Western Australia's Development and Future Prospects for Tree Crop Industries

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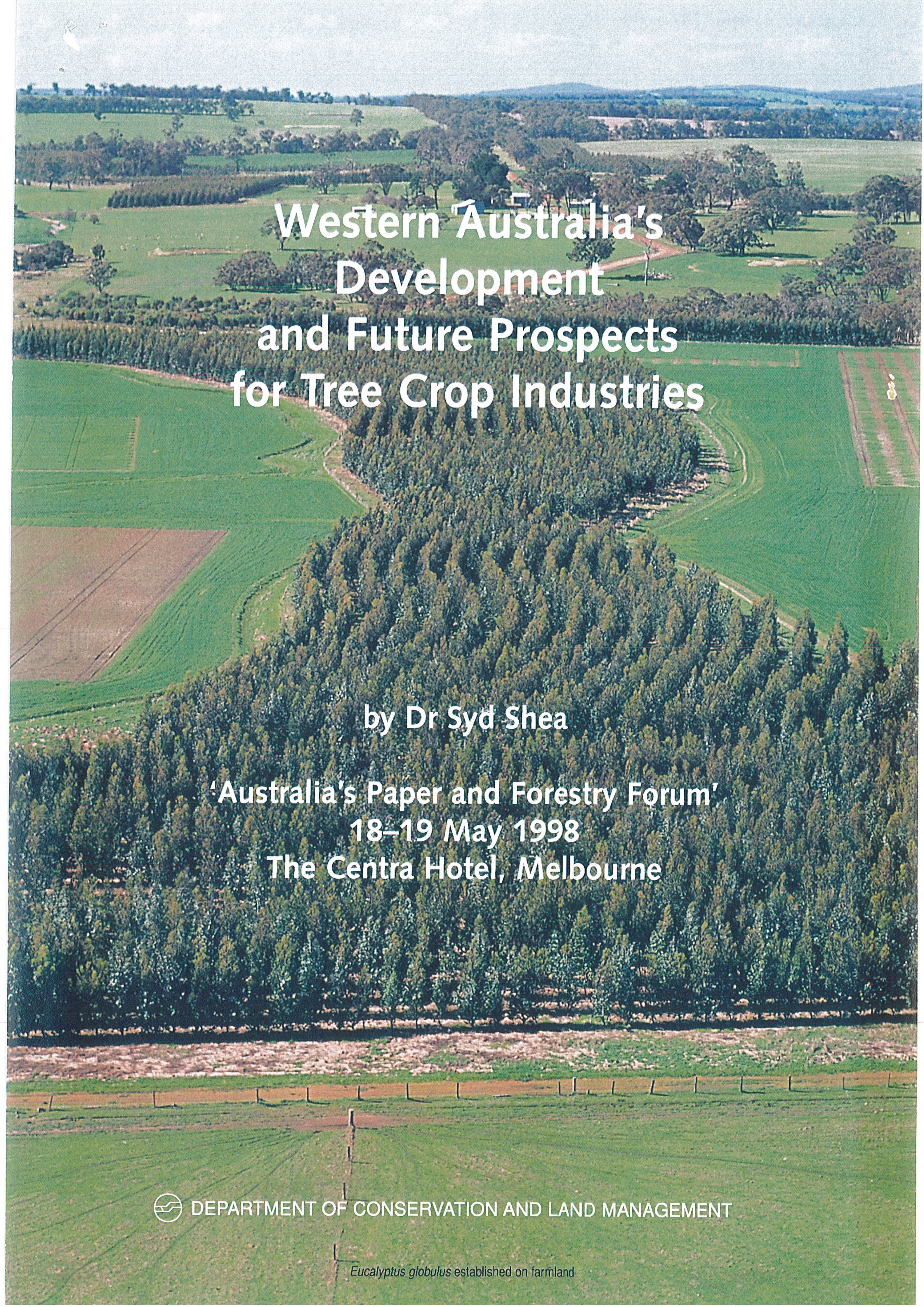


Eucalyptus globulus established on farmland

Abstract

Over a 75-year period from the 1920s until the mid 1980s Western Australia established 80 000 hectares of exotic plantations on Crown land and repurchased farmland. This resource is increasing and is producing feedstock for a major sawmill, several medium size mills and a medium density fibreboard and particleboard factories.

In the mid 1980s a series of political and environmental factors (the severe land degradation problem on farmland and concerns about the greenhouse effect) and the recognition that there were opportunities to capitalise on increased demand for high quality timber in the north-western Pacific countries led to the development of a tree crops on farmland program which was based on joint ventures between landowners and the Department of Conservation and Land Management.

Over a ten year period 100 000 hectares of E. *globulus* tree crops have been established on farmland by the Government and private investors. The program was expanded to drier zones of the agricultural region as part of a strategy to combat salination in 1996.

It is projected that by the year 2020, 800 000 hectares of tree crops will be established on farmland. These crops have the capacity to sequester 6 million tonnes of carbon per year and will generate 13 million cubic metres of wood fibre annually.

The planting program, if successful, will have a major impact on reducing land degradation, restoring biodiversity and generating significant employment opportunities in rural Western Australia.

Introduction

For almost a century the basic strategy for the production of wood from exotic plantations in Western Australia was the attainment of timber self-sufficiency.

The characteristics which dominated this strategy were (i) management principally by a State agency, the Western Australian Forests Department, (ii) block plantings on public lands cleared of natural forests and woodlands for this purpose, supplemented by planting on repurchased agricultural land, and (iii) densely stocked monospecific stands of one or the other of two species of pines of temperate northern hemisphere origin. Their product was destined primarily for conversion to sawn timber for sale on the domestic home building market.

From the close of the Second World War until the early 1980s, cultural methods based on scientific advances in nutrition and tree selection were improved. At the same time industrial methods for seasoning, slicing and reconstituting of wood by laminating, chipping and glueing of pines, increased the variety of their end uses leading to the establishment of a particle board and medium density factories using principally thinnings as their feedstock from Government plantations.

In the 1980s a combination of political and environmental factors resulted in the initiation of a new approach by the Department of Conservation and Land Management (CALM) (an integrated land management agency which incorporated the Forests Department) to plantation establishment - the establishment of tree crops on agricultural land. This paper summarises the history of plantation development in Western Australia, describes the factors that led to the initiation of the tree crops on farmland program, and the technical, economic and legal skills needed to ensure its success. The paper also outlines a vision for the future of the "tree crops on farms industry" in Western Australia.

The History of Plantation Development in Western Australia

Western Australia's first hardwood plantations, initiated in 1926, were of *Eucalyptus astringens* (brown mallet), grown for tannin production. Six thousand two hundred hectares were established. Western Australia's first softwood plantations were established in the 1920s following trial plantings in 1896 to find a conifer suited to local conditions. From 1950, the area of softwood plantation increased steadily to 50 000 hectares by 1985 and 70 294 hectares by December 1995 (CALM 1996). There are two main softwood plantation areas; *Pinus pinaster* is grown at Gnangara north of Perth (24 659 hectares) and *Pinus radiata* in the Blackwood Valley in the south-west (38 220 hectares) (Figure 1).

Fifty two thousand hectares of softwood plantations were established on public land which had been cleared of native vegetation and 13 000 hectares of softwood plantations were established over the period 1933 to 1991 on agricultural land purchased for pine planting, principally in the Blackwood Valley. These plantations were funded by a combination of State and Federal Government funds under the Federal Softwood Forestry Agreement Acts of 1967 and 1972 (Bureau of Agricultural Economics, 1977). Over the period 1969 to 1975, approximately 17 000 hectares of *P. radiata* plantations were established by private companies on former agricultural land.

By the beginning of the 1980s, opposition to the clearing of native vegetation for the establishment of softwood plantations had become a major environmental issue. The Labor Party, then in opposition, adopted a policy which prohibited the clearing of native vegetation for plantation establishment. Consequently, when the Government changed in 1983, the Western Australian Forests Department's strategy to establish a 60 000 hectare area of softwood plantations over a period of 30 years in an area known as the Donnybrook Sunklands, south of the existing P. radiata plantation in the Blackwood Valley, was terminated (Forests Department 1982).

At the same time, the new Labor Government proceeded to reserve a major river catchment system (the Shannon River basin) which contained a significant hardwood timber resource. The Government promised to fund the establishment of an area of softwood plantations sufficient to compensate for the timber foregone because of the reservation of the Shannon River basin.

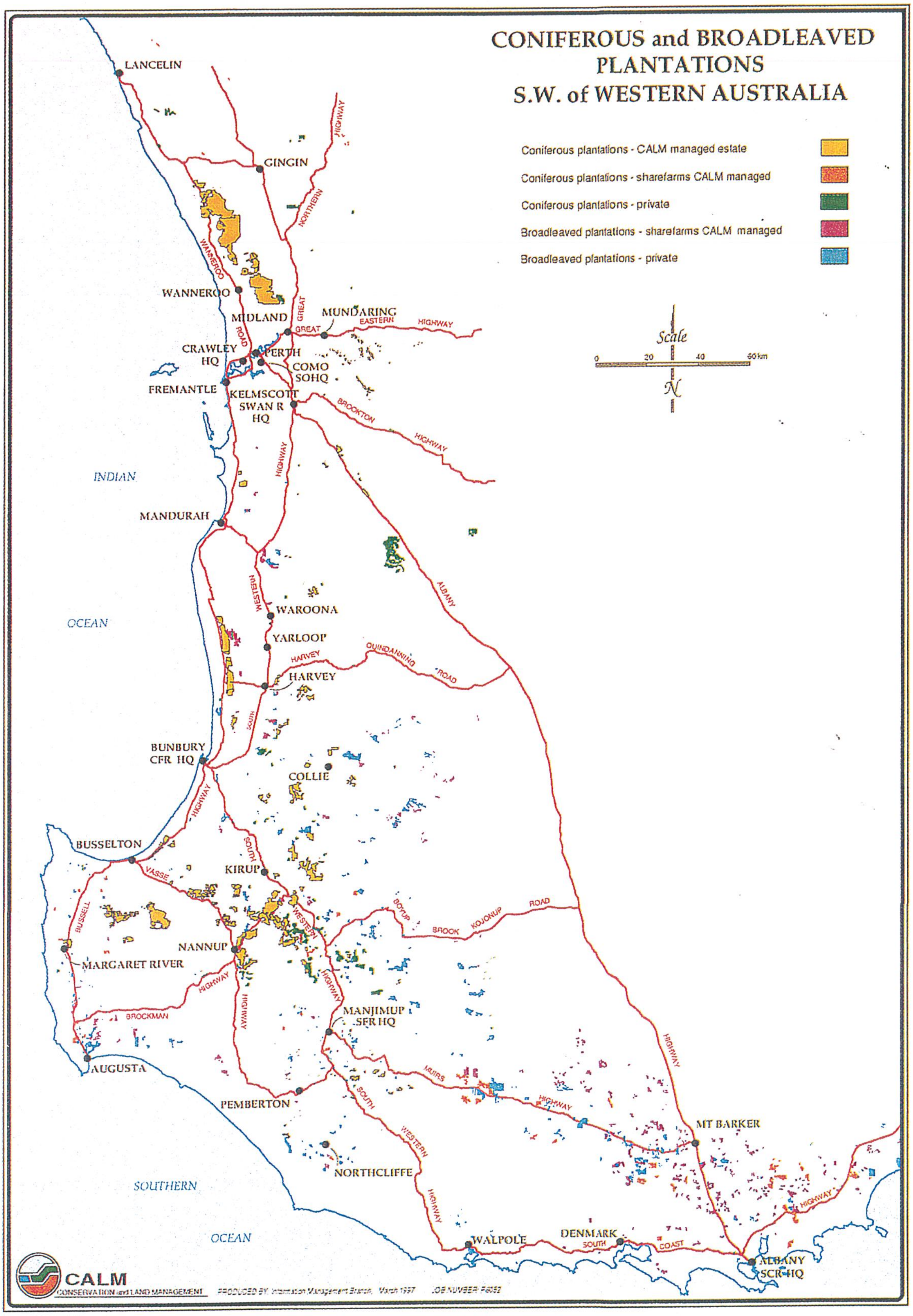
The purchase of agricultural land for pine planting by the State, which had been stopped in the 1970s in part because of objection from rural communities, recommenced in 1985. The decision to purchase agricultural land in the Manjimup Shire, where only 14 per cent of the land base was alienated and available for agriculture, provoked major opposition from both farmers and the local government. It was evident that land purchase by itself was not a viable way to obtain land for plantations.

In 1987, CALM undertook a major review of forest management and the forest industries in Western Australia which culminated in the production of a Timber Strategy (CALM 1987). With respect to the production of timber from plantations, the Strategy was influenced by two major developments.

Firstly, by the middle of the 1980s it had become apparent that a major wood fibre deficit was developing in the Pacific Rim countries (Groome 1987, Groome 1989). Secondly, it was recognised that the land and water degradation problems in Western Australia which had resulted primarily from clearing native vegetation and excessive fertilisation application could only be solved by the implementation of a major planting program of perennial crops on cleared agricultural land.

CALM recognised the potential of using the increasing demand for wood fibre to pay for the establishment of trees on farmlands which were required to reverse land degradation (Shea and

Figure 1



Plantations and tree crops
South-West of Western Australia

Bartle 1988, CALM 1987). CALM abandoned the self-sufficiency strategy which had set an upper limit on commercial tree planting and set out to develop the technical, economic, social and legal mechanisms which would make wood fibre production on Western Australian agricultural lands competitive in the international market. The objective was to develop a major commercial tree crop industry, on privately owned land in partnership with farmers, at a scale which would make a significant contribution to the rehabilitation of degraded agricultural land and river systems. From its inception the tree crops on farms program also recognised the potential role of tree crops to sequester carbon. The Western Australian Government funding required to initiate the project was, in part, provided in response to the emerging greenhouse gas issue (Government of Western Australia, 1989).

The Land Degradation Problem

Western Australia has over 70 per cent of Australia's reported dryland salinity (Table 1). An estimated 1.8 million hectares of farmland are already salt-affected to some extent. If unchecked, this area will double in the next 15 to 25 years and double again before reaching an equilibrium (Agriculture WA *et al.* 1996).

Table 1
Area of land reported to be affected by dryland salinity in Australia

State	Area salt-affected in 1982 (ha)	Area salt-affected in 1996 (ha)	Potential area at equilibrium
Western Australia	264 000	1 804 000	6 109 000
South Australia	55 000	402 000	600 000
Victoria	90 000	120 000	unknown
New South Wales	*unknown	120 000	5 000 000
Tasmania	*unknown	20 000	unknown
Queensland	*unknown	**10 000	74 000
Northern Territory	*unknown	Minor	unknown
Total	**NA**	**2 476 000**	**>11 783 000**

* salinity was likely to be present but its extent had not been assessed.
** only severe salinity
Source : Agriculture WA *et al.* (1996)

Salinity is caused by replacing the deep-rooted, perennial native vegetation with annual crops and pastures used in agriculture which cannot transpire as much of the rainfall as the native vegetation. The result is an accumulation of excess groundwater, which causes water tables to rise, mobilising stored salts and causing waterlogging and salinity on low areas. Salt concentrations in river systems have increased in more than 50 per cent of the river and stream systems in the south-west region of the State. Enhanced runoff can also cause erosion of stream lines.

Excessive fertiliser runoff from agricultural land has also caused eutrophication of estuaries throughout the south-west of the State, with adverse effects on the biota, particularly fisheries, recreational utility and air quality in residential developments around the estuaries. Wind erosion is also a significant problem in the south coast agriculture zone.

Salination and eutrophication also have a major impact on conservation reserves and wetland systems. Most of the wetland systems in the agricultural zone have been destroyed by salination and if unchecked salination will destroy up to half of the remaining native vegetation in public reserves and on farmlands in the agriculture zone (Agriculture Western Australia *et al.* 1996).

Revegetation with trees and shrubs is the only practical long-term option for controlling dryland salinity, although the magnitude of the replanting required will be reduced if the health and vigour of remnant vegetation can be improved and the water use of annual crops and pastures increased.

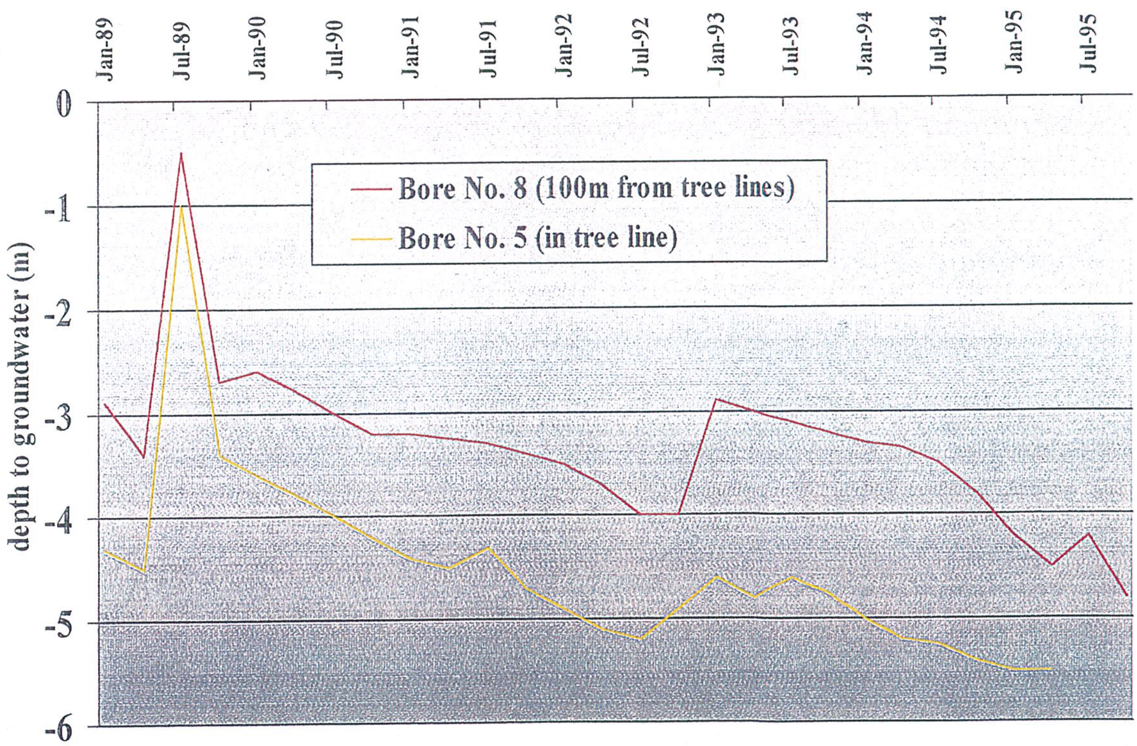
The capacity of tree crops to reduce water table levels significantly by exploiting water stored in the soil profile has been demonstrated in trials with several different species (Farrington and Salama 1996). The proportion of the landscape that needs to be revegetated with perennial crops will decrease in areas with lower annual rainfall because the winter rainfall "surplus" decreases and the amount of water transmitted to the groundwater table each year is less.

It is theoretically possible to increase water availability above what would be expected for a given rainfall and reduce the proportion of the farm planted to trees to achieve reduction in groundwater table levels by altering the configuration and location of tree crops to capture surplus water.

It has been estimated that provided trees are strategically located, groundwater control can be achieved by revegetating between 10 per cent and 30 per cent of the landscape with perennial crops (Schofield 1990, Farrington and Salama 1996). For example, in the south coast region *P. radiata* planted on a deep sand soil in three-row belts 200m apart for wind protection, is showing a steady lowering of the water table at a rate of approximately 50 cm per year across the whole land unit (Short and Skinner 1996) (Figure 2).

Figure 2

Hydrograph showing groundwater response to alley farming system
(after Short and Skinner, 1996)



It is also possible to minimise or eliminate the opportunity cost of withdrawal of land from crop or pasture production by skilful location of tree crops. There is increasing evidence that grazing and crop productivity can be significantly increased by skilful integration of tree crops into farming systems (Shea *et al.* 1993).

It is estimated that three million hectares of trees and perennial shrubs will have to be established in the agricultural zone at a cost of $3 billion to control salination (Agriculture Western Australia et al. 1996). The development of a major commercial tree crop industry on farmlands provides a method to partially fund the rehabilitation of the soil and water systems of the agricultural zone, while at the same time providing another source of income to farmers.

Critical Factors Affecting the Development of a Tree Crop Industry

1. Land acquisition

Extensive clearing of native vegetation has been carried out in Western Australia over a period of 150 years for agricultural development. It is theoretically possible to establish commercial tree crops on a significant proportion of this landbase provided that the social and economic barriers can be overcome (Table 2).

Table 2
Farm Forestry Zones by area and rainfall

	Rainfall (mm)		Area (x 10^6 ha)	
		Cleared land[1]	Suitable land[2]	Plantable land[3]
Pine and Bluegum	>600 mm	2	1.3	.26
New Maritime Pine	400-600 mm	6	4.0	0.8
Wheatbelt	<400 mm	10	6.7	1.3
Total		**18**	**12.0**	**2.36**

[1] Cleared farmland from Beeston et al (1994)
[2] land without limitations such as shallow soils, salinity
[3] assumes can plant 20% of suitable land

Economic analyses of the relative profitability of grazing and forestry in the lower south-west demonstrated that the latter was more profitable but very few farmers had established, or intended to establish, commercial tree crops on their farms (Malajczuk *et al.* 1984). Analyses of farmer attitudes showed that there were a number of reasons for this, but one of the major factors was the relatively poor cashflow of tree crops. There was also strong community concern that whole farm tree planting would result in a reduction in basic services.

The strong opposition to whole farm purchase for plantation establishment and the large amount of capital required for land purchase made it essential that alternative methods of land acquisition were developed. A review of the relevant costs of land purchase and leasing over the period of a 30-year pine rotation was undertaken. The study concluded that leasing would not cost more than land purchase and had the added advantage of requiring less up-front capital (Malajczuk *et al.* 1984).

The first leases were developed in the mid-1980s to enable the establishment of *P. radiata* plantations on privately-owned farms. The agreement involved payment of an annuity throughout the rotation and ten per cent of the value of the final crop at harvest. These agreements were described as "pine sharefarming agreements" because the concept of "sharefarming" (that is, leasing of part of the farm to another farmer) was well understood by farmers. This simple model was adequate to procure land when the government was providing the finance and managing the scheme. But it was not robust enough to be used to establish hundreds of joint ventures between large private companies and individual farmers.

Consequently, extensive negotiations were undertaken with prominent farmers, the Western Australian Farmers' Federation, agricultural and legal advisers and local government authorities, to develop a new land acquisition package.

The central feature of the commercial land acquisition package that was developed is a Deed of Grant of Profit a Prendre in which the landowner grants to a third party a right to (in this case) establish, manage and harvest a plantation on the land. The contract is registered on the title to the land and is transferred with the sale of the property. The sharefarming contract between the landowner and CALM is based on the sharing of the harvest revenue in the same proportions as the discounted inputs of each party in the land costs, establishment and management of the crop.

The profit a prendre or timber sharefarming contract allows an investor the flexibility to cater for all sorts of landowner wishes and provides a simple method of accessing a portion of a farm thereby overcoming concerns by farmers and local government authorities about the social, economic and political impacts of whole farm purchase for tree establishment.

The landowner can choose to be an active partner in the crop by taking a share of the returns through a lump sum return at harvest time only (full crop share). The landowners may elect to increase their share of the returns by investing directly in the establishment of the plantation - a $1000/ha investment increases the share to approximately 65-70 per cent and attracts a tax deduction for the investor in the year of establishment.

In each of the above cases, the returns to the landowner are ultimately dependent upon the value and the volume of the timber at harvest time.

For those landowners who require maximum returns as early as possible, the full annuity option is more appropriate, characterised by annual payments of up to $250 per hectare with no share of the harvest revenue, with annuities based on haul distance to the processing plant and the productivity of the site. This is feasible on highly productive sites.

There have been a number of variations of the basic sharefarm agreement developed in response to landowner requests. For example -

- Planting of non-commercial species on salt-affected sites unsuitable for main commercial species or as aesthetic or conservation plantings on an area equivalent to 10 per cent of the commercial planting at no cost to landowner.

- Planting of alternative woodlot species for special purposes, eg specialty timbers, sandalwood, sawlogs, craftwood. Funded under similar conditions to above.

Apart from the poor cashflows and concern about the impact of tree planting on the social structure of rural communities, there was a general lack of information about the benefits of tree crops. It is less than two decades since a condition was placed on purchase of land by farmers from the Government that required a proportion of the farm to be cleared within a specific period.

Consequently, some farmers have found it difficult to adjust to the idea of re-establishing trees on farms. CALM and Agriculture Western Australia have implemented a major education and marketing program to inform farmers of the benefits of tree crops.

CALM has established 1400 treecrop joint ventures with farmers based on the Profit a Prendre contract since the inception of the scheme. The average annual area planted per property has increased from three hectares in 1988 to around 120 hectares in 1995 and 1996. This increase is in response to a number of factors but the most important is the general increase in acceptance amongst the farming community that commercial tree crops are a viable complementary crop for the farm and contribute significantly to landcare.

2. Species Selection and Genetic Improvement

CALM is currently field trialling more than 44 species on farmland including salt resistant E. camaldulensis and E. wandoo and a range of Acacia species, but *P. radiata, P. pinaster, E. globulus* and *mallee eucalyptus* are the only species which have been planted extensively for commercial purposes.

Pinus radiata

The breeding program for P. radiata in CALM was started in the early 1960s. The improvement in productivity with open pollination is between 16-18 per cent, control pollination can increase volumes by 25 per cent. Selecting for *Phytophthora* resistance has been successful enabling CALM to establish *P. radiata* on moisture gaining and infested sites.

The deployment of the genetic gains of *P. radiata* in CALM has been through seed. All seed production of *P. radiata* is from hedged artificially pollinated seed orchards (HAPSO).

E. globulus

Over 100 000 trees have been planted to capture the *E. globulus* gene pool and trials have been established on a diverse range of sites in Western Australia. The superior trees have been cloned by grafting and are established in clonal orchards and archives. As well as breeding for volume, wood density, stem form, crown quality and drought tolerance, trials for salinity tolerance and resistance to insect attack have also been established. Nine hundred and ninety one parent trees have been tested as 97 000 progeny in 32 trials occupying an area of 109 hectares. A further 27 hectares of King Island parents (endangered Bass Strait Islands populations) have been planted as a gene pool.

The Western Bluegum (WBG) trademark has been registered by CALM to be used for *E. globulus* seedlings or cuttings produced from CALM's Plant Propagation Centre that have been developed from the Department's tree breeding and improvement program. Western Bluegums are genetically superior for a number of specified traits. Based on measurements of two-year-old trials Western Bluegum have achieved gains of 32 per cent improvement in volume produced over routine seed, and stem and crown quality were also improved. If problems with flowering synchronization can be overcome, based on the performance of elite trees, it will be possible to achieve productivity gains of 80 per cent (Butcher pers. comm.).

P. pinaster

Research on genetic improvement of *P. pinaster* commenced more than 40 years ago. Ninety seven genetic trials covering an area of 203 hectares and 216 000 trees have been established in

Western Australia to provide the base population and database required to quantify genetical parameters of P. pinaster. Initial yield trials showed a 36 per cent increase in volume. Recent orchard plantings have shown increases of 50 per cent in volume production over the first seed orchards. For selections now being grafted, a 80 per cent improvement in productivity compared to the first seed orchards has been achieved.

These genetic gains are being deployed by vegetative cuttings because it is logistically impossible to protect seed orchards from native cockatoos.

Eucalyptus oil species

Six mallee species have been chosen to provide at least one suitable species for any wheatbelt location. Superior parent trees are selected from native populations based on leaf oil content. Progeny trials and seed orchards incorporating superior selections have been established for six species.

Deployment of gains will be achieved via seed produced, as mallee eucalypts flower prolifically within three years of age.

3. Site Selection for Tree Crops

The ability to predict site productivity is even more critical to the success of the establishment of tree crops on farmland than in traditional plantation establishment. Site conditions can vary markedly on farms because of different fertiliser histories and salination as well as variations resulting from geological structures and soil types.

The principal biological constraint on commercial tree crop growth in Western Australia, which has Mediterranean climate, is rainfall. Until recently, tree crops have been restricted to areas with rainfall in excess of 600 mm per annum. But *P. pinaster* grows on an annual rainfall of 400 mm and greater and mallee eucalypt species occur naturally in areas where annual rainfall is less than 200 mm per annum.

Eucalyptus globulus

Eucalyptus globulus is not established in areas where annual rainfall is less than 600 mm. The evaluation of land for *E. globulus* plantations in Western Australia is currently carried out using the *E. globulus* growth simulator (EGGS) (Beadle and Inions 1990, Inions 1991, Inions 1992). This model was developed by relating the growth of E. globulus in 56 different plots throughout the south-west of Western Australia to 74 environmental attributes (21 climatic variables, 29 soil physical and chemical properties and 24 other variables).

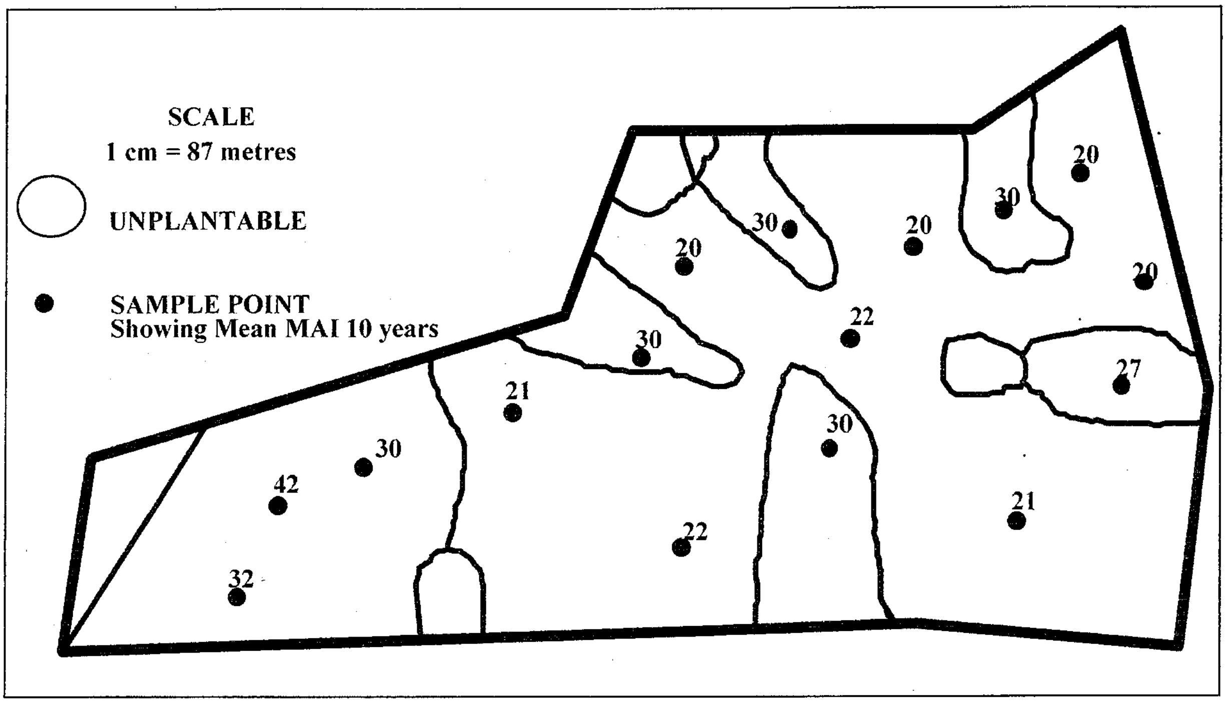
Using the combination of climatic, soil physical and soil chemical data from each site, the growth simulator predicts site potential in terms of a site index. Relatively small changes in site characteristics can have a profound effect on productivity (Figure 3).

Pinus pinaster

Soil factors which are most likely to affect *P. pinaster* survival and growth are related to soil water storage and salinity. For trees to establish successfully and grow in the 400mm - 600mm medium rainfall zone, soils must be non-saline, of adequate depth and have fresh water additions from seepage or groundwater (Harper, 1996).

Figure 3

E. globulus site productivity assessment for a typical farm



Potential planting areas are assessed using aerial photography and land management units are identified by examining landform and vegetation features. Soil sampling of different land management units is then carried out using a hand-held auger in sandy soil, or a backhoe if necessary. Sampling intensity varies with changes in land management units, but a minimum of one observation hole every 25 hectares is required. For soil to be suitable for planting, depth of root-penetrable material must be 2-3m. One hundred and eighty plots have been established in 100 P. pinaster stands which have been identified in the 400-600mm rainfall zone and are being used to develop a growth prediction model (P. Ritson pers. comm.). Preliminary stand measurements indicate that P. pinaster can establish and grow in a wide range of soils including duplex and sandy loams, in addition to sandy soils. Typically, growth rates for these stands, which were not derived from elite seed and have not been established with the benefit of new establishment technologies and fertilisation that have been developed over the past 10 years, vary from 4 to 12 cubic metres per annum.

Pinus radiata

Land suitability criteria for *P. radiata* differ to those for *P. pinaster* in that *P. radiata* is less tolerant of waterlogged, infertile or drought prone sites. Planting is generally confined to areas with mean annual rainfall of greater than 600 mm.

Mallee eucalypts

The range of species being developed for oil production has been selected to include species well adapted to all major wheatbelt sites.

4. Tree Crop Establishment

One of the most vital components of tree crop establishment on farmland is weed control. Failure to appreciate the impact of weeds on survival and growth of tree species established on farmland is probably one of the major reasons why early trials of commercial tree crops on farms were not successful. Uncontrolled weeds or poor use of herbicide can markedly affect both survival and growth. Extensive field trials have shown that the right combination of herbicides can improve survival from less than 50 per cent to over 90 per cent, and height can be increased by more than 50 per cent (Ellis, 1992). The weed control strategy required must be tailor-made to the species, site, weed type and seasonal conditions. Timing of application of weedicides is critical. Second-year weed control has been shown to increase the volumes by up to 129 per cent on some sites.

Quality and cost of seedlings is another critical factor. CALM's major commercial nursery located at Manjimup currently produces in excess of 20 million seedlings per year and will be expanded to increase the production capacity to 60 million seedlings per annum within 18 months. Seedling production at this scale enables unit costs to be reduced below 20 cents and the mechanisation that is possible because of the large throughput, increases quality control. All seedlings used for tree crop establishment on farms will be grown in containers when the Manjimup nursery expansion is completed.

Site preparation varies according to tree species and soil conditions. But generally all sites on farmlands are ripped and mounded to a minimum depth of 500 mm. On some sites scalping to a width of 1.2m and depth of .3m is carried out to remove non-wetting soils allowing water accumulation at the bottom of the scalp line and for weed control.

5. Silviculture and Maintenance

The configuration and size of tree crop plantings on farmland is determined in consultation with the landowner and site and catchment characteristics.

One of the major benefits of establishing tree crops on farmland, rather than on areas cleared of native vegetation, is the existence of a nutrient soil bank resulting from previous agriculture practices.

Unlike fertilisation on cleared native forest sites where responses to many nutrients occur, fertilisation of tree crops growing on farmland has not generally produced large responses. Virtually no responses to phosphorus have been recorded. The exception is the response to the application of nitrogen and potassium on some light textured soils in the higher rainfall zones, which has produced some spectacular increases in growth. These responses appear to last for some years and have resulted in a doubling of growth on some sites.

The lack of response to phosphorus application on farmland sites is consistent with the long lasting responses to phosphorus fertilisation on a range of soils by *P. radiata*. The residual activity of phosphorus applied to annual crops and pastures appears to be sufficient to supply the requirements of tree crops for at least a considerable part of the tree rotation.

Although nutrient supply is less likely to limit tree growth on farmland, responses to both nitrogen and potassium have been found on some sites in the early part of the rotation for both *P. radiata* and *E. globulus*. Increases in growth rate of up to 40 per cent have been recorded from intermediate and mature-aged *P. radiata* and *P. pinaster* stands growing on ex farmland sites in the Blackwood Valley (McGrath pers. comm.). This suggests that substantial responses to fertilisation may occur later in the rotation or in subsequent rotations on agricultural land.

Eucalyptus globulus

Seedlings are planted by hand at 1 250 sph (spacing of 4m x 2m), and fertilised according to the requirements of the site. Monitoring of insects is carried out on a weekly basis during summer, and insecticides are used where required. The main insects of concerning the first year are wingless grasshopper and spring beetle. After the first summer, CALM relies on the landowner to check for insect activity.

Second-year weed control is undertaken on all *E. globulus plantations*. Maintenance fertilising is carried out as required and foliar analysis is the preferred way of deciding how much and what type of fertiliser to use.

Plantations will be clearfelled at between 6 and 14 years of age depending on growth rates and wood flow requirements. The second rotation may be either a coppice rotation, or if genetic gains are large enough, it may be economic to replant with genetically improved stock.

Pinus radiata

The silvicultural regime for *Pinus radiata* are shown in Table 3.

There are two thinnings at 12 and 24 years yielding mainly industrial wood and small sawlogs. Fertilising is planned for immediately after these thinnings so that the remaining crowns can quickly use the additional space created from the thinning. Clearfall occurs at approximately 30 years of age.

Pruning is only done on trees in the outside rows to allow access for fire control. The initial stocking of 1 500 sph keeps branch sizes to a minimum. Grazing by rabbits can be a problem, but is controlled by baiting with 1080 oats. New plantations are surveyed for insect attack (particularly by wingless grasshopper and budworm) every week over summer, and if insects are detected, the plantation is sprayed with insecticide.

Table 3

	P. radiata Conventional Regime	
Year	**Action**	**Product**
0	Plant 1500 sph	
12	Thin to 800 sph fertilise	Industrial wood
24	Thin to 300 sph fertiliser	Small sawlogs and industrial wood
30	Clearfall	Small and large sawlogs

Pinus pinaster

Two regimes have been determined for the maritime pine project. A conventional regime over a 30-year period (Table 4) and one which involves only one thinning and clearfall at 25 years (Table 5). The second regime is particularly aimed at farmers wanting multiple benefits from maritime pine, because it is suitable to narrow belts which produce timber while also providing shelter and controlling wind erosion.

Table 4

Maritime Pine Conventional Regime		
Year	Action	Product
0	Plant 1500-1800 seedlings per hectare	
12	Thin to 450 sph	Industrial wood
18	Thin to 250 sph	Small sawlogs
24	Thin to 125 sph	Sawlogs
30	Clearfall	Sawlogs and peeler logs

Table 5

Maritime Pine Single Thinning Regime		
Year	Action	Product
0	Plant 1500-1800 seedlings per hectare	
12	Thin to 150 sph	Industrial wood
	Prune to 6m	
25	Clearfall	Small, peelers and industrial wood

Mallee eucalypts

Mallees are planted in a twin-row "hedge" configuration. This provides a dense sward of leaf for efficient harvest. First harvest is possible at age three years. Mallee coppices prolifically and subsequent harvests can be taken on a 1-2 year cycle.

The dispersed nature of tree crop plantings reduces the probability of losses from bush fire. The landowner is responsible for the construction and maintenance of firebreaks. There is a well-organised rural fire brigade system which has been supported by CALM and investors in tree crops by the provision of training and fire fighting equipment.

Costs of Production and Economic Return from Tree Crops

The cost of production of the three main tree crop species being used is shown in Table 6.

While the cost of production to final cropping stage is significant it often is less than half of the cost of delivery of logs or chips to the mill door or port where the logs or chips are sold. Factors such as wood density can also have a major impact on the price of logs or chips. CALM's costs for harvesting, chipping and transport are, respectively, $15, $8 and $7 (assuming an average rail distance of 70 km).

Table 6
Costs of Production

Species	Rotation	Net Present	Establish-	Intermediate	Total
	Age	Value @ 7%	ment Costs	Costs	$
		$	$	$	
Maritime Pine	30	1 920	1 580	860	2 440
P. radiata	30	4 332	2 120	5 890	8 010
E. globulus	10x2	4 920	2 117	5 920	8 037
Mallee	100+	1 000	1 000	—	1 000

Assuming the above costs, the delivered average price of *P. pinaster* industrial (pulp, MDF and OSB and particle board products) would be \$35-\$40 per cubic metre and the price of sawlogs (unpruned) would average \$60-\$80. These costs and prices correspond to the returns for landowners and investors shown in Table 7 and 8.

At current costs and timber prices the real internal rate of return for *P. radiata* is between four per cent and six per cent.

Table 7
Returns per hectare in 1998 dollars to an investor from maritime pine growing at 12m3/ha/year under an 80:20 cropshare agreement

		Timber income	
Year	**Yield (m3ha)**	**Investor($/ha)**	**Landowner ($/ha)**
		(80% share)	**(20% share)**
12 Thin	66	844	206
18 Thin	72	1172	286
24 Thin	72	1466	358
30 Clearfell	150	3414	834
Total	**360**		

Table 8
Effect of growth rate on the timber rate of return from a conventional regime of 30 years

Increase in stumpage	**Growth rate**	
current		
	12m³/ha/yr	**16m³/ha/yr**
Current	5.1%	6.7%
20%	6.2%	7.8%
40%	6.8%	8.4%

The average cost of production of a bone dry unit of *E. globulus* assuming a MAI of 25 cubic metres per hectare per annum, an annual annuity of \$172 per hectare and a haulage distance of 80 kilometres over two rotations is \$A140 per BDU, FOB.

This corresponds to an internal real rate of return (assuming the costs shown in Table 6) of 12 per cent.

A preliminary economic analysis was undertaken of the potential economic returns from mallee eucalypts by Bartle *et al.* (1996). The analysis was based on a ten per cent planting of a typical wheatbelt farm in an alley-farming layout. All costs and benefits over a 20-year term were converted to net present value at a discount rate of 6.5 per cent. A halving of the rate of expansion in salinity was incorporated into the analysis. The analysis showed no reduction in net present value of the farm business at an oil price of \$2.65 per kilo, well below prevailing market prices, but probably too great for rapid penetration of solvent markets. However, it also showed that net present value could be significantly improved by increased leaf oil content and reduced processing costs. Preliminary studies showed that both these factors can be significantly improved.

The Bluegum Project

Eucalyptus globulus had been established in trial plots throughout the south-west of Western Australia since the 1960s. But it was not until 1980 that small operational plantings were commenced by the Western Australian Chip and Pulp Company (WACAP), (the major exporter of native woodchips from Western Australia) who foresaw the potential to supplement the native forest woodchip exports with high quality plantation grown *E. globulus* (Oldham pers. comm.). In the mid 1980s a proposal was made to establish a *E. globulus* estate on farmlands in the southern coastal region of Western Australia centred on Albany (McLean pers. comm.). But this was rejected by the Environmental Protection Authority principally because it was proposed to fund the plantations from the sale of woodchips derived from remnant vegetation on private farmland.

In 1989 CALM approached the two major timber companies in Western Australia (Bunnings and Western Australian Forest Industries) with a proposal to seek funds to establish a large commercial *E. globulus* (bluegum) tree crop estate on farmlands to assist land rehabilitation. The Western Australian Government subsequently approved the formation of a consortium consisting of CALM and the two private companies to investigate the potential of obtaining funds for tree planting on agricultural land. The proposal became known as "Tree Trust". Consultants were employed, and over a period of several months legal and financial vehicles were developed. But all attempts to induce the institutional funds and other potential investors to commit to the Tree Trust project failed and the consortium was dissolved in June 1990.

One of the participants in the consortium, Bunnings, decided to investigate the potential to raise funds for tree planting by forming a prospectus company. The first Tasmanian Bluegum prospectus was launched in 1990 and was only partially successful. The 1993 prospectus was withdrawn. By 1994, however, a number of companies were successful in raising funds for these bluegum plantings by public subscriptions.

Following the failure of "Tree Trust" CALM, on the advice of New Zealand forestry consultants (Groome Poyry), sought investment in the tree crops on farmland project from the major importers of fibre in the world - the Japanese pulp and paper companies. In 1989 the first of approximately 30 delegations of representatives of the Japanese pulp and paper industry visited Western Australia to examine the proposal in the field.

It soon became apparent that although the bluegum project was appealing to investors from either Australia or overseas, it required more than trial plots before they would commit funds. Consequently, CALM undertook an extensive planting program funded by loan funds. In the period 1988 to 1994, 8 000 hectares of *E. globulus* were established by CALM on farms throughout the south-west of the State using the sharefarming concept that had been developed for *P. radiata* tree crops in the mid-1980s.

The fact that the Government was prepared to commit significant funding to establish tree crops on farms, the willingness of farmers to participate in the scheme and the overall success of the plantings resulted in major overseas companies agreeing to invest in the project.

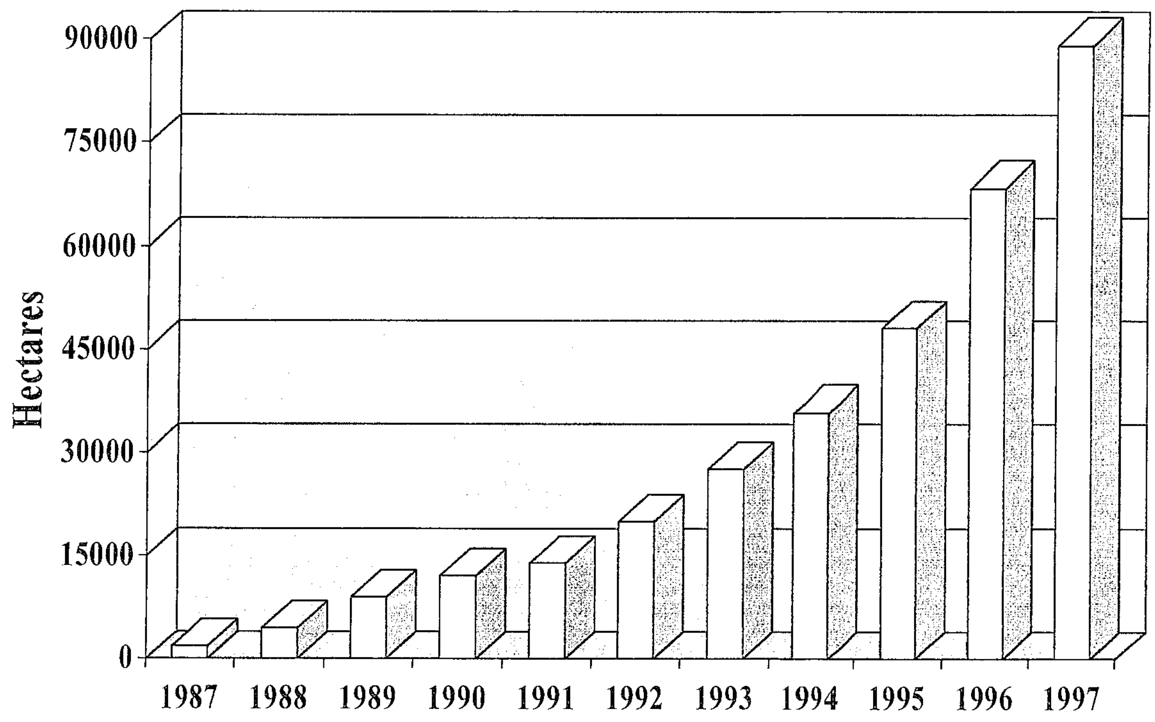
Over the period from 1993-1995 CALM signed agreements to undertake the establishment and management of a total of 40 000 hectares of E. globulus on farmlands over a ten-year period with two groups of Japanese companies and a Korean company (Albany Plantation Forest Company of Australia Pty Ltd - a consortium of Oji Paper Company Ltd, Itochu Corporation and Senshukai Company Ltd; Bunbury Tree Farms - a consortium of Mitsui Plantation Development (Australia) Pty Ltd, Nippon Paper Company and MCA Afforestation Pty Ltd; Hansol Australia Pty Ltd. Subsequently the area has been increased to 60 000 hectares.

Each agreement is backed by an Agreement Act passed by the State Parliament and a legally binding contract with CALM.

The participation of large overseas companies who are end-users of high quality wood fibre for the production of pulp and paper has, in part, been responsible for a major increase in investment in bluegum by private companies in Western Australia. In 1997 it is estimated that 20 000 hectares of bluegums will be established on farmlands in south-west Western Australia. With the completion of the 1999 plantings, the original Tree Trust target of 100 000 hectares will be reached two years ahead of schedule (Figure 4).

Figure 4

Total area of E. globulus in WA



Maritime (Pinus pinaster) Pine Project

In 1996 the Western Australian Government endorsed a CALM proposal for a major expansion of the tree crop industry into the intermediate rainfall areas of the State and selected catchments on the coastal plain.

The maritime pine project is a significant component of the government's salinity strategy (Agriculture WA *et al.* 1996). The intermediate rainfall zone in the State makes its disproportionate contribution to the salinity problem because of its relatively high winter rainfall surpluses, high salt loads and broad valley systems. It is also important to establish tree crops on sandy soils on the coastal plain in key catchments to ameliorate the impact of excess fertiliser discharge into the river and estuary systems from agriculture.

The maritime pine project also aims to capitalise on the increasing demand for softwood wood fibre in Pacific Rim countries. Competition for land from intensive agriculture and the rapidly expanding bluegum industry makes it unlikely that it will be possible to establish significant additional areas of *P. radiata* in the south-west of the State in the future. It is estimated that there are 4 million hectares of land suitable for maritime pine tree crops within the 600-400 mm rainfall zone within 150 km of existing or proposed processing facilities or ports.

Trees will be integrated with farming in belts or blocks and occupy no more than 20 per cent of farms, resulting in a potential area of 0.6 million hectares which can be used to establish *P. pinaster* tree crops.

Maritime pine has already been planted extensively in Western Australia and 30 000 cubic metres of maritime pine sawlogs are harvested for packaging and structural products and 90 000 cubic metres of wood is used annually to produce medium density fibreboard and particleboard in Western Australian factories.

While productivity of *P. pinaster* is significantly less than that achieved by *P. radiata* and *E. globulus*, land costs and establishment costs for maritime pine are significantly lower than these species. Thus rates of return for maritime pine tree crops, although less than those achieved for *E. globulus*, are higher than for *P. radiata*.

The maritime pine tree crop industry is at a similar stage of development to that which *E. globulus* was in the mid-1980s. Currently there is very little private establishment of tree crops in the target areas described above by either farmers or investors. Accordingly, the Government has endorsed a proposal for CALM to establish 150 000 hectares of *P. pinaster* in partnership with private landowners over the next ten years on coastal plain sands and in the intermediate rainfall zone to demonstrate to the private sector the capacity for the commercial viability of this species. As part of the decision to establish maritime pine as a tree crop, the Government has decided to cease planting on Government-owned land north of Perth where the majority of existing *P. pinaster* plantations are established and progressively convert the area into a conservation reserve over a period of 20 years. The decision is in part as a consequence of the fact that there is increasing conflict between intensive plantation development and exploitation of a groundwater mound located under the plantations. Catchment managers require that existing plantations be thinned to sub-optimum levels to ensure recharge of the groundwater aquifer and there are increasing constraints on the use of herbicides and fertiliser.

The maritime pine project will be funded by CALM from profits derived from commercial plantation activities and by the sale of assets, including land purchased to establish *P. radiata*, *P. pinaster* and *E. globulus* plantations in the 1970s and 1980s. Maritime pine plantings will be supplemented with commercial and non-commercial plantings of native species, including *Santalum spicatum* (Western Australian native sandalwood).

The first 700 hectares of *P. pinaster* tree crops were established on farms in 1996 and in 1997 this has been increased to 2 000 hectares, with the objective of achieving an annual rate of 15 000 hectares by the year 2000. Beyond 2000 a planting rate of 25 000 hectares per year is projected to the year 2020.

Carbon Sequestration

The carbon sequestration potential of tree crops in Western Australia was recognised from the inception of the tree crops on farms program. The Western Australian Government approach to proceed with "Tree Trust" was, in part, in recognition that tree planting could partially offset the addition of CO_2 to the atmosphere by major Western Australian energy companies (Government of Western Australia 1989). The Federal Government's "Bush for Greenhouse Program" and "Plantations 2020" are more recent initiatives.

There have been several major investment by international energy companies into reafforestation programs, principally in the tropical forests, over the past decade. The signing of the Kyoto protocol in 1997 which recognised the use of perennial vegetation in national carbon accounting budgets and provided for the trading of carbon has resulted in a significant increase in interest in the potential use of tree crops for carbon sequestration (Borough *et al.* 1988).

It is generally recognised that carbon sequestration by the establishment, rehabilitation or preservation of perennial vegetation will only be one of numerous strategies to reduce concentrations in the atmosphere and offset emissions. There is increasing recognition, however, that it is a significant and cost-efficient method of offsetting CO_2 emissions in the short-term allowing time to evaluate the effect of CO_2 on global warming and to develop other approaches to reducing CO_2 emissions.

One of the difficulties of evaluating the contribution of tree crops in reducing CO_2 emissions is the absence of a method of accounting for the fact that trees, even if they are not harvested, eventually decline and die returning the sequestered carbon to the atmosphere.

This difficulty can be overcome if a time dimension is incorporated into the carbon accounting process. Within 30 years about 40%-60% of the CO_2 currently released to the atmosphere is removed (Houghton *et al.* 1996). The adoption of a target period (sufficient to evaluate the greenhouse phenomenon and/or to develop new technologies) over which CO_2 emissions are to be reduced is a reasonable strategy given all of the uncertainties. No single lifeline for CO_2 can be defined because of different rates of uptake by different sink processes, but strategically one can consider 100 years consistent with the uptake in the deep oceans. (Houghton et al. 1996).

If it is accepted that there is a different time dimension to carbon accounting, the potential role of different tree crops can be more easily and realistically evaluated by adopting a carbon tonne year as a greenhouse gas unit. Annual carbon accretion rates of different tree crops can be determined by calibrating standard forest inventory procedures. Assessing the period of time carbon remains sequestered in the different carbon pools within a tree (litter, branches, various timber products from the trunk, roots etc) is more difficult but not impossible. Using this method of "greenhouse accounting" it would be possible, for example to devise a planting strategy and silvicultural program that would account for the carbon emissions of a factory or industry. For example, if an oil refinery was producing 100 tonnes of CO_2 per year and it was assumed that this quantity of CO_2 needed to be "removed" from the atmosphere for 100 years, then a tree crop planting strategy that produced 10 000 "tonne years" would be required to neutralise the emissions for 100 years from that year's emissions from the factory.

Preliminary estimates of the carbon sequestration potential of the three species which will be used extensively in the tree crops on farms program in Western Australia have been made and are shown in Table 9.

Table 9

Estimates of Carbon Sequestration

Species	Mean annual increment per ha	Estimated carbon sequestration per ha per annum (tonne)	Estimated average carbon "life" (years)	Carbon "tonne years" per ha
Maritime pine	12	5	40	200
Bluegum	20	10	10	100
Mallee	1	1	100	100

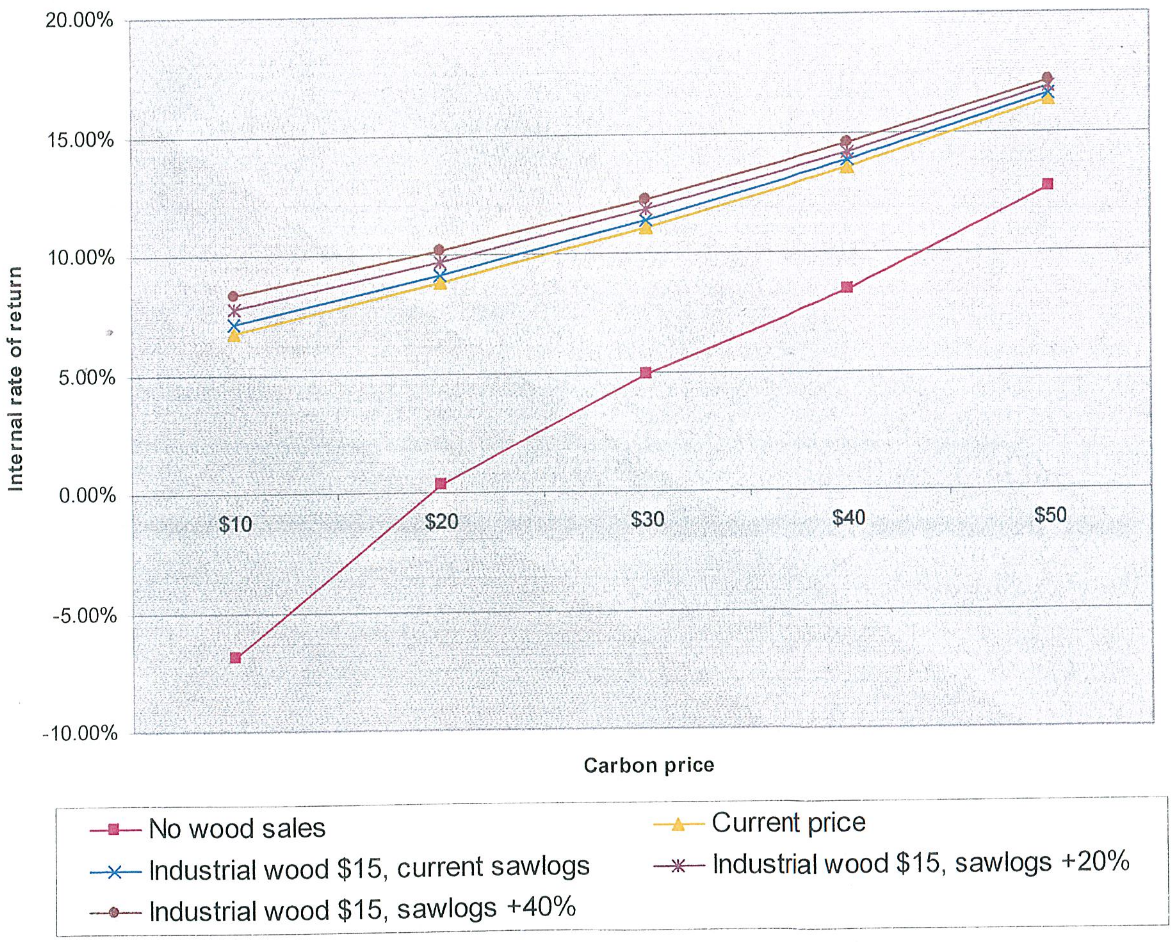
(Note: The above are estimates based on limited field sampling and calibration factors derived from this literature).

If the projected tree crop areas are achieved (see Figure 6) it is estimated that 6 million tonnes of carbon or 225 million "tonne years" would be sequestered annually.

It is pointless to evaluate the impact of the "carbon market" on the cost of sequestering a tonne of carbon or the potential economic returns to tree growers from "farming" carbon alone or in combination with timber production until the international rules for carbon accounting are determined. If carbon cropping becomes a reality, however, it could have a major impact on the economic feasibility of tree crop programs such as is proposed in Western Australia (Figure 5).

Figure 5

Effect of varying wood and carbon price on internal rate of return for 30 year rotation



The south-west of Western Australia has a number of characteristics which make it particularly suitable for large scale carbon sequestration. The land base available is large and the legal and economic processes to secure land are already in place. The technical and operational skills available have already been shown to be more than adequate to establish and manage large-scale tree cropping programs. Existing inventory processes could be easily adapted to comply with carbon accounting standards. In addition to the potential benefits to the environment of carbon sequestration, the Western Australian tree crop program will make a major contribution to reducing land degradation and increasing biodiversity on farmland. The participation of major international wood fibre using companies in the existing tree crop program will also assist the development of synergisms between commercial timber production and carbon cropping. Finally, the Western Australian tree crop program has all of the infrastructure and processes required in place to enable a rapid development of the tree cropping program to a scale which would result in significant carbon sequestration within a few years.

Conclusion

Large areas of the plantations of exotic species established principally by the Western Australian Forests Department on Crown land and funded by the taxpayers are now reaching maturity. Logs derived from these plantations support a significant manufacturing industry which includes major sawmills and panel board plants. If early foresters had not had the foresight to establish these plantations, there would not have been an infrastructure and funding platform on which the tree crops on farmland program has developed.

With an Australian net import bill of $2 billion in timber products it is apparent, however, that Western Australia, along with other States in the Federation, has failed by a long margin to achieve self-sufficiency. Included in the nation's imports are - eucalyptus pulp, Tasmanian bluegum veneer, tannin derived from *Acacia* species, and eucalyptus oil.

The tree crops on farms program in Western Australia, which was initiated in the mid-1980s, was principally driven by the need to establish trees on farmlands for environmental reasons and has been more successful than was contemplated even by those who supported the scheme.

The expanded program, if fulfilled, will result in the establishment of a total of 800 000 hectares of trees on farmland by the year 2020 (Figure 6). This will generate 13 million cubic metres of wood fibre per annum (Figure 7).

Figure 6

Predicted growth of tree crop plantings in Western Australia

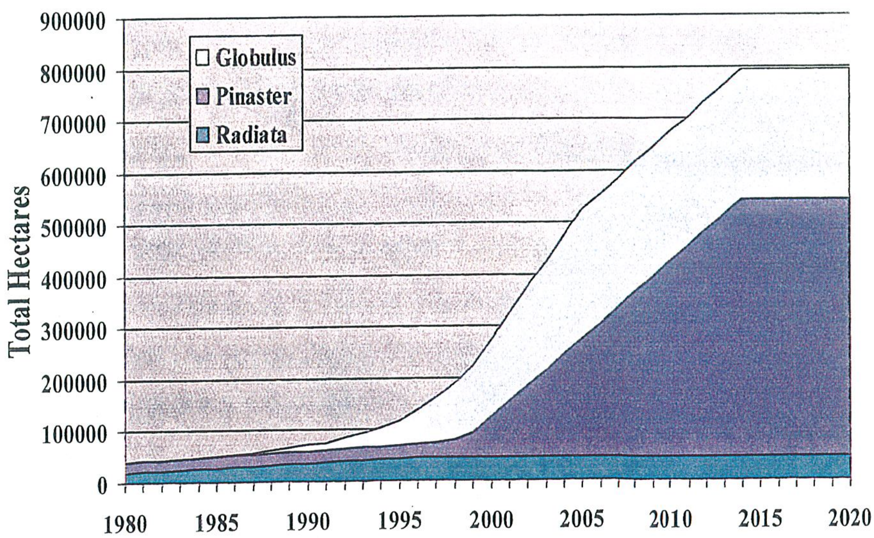
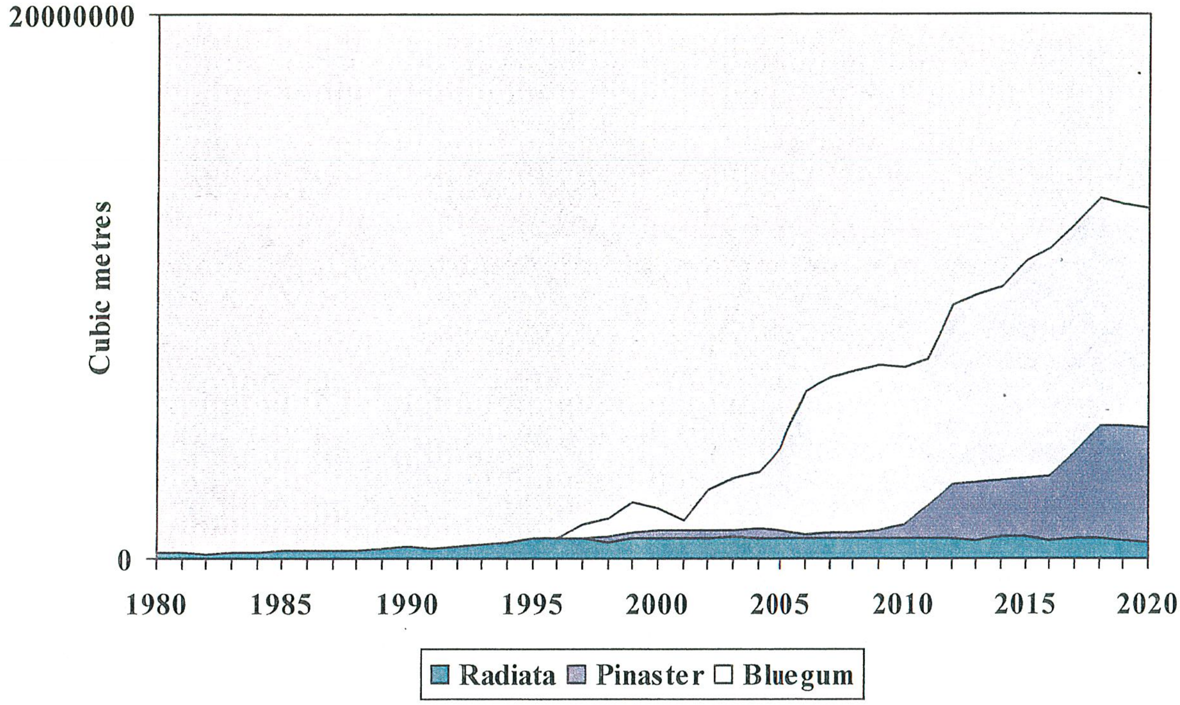


Figure 7

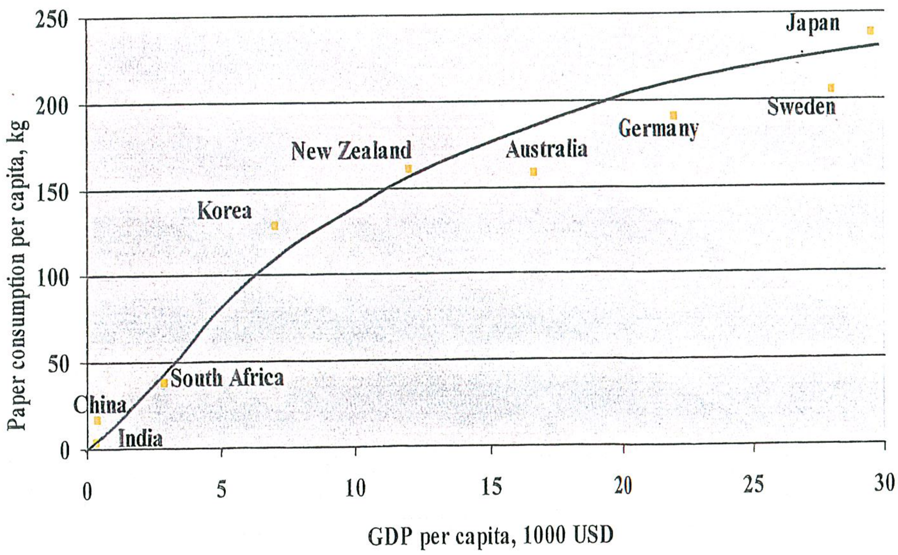
Current and predicted wood fibre production from tree crops and plantations in Western Australia



Inevitably, a proportion of this fibre will be used to reverse Australia's current account timber deficit. Our ability to sell a large proportion of this resource, however, will depend on whether we will be able to capitalise on opportunities provided by the increasing demand for wood fibre in nations in the north-western Pacific (Figure 8). This is occurring at the same time as the capacity of our neighbours to supply wood fibre from native forests is diminishing.

Figure 8

GDP and paper consumption (for selected countries in 1992)



- If growth 1990-96 (12% pa) continues, China will use the current world paper demand (279 million Mt) by 2015

Source: Jaakko Poyry Dana Ltd

Notwithstanding these opportunities, the market for wood fibre will be intensely competitive. Western Australia has a stable political environment which is one of the most important factors influencing buyers of wood fibre or carbon and investors in tree crops. I am confident also that Western Australia's land base, climate, technologies, and the partnerships in place, will result in wood fibre being produced at competitive prices. It is not unreasonable, if these efficiencies can be duplicated in manufacturing, that it will be possible to process a large proportion of this resource in rural Western Australia creating large numbers of jobs and helping to reverse rural depopulation.

While the economic and social benefits of the tree crops on farms program are significant, the contribution of the tree crops on farms to reversing land degradation and restoring biodiversity are probably of greater value in the long-term to the community.

Acknowledgements

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