	10.47	9	
2001	66.39	MILNER J	11%	4.55	2.87	7.42	9	
2000	90.91	OAKFIELD	3%	2.49	0.49	2.99	9	
2000	16.59	POND	0%				9	
2000	152.62	POWELL	0%				9	
2001	94.71	POWELL	0%				9	
2000	119.83	VAN BEEK	13%	9.31	6.60	15.91	9	
2001	50.92	VAN BEEK	4%	1.50	0.50	2.00	9	
1998	16.89	WADDELL	41%	2.10	4.74	6.84	9	
2000	51.40	WADDELL J & E	0%				9	
2001	28.15	WADDELL J & E	0%				9	
2000	30.40	WADELL	35%	3.68	6.93	10.62	9	
2001	107.22	WADELL	39%	20.45	21.83	42.28	9	
2000	62.22	WALSH	16%	4.34	5.73	10.07	9	
	1589.07			**96.03**	**85.61**	**181.64**	**9 Total**	
1999	13.06	GOOCH	4%	0.48		0.48	11	
2000	130.05	WAC	0%				11	
1998	48.89	ZAMPATTI	9%	3.39	0.96	4.34	11	
1999	47.97	ZAMPATTI	3%	1.26		1.26	11	
	239.97			**5.13**	**0.96**	**6.08**	**11 Total**	

Year	Area	Property	% Reduction in 2005	Min 2005 Reduction	Max 2005 Reduction	Total 2005 Reduction	Climate Point	% lo ob
2001	3.61	CHERITON	0%				14	
1998	6.83	SMITH	0%				14	
2001	22.29	SMITH DS	0%				14	
1998	16.07	WESTPORK GINGIN	0%				14	
1999	22.05	WESTPORK GINGIN	0%				14	
2001	16.79	WESTPORK GINGIN	0%				14	
1998	59.59	WESTPORK WANNAMAL	0%				14	
2000	44.34	WESTPORK WANNAMAL	0%				14	
2001	62.50	WESTPORK WANNAMAL	0%				14	
1998	29.79	WINTON	0%				14	
1999	19.25	WINTON	0%				14	
	303.11			**0.00**	**0.00**	**0.00**	**14 Total**	
1999	5.52	TALWYN	0%				15	
	5.52			**0.00**	**0.00**	**0.00**	**15 Total**	
1998	14.29	HAUSER	0%				18	
1999	40.91	HAUSER	0%				18	
2000	106.91	WILLIAMS	0%				18	
	162.11			**0.00**	**0.00**	**0.00**	**18 Total**	
2001	41.95	BAIN	0%				20	
1999	17.79	SAME	39%	3.36	3.57	6.93	20	
	59.74			**3.36**	**3.57**	**6.93**	**20 Total**	
2001	92.91	ASHWORTH	0%				21	
2001	110.61	DEMPSTER P J	0%				21	
2001	32.78	DEMPSTER V	0%				21	
1998	21.33	DENNIS	0%				21	
1998	20.74	HAGBOOM	54%	4.53	6.74	11.27	21	
1999	20.21	HAGBOOM	32%	2.84	3.67	6.50	21	
2000	52.16	HAGBOOM	26%	6.36	7.45	13.81	21	
2001	49.42	HAGBOOM	26%	7.69	5.10	12.79	21	
1999	30.55	HENDERSON	0%				21	
1999	49.08	MCDONALD / BINGHAM	0%				21	
2000	115.09	MCDONALD / BINGHAM	0%				21	
1999	9.12	O'NEIL	0%				21	
1999	38.49	QUARTERMAINE	0%				21	
1998	13.20	SEWELL	0%				21	
	655.70			**21.43**	**22.95**	**44.38**	**21 Total**	
1998	22.73	HANCOCK	0%				22	
	22.73			**0.00**	**0.00**	**0.00**	**22 Total**	
1998	59.34	ELLIOT	0%				25	
1999	6.47	ELLIOT	0%				25	
	65.81			**0.00**	**0.00**	**0.00**	**25 Total**	
1998	268.73	CAMPBELL SHAW	0%				28	
	268.73			**0.00**	**0.00**	**0.00**	**28 Total**	

Year	Area	Property	% Reduction in 2005	Min 2005 Reduction	Max 2005 Reduction	Total 2005 Reduction	Climate Point	% lo ob
1999	282.49	ADAMS	0%				30	
1998	34.74	AYNSLEY	0%				30	
2001	56.01	BLECHYNDEN	0%				30	
2001	33.18	BUTCHER C J	0%				30	
2001	37.93	BUTCHER I H	0%				30	
2001	18.74	FISHER	0%				30	
1999	39.28	HUNDLEY / SMART	0%				30	
1998	3.34	HUNDLEY NOMINEES PTY LTD	0%				30	
2001	58.61	MEECHAM	0%				30	
1998	27.76	MEERES	0%				30	
2001	51.14	MEERES	0%				30	
1998	18.69	MORTEN FARMS PTY LTD	0%				30	
1999	5.30	RICHARDSON	0%				30	
1998	29.48	RIDGWAY	0%				30	
	696.70			**0.00**	**0.00**	**0.00**	**30 Total**	
1998	47.11	HASSELL	0%				32	
	47.11			**0.00**	**0.00**	**0.00**	**32 Total**	
2001	71.88	HALL G H & A L	0%				34	
2001	71.31	HALL I D & G M	0%				34	
2001	213.86	MILLS C & K	0%				34	
2001	34.69	TURNER	0%				34	
	391.74			**0.00**	**0.00**	**0.00**	**34 Total**	
1998	25.11	GENT	0%				35	
	25.11		**0%**	**0.00**	**0.00**	**0.00**	**35 Total**	
2000	3.75	OCALLAGHAN B & M	0%					
1999	35.94	YORK	0%					
	6847.26			241.88	156.80	398.68	**Grand Total**	

Red Highlight -Indicates that these properties were identified as having deaths form aerial reconnaissance, however remote sensing failed to detect a reduction in density between 2004 and 2005 images.

Appendix B Area per Plantation and %

Year	Area	Property	% Reduction in 2005	Total 2005 Reduction
1999	282.49	ADAMS	0%	
1998	114.15	ALIDALE (Richards)	8%	9.32
2001	23.99	ALIDALE (Richards)	0%	
2001	92.91	ASHWORTH	0%	
1998	34.74	AYNSLEY	0%	
2001	41.95	BAIN	0%	
1998	26.8	BENEDICTINE COMMUNITY	27%	7.26
2001	37.65	BICKFORD	16%	5.96
2001	56.01	BLECHYNDEN	0%	
2000	19.38	BROOKS	0%	0.08
2001	131.31	BROOKS	0%	0.47
2001	33.18	BUTCHER C J	0%	
2001	37.93	BUTCHER I H	0%	
1998	268.73	CAMPBELL SHAW	0%	
2001	3.61	CHERITON	0%	
2000	64.29	CREAGH 2	8%	5
2001	41.75	CREAGH 2	4%	1.57
2000	34.67	DAVIES G & G	0%	
2001	116.8	DAVIES G & G	0%	
2001	110.61	DEMPSTER P J	0%	
2001	32.78	DEMPSTER V	0%	
1998	21.33	DENNIS	0%	
1998	59.34	ELLIOT	0%	
1999	6.47	ELLIOT	0%	
2001	18.74	FISHER	0%	
1999	25.41	FITZGERALD	5%	1.32
2000	47.26	FLEAY	12%	5.61
2001	42.05	FLEAY	33%	13.86
2000	54.73	FLUCK	0%	
1998	25.11	GENT	0%	
1999	59.13	GLASFURD J	10%	5.86
2000	96.72	GLASFURD J	0%	0.36
2001	35.2	GLASFURD J	1%	0.18
1999	33.8	GLASFURD R	1%	0.44
2000	62.17	GLASFURD R	1%	0.49
2001	39.63	GLASFURD R	0%	
1999	13.06	GOOCH	4%	0.48
2000	40.16	GRIFFITHS	0%	
2001	21.31	GRIFFITHS	0%	
1998	20.74	HAGBOOM	54%	11.27
1999	20.21	HAGBOOM	32%	6.5
2000	52.16	HAGBOOM	26%	13.81
2001	49.42	HAGBOOM	26%	12.79

2001	71.88	HALL G H & A L	0%	
2001	71.31	HALL I D & G M	0%	
1998	22.73	HANCOCK	0%	
1998	47.11	HASSELL	0%	
1998	14.29	HAUSER	0%	
1999	40.91	HAUSER	0%	
1999	30.55	HENDERSON	0%	
1999	39.28	HUNDLEY / SMART	0%	
1998	3.34	HUNDLEY NOMINEES PTY LTD	0%	
1998	27.99	KEMPTON	6%	1.55
2001	46.82	LOVE	0%	
1999	49.08	MCDONALD / BINGHAM	0%	
2000	115.09	MCDONALD / BINGHAM	0%	
2000	55.35	MCGILLIVRAY	24%	13.12
2001	95.11	MCGILLIVRAY	28%	26.63
2001	24.54	MCKINLEY	0%	
2000	63.8	McNEIL	1%	0.94
2001	25.16	McNEIL	5%	1.21
2001	58.61	MEECHAM	0%	
1998	27.76	MEERES	0%	
2001	51.14	MEERES	0%	
2001	213.86	MILLS C & K	0%	
1999	94.9	MILNER J	0%	
2000	208.78	MILNER J	5%	10.47
2001	66.39	MILNER J	11%	7.42
1999	31.56	MINTY	0%	0.04
2000	47.78	MINTY	1%	0.28
2001	32.07	MINTY	0%	
2000	84.76	MOLTONI	0%	
2001	67.32	MOLTONI	0%	0.12
1999	29.35	MORCOMBE	6%	1.89
1998	18.69	MORTEN FARMS PTY LTD	0%	
1998	44.11	NORCIA	37%	16.17
2000	90.91	OAKFIELD	3%	2.99
2000	3.75	OCALLAGHAN B & M	0%	
1999	9.12	O'NEIL	0%	
2001	85.21	PEACOCK	0%	
2000	16.59	POND	0%	
2000	152.62	POWELL	0%	
2001	94.71	POWELL	0%	
1999	38.49	QUARTERMAINE	0%	
1999	5.3	RICHARDSON	0%	
1998	29.48	RIDGWAY	0%	
1999	17.79	SAME	39%	6.93
1998	13.2	SEWELL	0%	
1998	6.83	SMITH	0%	
2001	22.29	SMITH DS	0%	

1999	22.21	STEFANELLI (MANNS)	54%	11.95
2000	39.81	STEFANELLI (MANNS)	0%	
2001	70.24	STEFANELLI (MANNS)	1%	0.81
1999	48.64	SUDHOLZ	1%	0.27
1999	5.52	TALWYN	0%	
2000	91.57	TOMLINSON P	9%	7.8
2001	30.5	TOMLINSON P	10%	3.12
1998	18.99	TOMPALL NOMINEES	2%	0.45
1998	34.29	TONKIN B	17%	5.69
1999	3.98	TONKIN B	6%	0.25
2000	32.52	TONKIN B	14%	4.48
2001	57.2	TONKIN B	3%	1.44
1998	55.69	TONKIN C	30%	16.82
1999	109.82	TONKIN C	36%	39.56
2000	14.08	TONKIN C	31%	4.4
2001	34.69	TURNER	0%	
2000	119.83	VAN BEEK	13%	15.91
2001	50.92	VAN BEEK	4%	2
2000	130.05	WAC	0%	
1998	16.89	WADDELL	41%	6.84
2000	51.4	WADDELL J & E	0%	
2001	28.15	WADDELL J & E	0%	
2000	30.4	WADELL	35%	10.62
2001	107.22	WADELL	39%	42.28
2000	62.22	WALSH	16%	10.07
2001	74.89	WALSH	13%	9.77
1999	37.88	WARD	16%	6.15
1998	16.07	WESTPORK GINGIN	0%	
1999	22.05	WESTPORK GINGIN	0%	
2001	16.79	WESTPORK GINGIN	0%	
1998	59.59	WESTPORK WANNAMAL	0%	
2000	44.34	WESTPORK WANNAMAL	0%	
2001	62.5	WESTPORK WANNAMAL	0%	
2000	106.91	WILLIAMS	0%	
1998	29.79	WINTON	0%	
1999	19.25	WINTON	0%	
1999	35.94	YORK	0%	
1998	48.89	ZAMPATTI	9%	4.34
1999	47.97	ZAMPATTI	3%	1.26

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