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# **The Role of Trees in Sustainable Agriculture A National Conference**

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**Prepared for the National Land and Water Resource Audit  
Dryland Salinity Theme - Project 3**

**Disclaimer**

The contents of this report were based on the best available information at the time of publication. It is based in part on various assumptions and predictions. Conditions may change over time and conclusions should be interpreted in the light of the latest information available.

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## **PREFACE**

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### **Degradation of the land resource**

Reduction of the inherent productive potential of the resource base for agriculture (landscape, soils and water) via the processes of wind erosion and salinity/waterlogging is being increasingly recognised. These processes are estimated to cost an average of \$173 million/yr in lost agricultural production in Western Australia alone, with a potential loss that could expand up to \$1063 million/yr if nothing is done (WA Parliamentary Select Committee into Land Conservation 1991). Trees have a role to play in the amelioration of these processes and in providing a more stable, robust and sustainable agricultural system.

### **The benefits of revegetation**

Farmers who have undertaken substantial revegetation programs commonly state that their farm productivity has been enhanced because of the revegetation on the farm. Tree systems on their farms is likely to influence their productivity in one or more of the following ways:

- a) reducing the amount and intensity of events and processes that cause land degradation problems (e.g. wind erosion, groundwater recharge events);
- b) ameliorating the symptoms of the land degradation processes (e.g. uptake of saline groundwaters);
- c) modifying the average microclimatic conditions in favour of increased growth (sometimes at critical times of the year);
- d) providing a productive and profitable component of the system themselves through fodder, timber or other products;
- e) using existing resources such as water, solar energy and nutrients more efficiently;
- f) subdivision of the farm into smaller, more efficient management units that are checked more regularly.

The benefits of tree-based agricultural systems has been recognised by many Australian farmers and scientists. Evidence of this is the increasing number of farmers who are planting trees on a significant scale. The increasing quantity of research output that deals with this issue is evidence of scientific recognition. 'The Role of Trees in Sustainable Agriculture' conference was a national conference with the following objectives:

- 1) To familiarise participants with the latest technical and economic information about the role of trees in sustainable agriculture, in order to encourage more tree establishment on farms.
- 2) To determine gaps in research and extension, obstacles to the implementation of agroforestry and action needed to overcome these.

In order to achieve these objectives the conference was split into the main conference proceedings where reviews of the key aspects of current agroforestry research were presented, and workshops, where the constraints and opportunities for agroforestry were discussed.

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## **The main conference proceedings**

The main conference proceedings were split into State review papers and National review papers that were distilled from the State contributions. Of these, only the State review papers are presented here. They contain the most up to date information on agroforestry research in WA in the following subject areas; Salinity, Shelter and erosion, Native vegetation, Timber, Fodder and Other products.

## **Workshop papers**

Seventeen workshop sessions were held in eight subject areas. The papers presented in this publication are those contributed by West Australian scientists and farmers.

The WA Agroforestry Working felt that the information contained in these papers was of sufficient quality and interest to farmers, LCDC's, Project Officers and other scientists to warrant more widespread exposure than that achieved by the entire conference proceedings. The distillation of the National summaries into a farmer handbook has been undertaken by Greening Australia. That publication will not reflect the local perspective and detail contained in the State papers.

Understanding the processes in and effects of agroforestry systems will allow better planning of the distribution and density of trees in the agricultural landscape. Agriculture will consequently be more robust, stable and productive.

## **Reference**

WA Parliamentary Select Committee into Land Conservation(1991). Final Report. Legislative Assembly Perth. 171 pp.

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# **The Role of Trees in Sustainable Agriculture A National Conference**

## **Reprints of Western Australian Papers**

The role of trees in sustainable agriculture conference was held in Albury, NSW 30 September - 3 October 1991.

It was sponsored by the Rural Industries Research and Development Corporation, National Afforestation Program, Greening Australia, Bureau of Rural Resources, Treecorp Group, National Agroforestry Working Group and the National Farmers Federation. It was convened under the auspices of the standing committees on agriculture and forestry.

All of the articles within have been reproduced with the permission of the conference organisers and the authors. Due recognition is afforded. The information provided is the opinion of the authors and does not necessarily constitute the endorsement of the Department of Agriculture. It is provided as a source of technical information for farmers and landcare officers.

Reference to the papers contained herein should be to the proceedings of the conference, with the page numbers for the section quoted as on the text.

## The role of trees in land and stream salinity control in Western Australia

Nicholas J. Schofield<sup>1</sup>, Mohammed A. Ban<sup>1</sup>, David T. Bell<sup>2</sup>, Wendy J. Boddington<sup>1</sup>, Richard J. George<sup>3</sup> and Neil E. Pettit<sup>1</sup>

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### Abstract

Land and stream salinisation in southern Western Australia has now reached a state where 4430 km<sup>2</sup> of agricultural land has become salinised and less than 50% of streamflow remains fresh. Salinisation has been brought about by rising, saline groundwater following clearing of native vegetation. Experimental evidence shows that replanting trees on farmland can halt and reverse rising groundwater. The most promising strategy is dense replanting in the valley and on adjacent sideslopes. A small percentage planting is effective for perched aquifers associated with sandplain seeps in lower rainfall areas. On salt/waterlogging affected sites, tolerant species or clones and special tree establishment techniques are required. On areas away from seeps, commercial tree species can be planted to give a financial return and thus provide an incentive for farmers to implement land rehabilitation measures. Treatment of saltland is best viewed in a 'whole farm' plan within a catchment plan, utilizing a range of management options available, of which tree planting is an important component.

### 1. Introduction

The many beneficial uses of trees in the landscape are increasingly being appreciated by the community. This paper focuses on the use of trees to control salinity. Land and water salinisation is clearly one of Western Australia's most serious environmental and economic problems. These problems have been brought about by rising saline groundwater tables following clearing of native forests and woodlands for agriculture. Control or reversal of rising water tables can be effected by selectively introducing and incorporating trees into farmland. This paper summarises our current status of knowledge of this management option.

### 2. The salinity problem

Since European settlement of the State in 1829, 443 000 ha or 2.8% of cleared land has become salinised (11). This figure has risen from 73 000 ha or 0.5% of cleared land in 1955 when the first survey was conducted. The area of land becoming salinised is accelerating, with a rate of increase over 1979-89 of 18000 ha yr<sup>-1</sup> (33). Most of the rivers and wetlands in agricultural areas have also become saline (37). By 1985 only 48% of the total divertible streamflow of the south-west remained fresh (42). Streams emanating from agricultural land with below 900 mm yr<sup>-1</sup> rainfall have rapidly increasing salinities which could continue to rise for at least another 50 years (36).

Stream and land salinisation is an unfortunate by-product of agricultural development. The dryland agriculture practiced involved the replacement of native, deep-rooted, perennial plants with shallow-rooted, annual species. Agricultural pastures transpire considerably less water than the native Salinity 21 vegetation. This alters the water balance in favour of groundwater recharge, and groundwater

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levels subsequently rise. A good example of this is shown in Fig. 1 for the experimental Lemon catchment (750 mm yr<sup>-1</sup> rainfall). About half of Lemon catchment was cleared and replaced with annual pastures in 1976 at which time groundwater levels were 16 m below the valley floor (32). Groundwater levels in the valley rose rapidly following clearing and reached the ground surface in 1989, 13 years after clearing. As groundwater levels rise, salt previously 'stored' in the unsaturated zone is mobilised and brought to the surface or discharged to streams (43, 23, 32). As the groundwater discharge area (seep) expands, waterlogging becomes an additional problem (31).

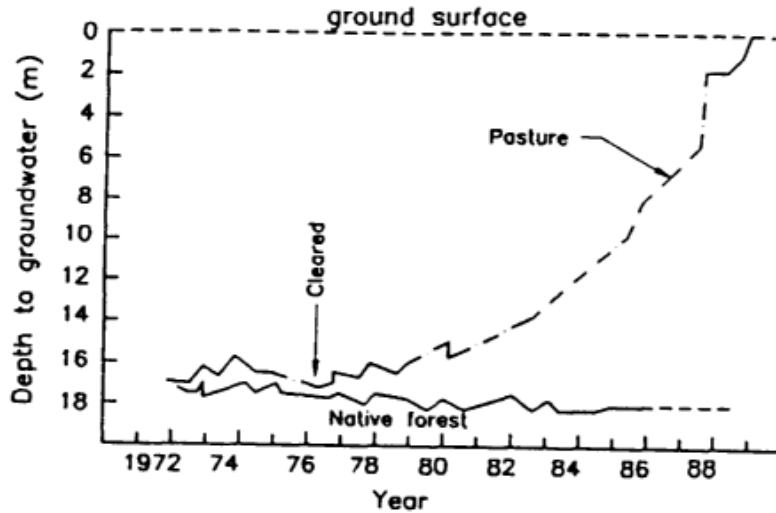


Figure 1. Groundwater response to clearing of Lemon catchment. compared to native forest.

In the medium to long term (10s - 1000s years), depending on location, land and stream salinisation will decrease due to leaching of the soil salt and export to the ocean via streams. However in the short to medium term (next 20-50 years) as much as a tenfold increase in salt-affected farmland could occur (2) and stream salinities may increase significantly. Because of these concerns, there has been much interest in attempting to reclaim or control salinity.

### 3. How can tree planting control salinity

If the clearing of trees causes salinisation then it is natural to expect that the replacement of trees will cure salinisation. This proposition, however, is not so straightforward. Firstly the landscape is no longer 'pristine'. In particular the salt/waterlogged areas provide very severe conditions for tree planting. Secondly substantial areas of farmland may be required for reforestation to re-adjust the water balance sufficiently for groundwater levels to decline. However production is often possible from within the reforested area, e.g. wood products, fodder and shelter for stock. There are also many facets to the selection, establishment, design and management of reforestation stands that require careful consideration. These questions are discussed in the following sections.



#### 4. Selecting tree species

Three criteria are often quoted when choosing tree species:

- adaptation to site conditions high water use multiple use Salinity 22.

##### 4.1 Adaptation

This is the first and primary criterion which must be satisfied. This criterion includes adaptation to climate, soils, pests, diseases, fire and, in places, waterlogging and salinity. For given planting conditions, there is now a growing knowledge of which species are best adapted. Screening tree species and provenance's and cloning superior individuals for tolerance to waterlogging/salt affected conditions typical of most saline seeps in the south-west has been carried out in Western Australia (40).

This work is being carried forward to commercialization by the 'Tree Technology Project'.

##### 4.1.1 Tree Technology Project.

This project involves cooperative research between Alcoa of Australia Ply Ltd, the University of Western Australia and Murdoch University with the aim to commercialize highly tolerant Australian species of trees for the reclamation of dryland salinity. The project has progressed to the stage where field trials have documented the superiority of clonal lines over unselected seedlings, and a range of species and genotypes are now ready for commercialization. More than 5000 clonal plants and comparable provenance seedlings have been planted in field trials in each of the last three years in sites in Western Australia, the eastern states of Australia and overseas. Ground electrical conductivity measurements in field trials have assisted in determining limits of tolerance for particular genotypes. Appropriate site conditions for the more tolerant species of *Eucalyptus* are associated with sparse coverings of barley grass (*Hordeum* spp.). Approximately one metre of height growth per year is achievable with the clonal lines of *Eucalyptus camaldulensis*, *E. sargentii* and *E. spathulata* under these conditions. The bare zones of scalds with ground conductivity values greater than  $150 \text{ mSm}^{-1}$  are planted with clonal lines of *Casuarina obesa*, *C. glauca* and several clonal lines of species in the genus *Melaleuca*. These species are more suitable for the production of post and/or fire wood and are being recommended for planting in many countries.

To date more than 100 species of Australian woody plants have been screened under glasshouse conditions (41). At present 22 species of the most tolerant species to saline waterlogged conditions have been targeted to cover a range of climatic conditions throughout Australia and overseas and to serve a range of economic uses (21).

##### 4.2 Water use

Knowledge of the water use of species for a range of planting conditions could allow trees to be selected for high water use to simultaneously control groundwater and minimise the area to be reforested. A number of measurements of tree water use have been made for farm plantations (e.g. 14, 15, 16). These measurements have shown that eucalypt trees can transpire up to 3-4 times the rain falling on the plantation. However, the results have not been sufficiently comprehensive to allow a confident ranking of species by water use (9).

As part of the Tree Technology Project, cooperative research with the CSIRO is evaluating the water use capabilities of clonal *E. camaldulensis* (19). Under sandy soil conditions, five-year old clones are capable of transpiring up to 60 L day'.

Recent findings have also indicated that the water use per leaf area ratio for *C. obesa* is up to three times greater than for *E. camaldulensis*. Further research at sites in the northern wheatbelt is documenting the effect of a gradient of salinity and waterlogging on water use in the superior *E. camaldulensis* clones.

#### 4.3 Multiple use

Multiple use refers to the range of other beneficial uses of trees which may influence selection. These include commercial tree cropping for timber, pulp, firewood, fodder or other products; shelter and shade; wind and water erosion control and aesthetics. Commercial tree planting is being actively pursued by the Department of Conservation and Land Management (CALM), private industry and individuals. Pine (*Pinuspinaster*, *P. radiata*) agroforestry plantations have been shown to increase land productivity (1). Species of *Acacia* have shown potential as emergency fodder crops for saline soils Salinity 23(10). Also fast growing eucalypts, e.g. *E. globulus* ssp. *globulus* (Tasmanian blue gum), show considerable promise for pulpwood production (5).

#### 5. Establishing trees

On well drained sites the following procedures give good establishment: ripping in late summer/autumn when soils are driest to give good break up; strip spraying of rip (planting) lines with a herbicide mix incorporating knock down and residual weed control ingredients; planting once autumn or winter rainfall provides sufficient soil moisture, followed by spot fertilising of each seedling with an N and P fertiliser.

Saline seep sites are more difficult for tree establishment. Good species selection is very important. Current research has shown *Casuarina obesa* has established well on severe saline and waterlogging affected sites. Salt tolerant clones of *E. camaldulensis* have also shown promise (24).

Even with salt/waterlogging tolerant trees, reforestation techniques are still being developed (25). Ripping, followed by herbicide spraying of most sites is usually necessary. Where a cemented layer (hardpan) occurs close to the surface, deep ripping is required to break up this layer to allow better root penetration. A large bulldozer is required to effectively rip the hardpan. Preliminary results show that significant improvement in ripping efficiency can be gained with improving ripper point design. Fertilising of seedlings at time of planting may not be warranted (29). Ridge mounding is important. This reduces waterlogging stress by providing an elevated planting position for seedlings above the watertable. Double ridge mounds with seedlings planted in the trough between the ridges are more effective than single ridge mounds as the trough collects rain which facilitates salt leaching from the soil in the seedling root zone (26,27). Mounds should be constructed on a grade so they can act as drains. Combining drainage with mounding can significantly improve seedling survival. This improvement is even greater where mound height is also increased (30). Other techniques found to be effective in improving tree establishment in saline seeps include the application of mulches such as hay to the mounds and increasing seedling container size (28).

#### 6. Where should trees be planted?

In the control of groundwater tables, planting location is probably still the question causing most confusion, with some people advocating recharge control (usually upslope planting) and others discharge control (usually lower slope planting) (38). Trees planted out of salt/waterlogged areas will grow faster and transpire more water so long as it is available. However, there is evidence in Western Australia that groundwater will still rise to or remain at the surface of valley floors if there are no tree plantings in these lower-slope areas (38). Thus to completely control land and

stream salinity it is necessary to have a significant component of lower slope/valley floor planting in the reforestation strategy. This is especially important in landscapes where groundwaters are structurally controlled, and where the catchments of surface and groundwater differ.

## 7. How many trees are needed to control salinity?

Since trees can transpire more than annual rainfall per unit area reforested (14), only a part of the farmland requires replanting. (34) developed a model to estimate area requirements for planting. The area depended on the water use of the tree species planted, the amount of remnant native forest and the water use of agricultural plants used. The area of planting required to lower water tables decreased with annual rainfall. Based on current limited water use data, the predicted planting area to lower the water table at  $200 \text{ mm yr}^{-1}$  ranged from 51% of farmland at  $1200 \text{ mm yr}^{-1}$  rainfall to 32% of farmland at  $750 \text{ mm yr}^{-1}$  rainfall. Salinity 24

A second method of determining reforestation area for salinity control is based on experimental data from reforestation sites with groundwater monitoring in the Collie and Mundaring catchments (Fig. 2) (7). A regression of average rate of water table reduction against proportion of cleared area reforested is shown in Fig. 3a. The four sites included in the regression have similar crown covers (39-47%) whereas the two sites excluded have significantly less crown cover (Flynn's Hillslope 29%, Flynn's Agroforestry 14%). Over the measurement period the groundwater levels beneath pasture at Flynn's and Stene's sites lowered on average by  $6 \text{ mm yr}^{-1}$ . Using this information and the regression in Fig. 3a, it can be shown that reforestation of 22% of the cleared area is required to lower the water table at a rate of  $200 \text{ mm yr}^{-1}$  (i.e. 2 metres over 10 years) relative to the ground surface at these sites with about  $700 \text{ mm yr}^{-1}$  mean annual rainfall.

Rainfall over the measurement period was 10% less than the long term (1926-88) average. If rainfall had been the long term average it is estimated that groundwater levels beneath pasture on Flynn's and Stene's site would, on average, have risen at a rate of  $360 \text{ mm yr}^{-1}$  (7). In this case the regression of Fig. 3a indicates that about 52% of the cleared area would need to be reforested to lower the water table at  $200 \text{ mm yr}^{-1}$  relative to the ground surface.

A second regression, which takes into account the crown cover of the reforestation, is shown in Fig. 3b. In this example the average rate of water table reduction was regressed against the 'total percentage tree cover' as represented by the product of proportion of cleared land reforested and reforestation crown cover. The quality of this regression, which includes all sites, implies that total percentage tree cover is the most important factor (for the given reforestation strategies) in the lowering of the water table beneath reforested areas.

## 8. Experimental evidence from some different planting strategies

Four partial reforestation strategies have been tested in the south-west for their ability to control groundwater levels. The strategies tested were (a) lower slope and discharge zone planting, (b) wide-spaced plantations, (c) strips or small blocks strategically placed but covering a small proportion of the cleared area and (d) dense plantations covering a high proportion (> 50%) of the cleared area. The characteristics of the experimental sites are summarised in Table 1. Results for the different strategies are discussed briefly below. For further details on these sites and the groundwater analysis the reader is referred to (38, 7, 35, 3, 4).

### 8.1 Lower slope and discharge zone planting strategy

High density tree planting on the lower slopes and discharge zone (seep) has been tested at two sites. Only one of these sites, Stene's Valley Plantings, has sufficient record for analysis. At this site, 44% had been cleared for agriculture. In 1979 35% of the farmland was planted with eucalypts. Over the period 1979-88 there was a lowering of the water table beneath the reforestation of 2.0 metres while under pasture the water table rose by 0.4 metres (Fig. 4). A comparison of the water table through a valley section for 1979 and 1988 is shown in Fig. 5. This figure clearly shows the depression of the water table beneath reforestation, a small rise under midslope pasture and no change under native forest. This indicates that, over this period at least, water tables are responding to the type of overlying vegetation.

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**Table 1. Reforestation of the experimental sites**

Site	Planting year	Main species planted	Proportion of site cleared (%)	Proportion of cleared area replanted (%)	Initial planting density (stems ha)	Estimated stem density in 1986 (stems ha <sup>-1</sup> )	Mean reforestation crown cover at December 1987 (%)
Flynn's Farm landscape	1977	<i>E. wandoo</i> <i>E. camaldulensis</i> <i>P. pinaster</i> <i>P. radiata</i>	98	8	670	500	43
Hillslope	1978/79	<i>E. camaldulensis</i> <i>E. wandoo</i>	100	54	1200	1000	29
Agroforestry	1978	<i>P. radiate</i> <i>P. pinaster</i> <i>E. camaldulensis</i>	51	58	380 760 1140	75 150 225	14
Stenes Farm							
Strip Plantings	1976/7/8	<i>E. camaldulensis</i> <i>P. radiate</i> <i>E. globulus</i> <i>P. pinaster</i> <i>S. wandoo</i>	31	14	1200	600	47
Valley Plantings	1979	<i>E. wandoo</i> <i>S. rudis</i> <i>S. camaldulensis</i>	44	35	625	500	41
Aboretum	1979	63 eucalypt plus 2 pine species	35	70	625	0-600	39
Boundain	1981	<i>E. globulus</i> <i>S. sargentii</i> <i>S. occidentalis</i> <i>E. camaldulensis</i> <i>C. glauca</i>	95	21	83-166	83-166	25
Bannister	1976	25 species	83	14	816	?	?

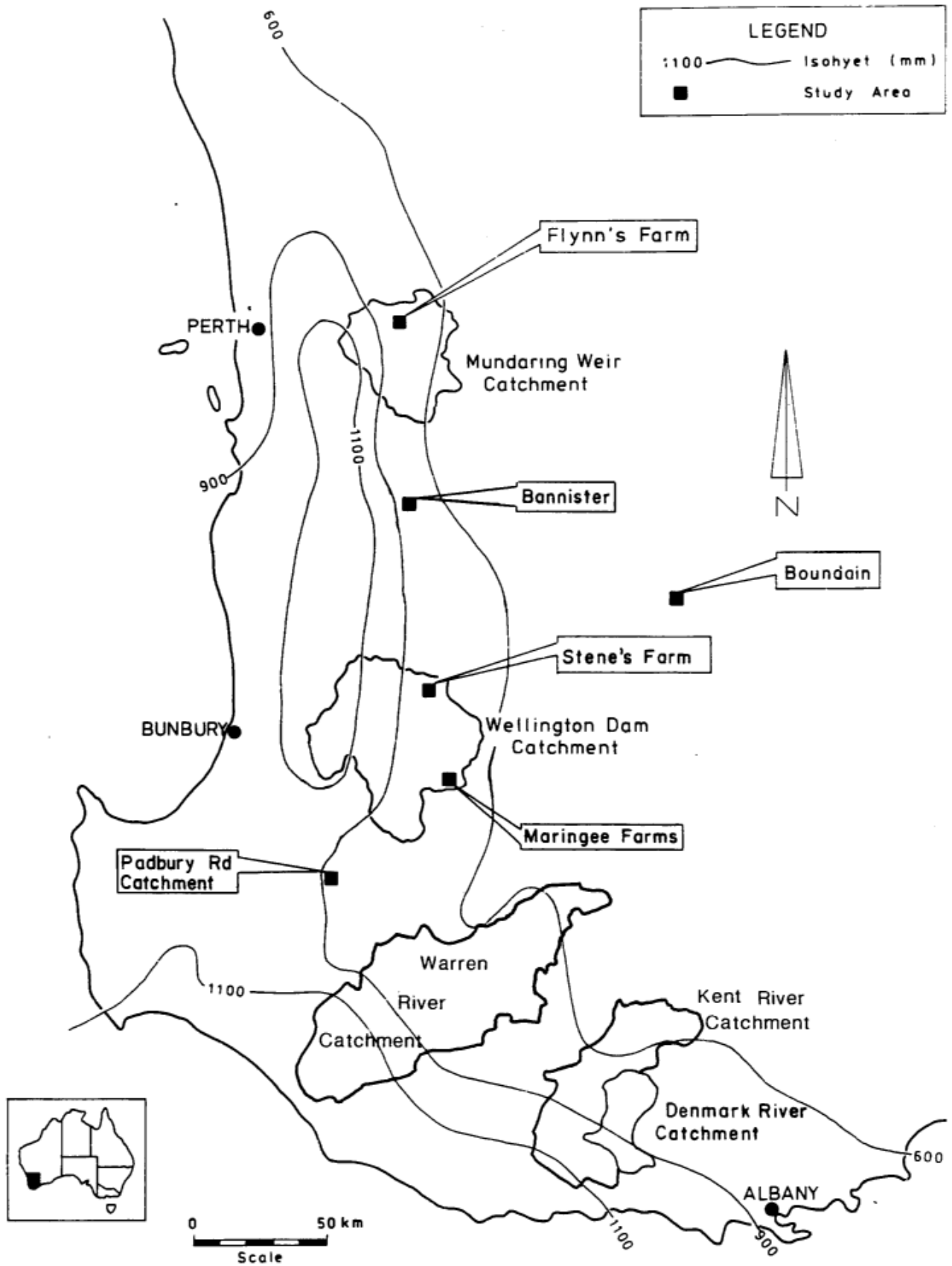


Figure 2. Locations of marginal water resource catchments and reforestation study sites.

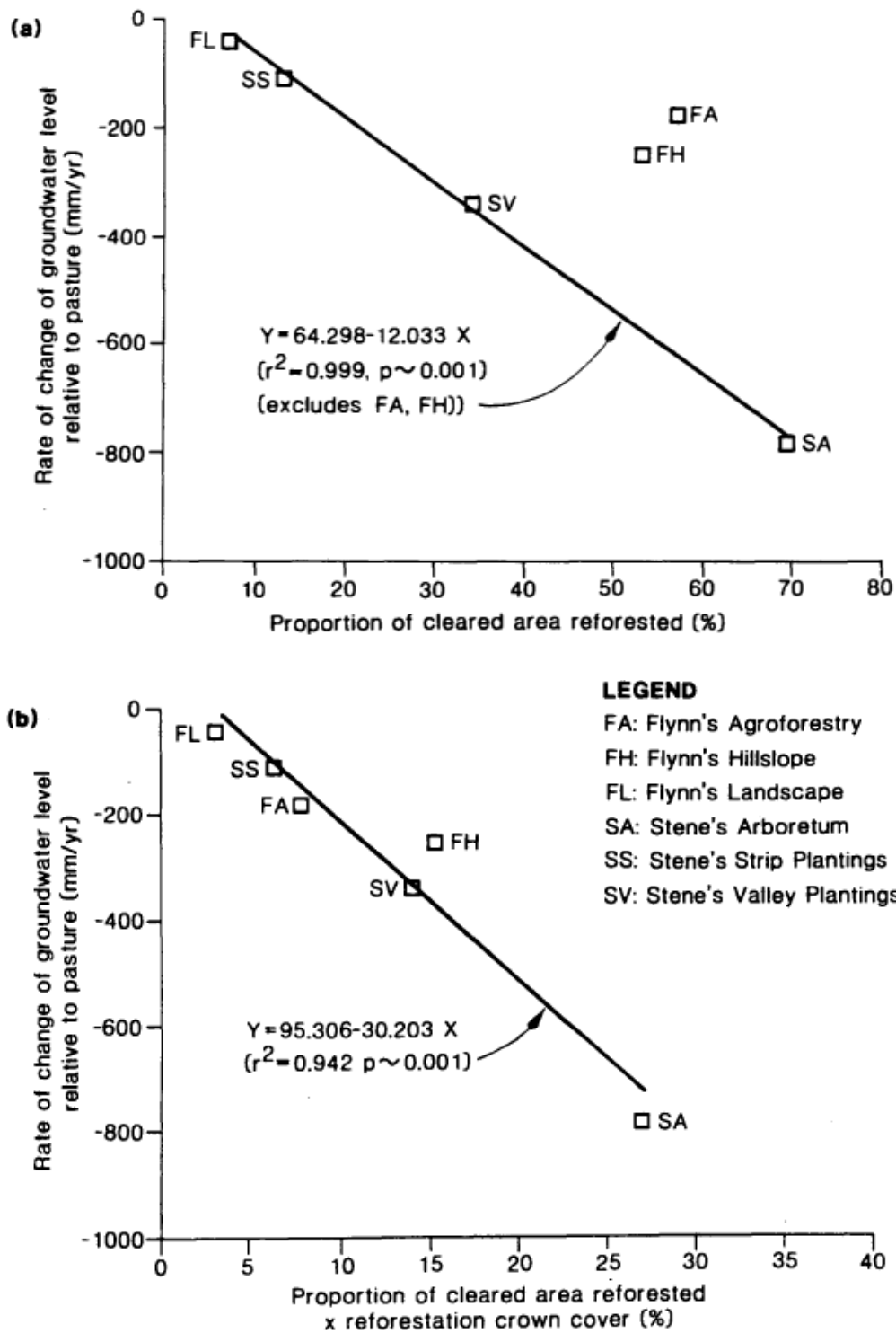


Figure 3. Dependence of rate of change of groundwater level under reforestation relative to pasture on (a) proportion of cleared land reforested and (b) product of the proportion of cleared land reforested and crown cover of reforestation.

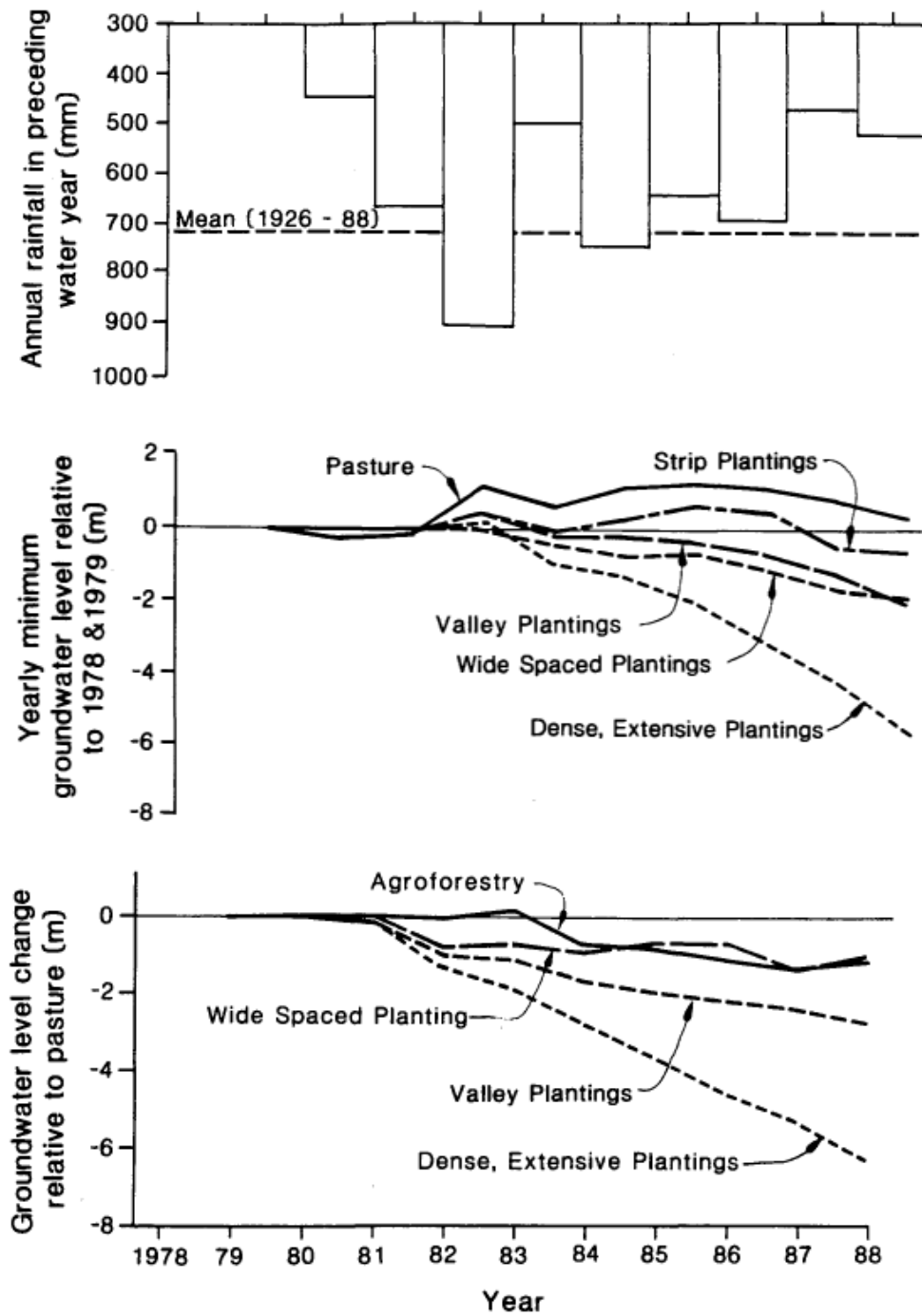


Figure 4. Groundwater level changes relative to the ground surface and pasture for various reforestation strategies at Stene's Farm.

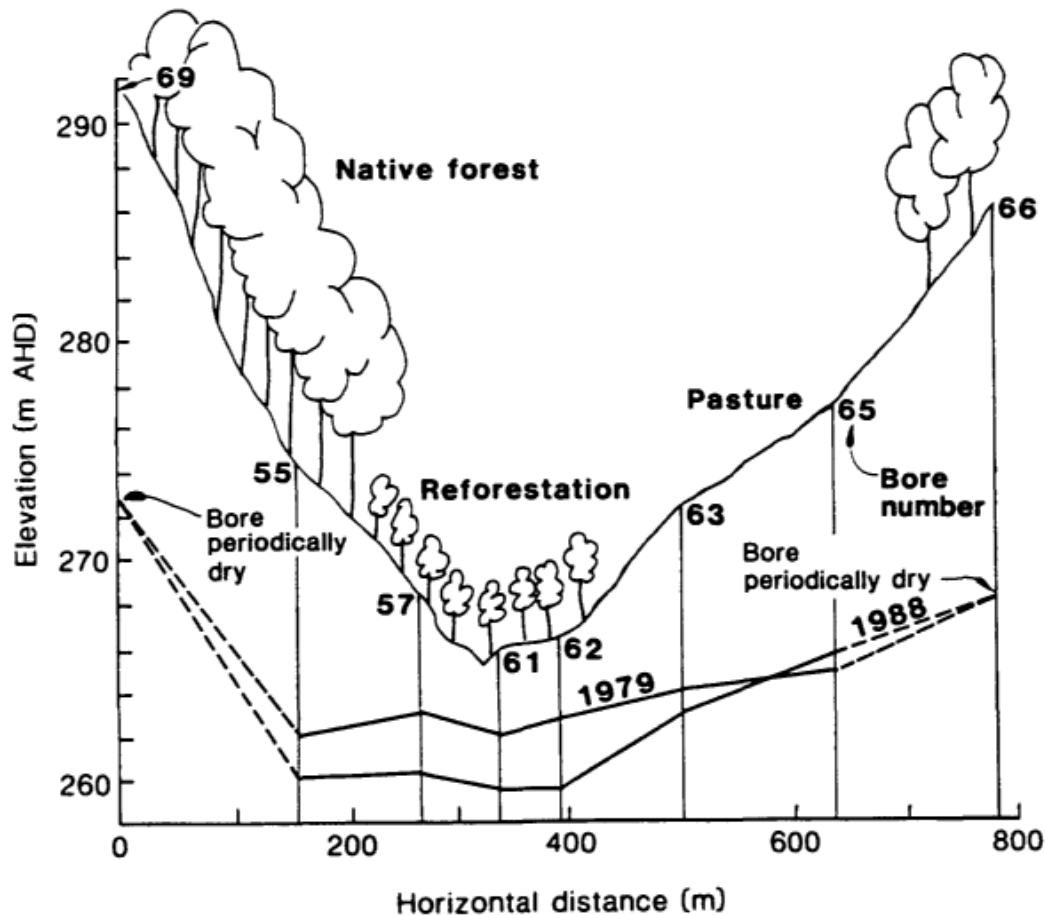


Figure 5. Comparison of the yearly minimum groundwater levels in 1979 and 1988 across Stene's Valley Plantings site.

## 8.2 Wide-spaced plantations

The effects of wide-spaced plantations on water tables have been investigated at three sites, Flynn's Agroforestry, Stene's Agroforestry and Boundain (Fig. 2). These sites represent a range of species and planting densities. The Flynn's and Stene's sites have similar average rainfall ( $720 \text{ mm yr}^{-1}$ ) while Boundain has somewhat lower rainfall ( $\approx 500 \text{ mm yr}^{-1}$ ). The average water table changes under agroforestry compared to pasture are shown in Fig. 4 (Stene's), Fig. 6 (Flynn's) and Fig. 7 (Boundain). At each site agroforestry has achieved a significant lowering of the water table relative to pasture and the ground surface. However, at the Flynn's and Stene's sites, the lowering of the water tables relative to pasture has halted, suggesting a new recharge-discharge equilibrium may have been reached.

## 8.3 Strip or block planting

The approach of strategically planting strips or blocks which cover only a small percentage ( $< 15\%$ ) of farmland has been investigated at three sites: Flynn's Landscape, Stene's Strip and Bannister (Fig. 2). In each case the tree planting has had little or no effect on the water tables (Figs. 4, 6 and 8). Thus in areas with annual rainfall greater than  $700 \text{ mm}$ , planting less than  $15\%$  of farmland is unlikely to have a significant impact on the water table.



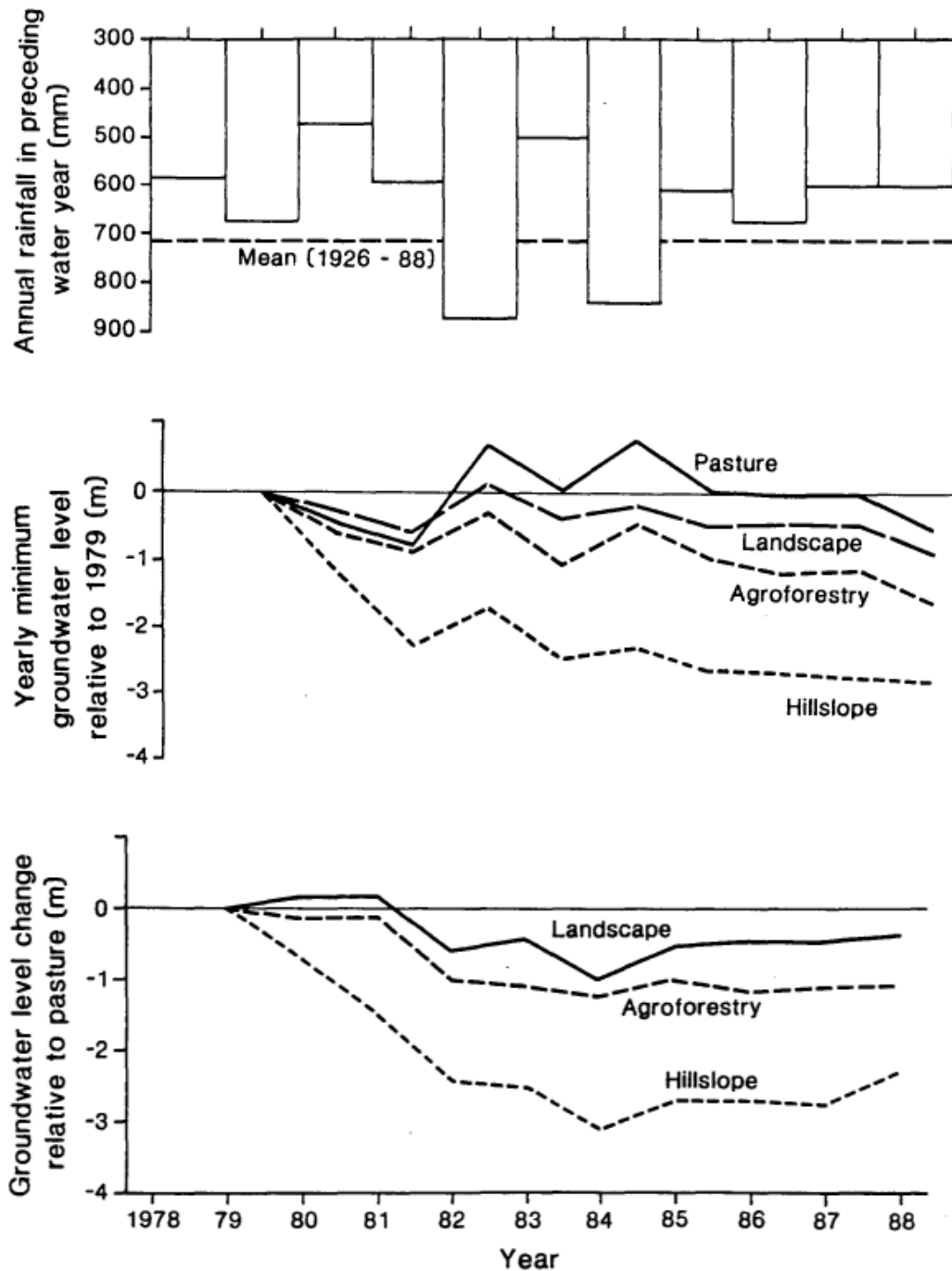


Figure 6. Groundwater level changes relative to the ground surface and pasture for various reforestation strategies at Flynn's Farm.

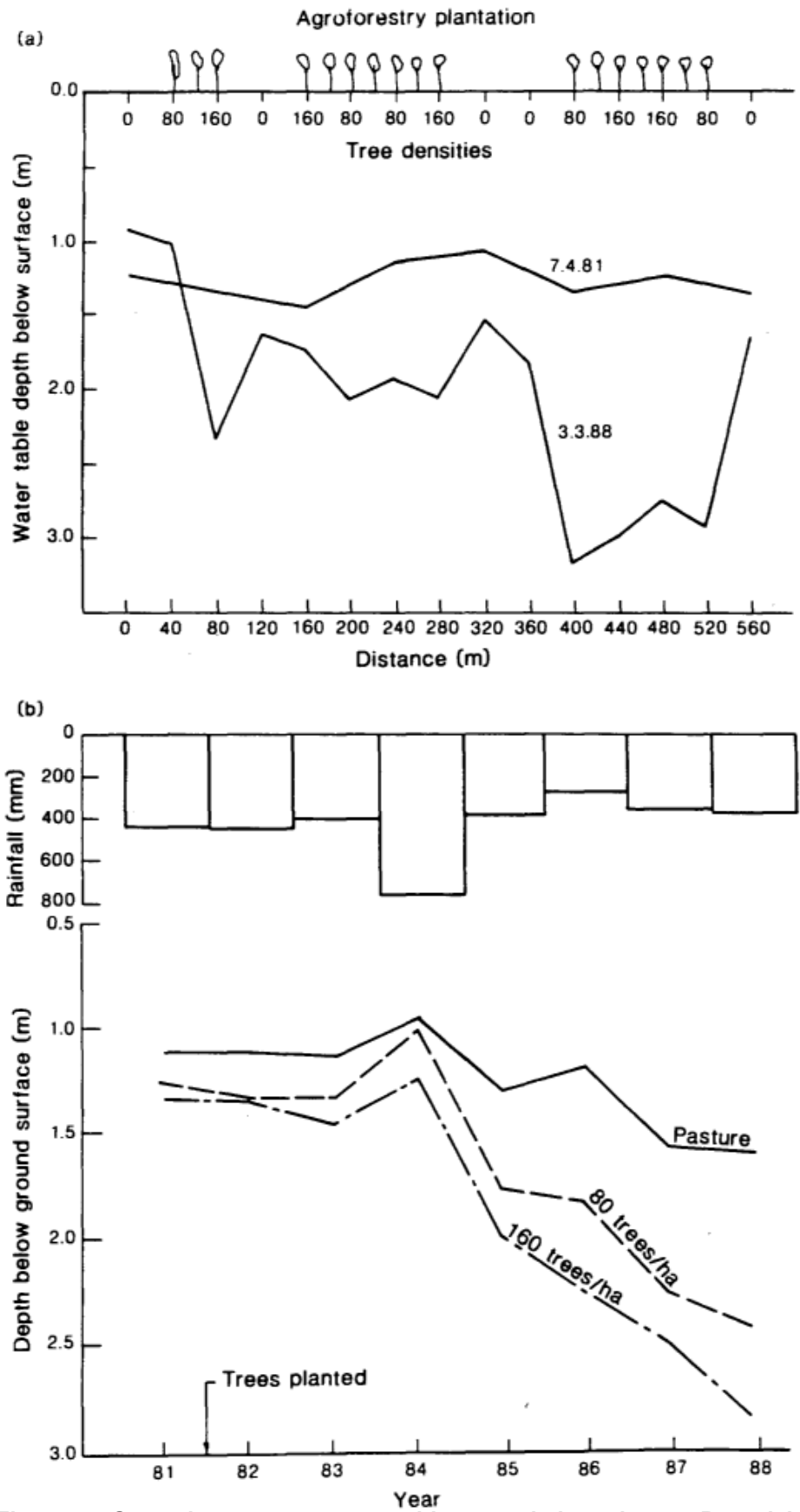


Figure 7. Groundwater response to wide-spaced plantations at Boundain: (a) comparison of groundwater levels across the site between 1981 and 1988, (b) annual rainfall and groundwater level variations beneath pasture and plantations.

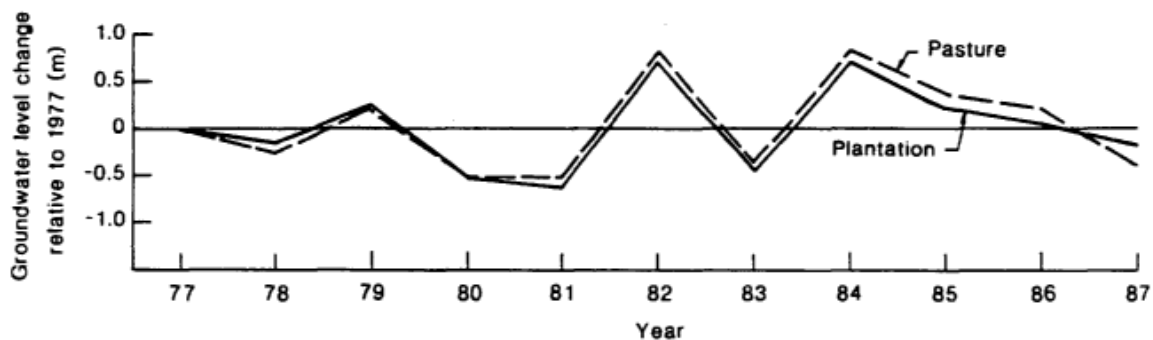


Figure 8. Annual groundwater level variations under reforestation and pasture at Bannister.

#### 8.4. Dense, extensive plantations

High density reforestation covering >50% of farmland has been investigated at two sites, Flynn's Hillslope and Stene's Arboretum. At Flynn's Hillslope the whole site had been converted to agriculture and 54% of this was replanted. Over the period 1979-88 the water table was lowered 2.8 metres while there was a slight lowering (0.5 m) of the water table beneath pasture over the same period (Fig. 6).

At Stene's Arboretum about 70% of the farmland was successfully replanted. Over the 1979-88 period there was a lowering of the water table beneath reforestation of 5.6 metres while under pasture the water table rose by 0.4 metres (Fig. 4).

#### 8.5 Small plantings to control perched aquifers

In low rainfall ( $\sim 350 \text{ mm yr}^{-1}$ ) areas of the Western Australian wheatbelt, sandplain seeps caused by the discharge of brackish to saline ( $< 10,000 \text{ mg L}^{-1}$ ) perched groundwater are common. The perched aquifer forms in deep ( $\sim 10 \text{ m}$ ) earthy sands and its waters are discharged when the aquifer thins downslope (Fig. 9). These seeps are estimated to constitute about 5-10% of the State's dryland salinity problem.

Reclamation of the seeps has been achieved by installing drains (13) and strategically placed plantations of trees (12). Drains may reclaim seeps quickly ( $< 2$  yrs) while the trees take longer (3-5 yrs). However the off-site disposal of waters derived by drainage is difficult, unless the waters are of suitable quality for storage in dams ( $< 2000 \text{ mg L}^{-1}$ ). By contrast, the phreatophytic behaviour of eucalypts provides a method of dewatering the aquifer without the disposal problems. Trees also provide shade and shelter for stock, habitat for fauna and a resource of farm timber.

The phreatophytic behaviour of trees was shown from observations of water table decline at an experimental site in the eastern wheatbelt (12). In 1986 about 300 trees (*E. camaldulensis* saltdown and Lake albacutya; *E. globulus* and *E. cladocalyx nana*) were planted on an area of 1.5 ha, immediately upslope from a sandplain seep (5 ha) and associated waterlogged area (7 ha), to intercept the inflowing perched groundwaters. By 1991 the trees had grown to heights of 6-9 m, dried the aquifer each summer since 1989 and lessened the maximum height of the water table in winter, despite years of above average (10-45%) rainfall (Fig. 10). To dry the aquifer in summer, the trees had to intercept about  $3000 \text{ L day}^{-1}$  of groundwater, equivalent to a phreatophytic consumption of  $10 \text{ L day}^{-1}$  per tree. Groundwaters had a salinity of about  $5000\text{-}7000 \text{ mg L}^{-1}$ .

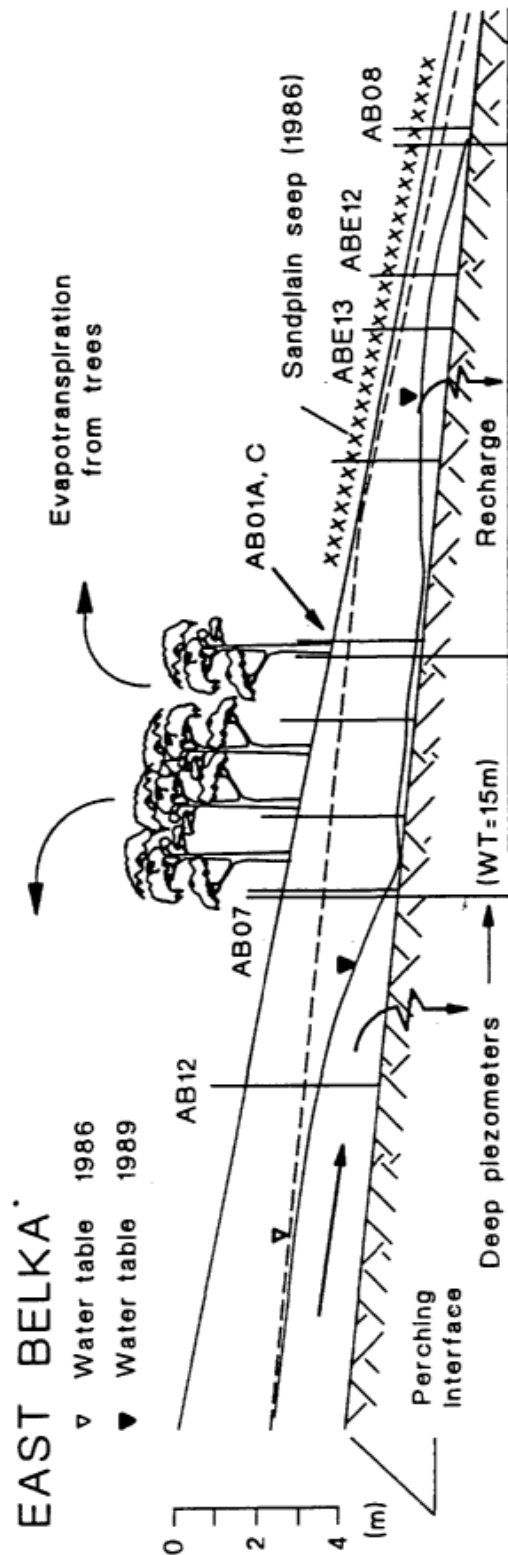
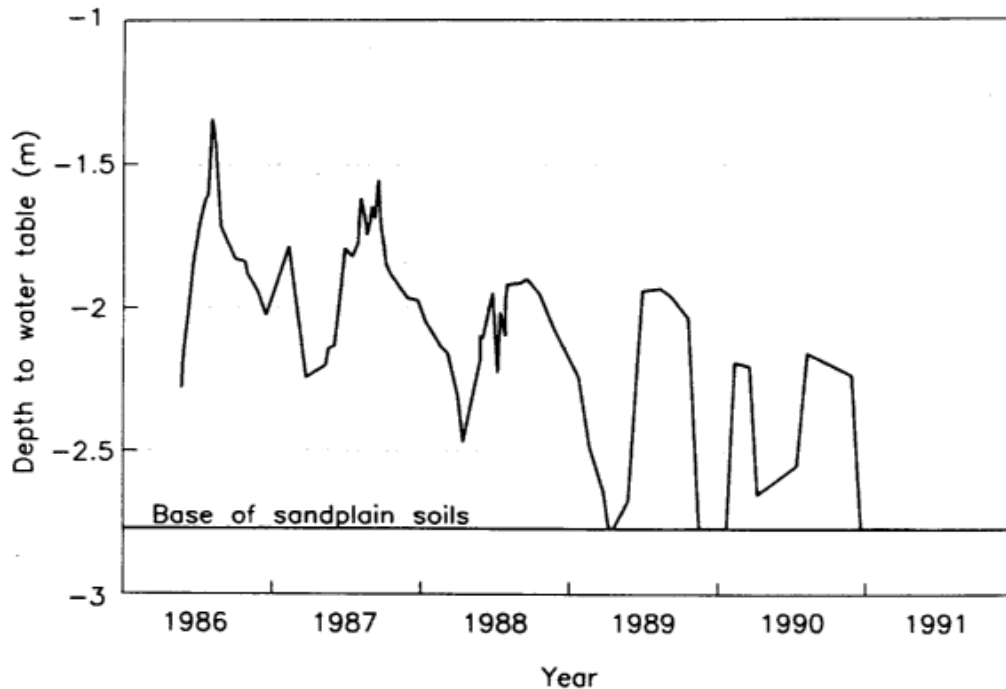


Figure 9. The cross-section of the site shows a perched water table and salt-affected area present in 1986. By 1989 trees had dried the aquifer and allowed leaching of salts in the seep. The perching layer is leaky, and drains to a deep water table, 15 m below the trees. The distance from ABO1 to ABO8 is approximately 200 m.



**Figure 10.** The water table trace at site ABO1A (see Fig. 9) shows a decline in the depth to the water table despite above average rainfall (1986-90: 20%, 10%, 15%, 10%, 45% above). The bore was still dry in July 1991.

The site investigated had been salt-affected and waterlogged for about 25 years when the trees were planted. In 1989 wheat was sown across the site, and later produced 1 tonne ha<sup>-1</sup>, about district average. In 1991, an exceptionally wet year, the barley crop produced less (0.6 tonnes ha<sup>-1</sup>) due mainly to waterlogging. The effect of the trees on the water table under the site is depicted in Fig. 10.

## 9. Operational reforestation for salinity control

In the late 1970s the Water Authority of Western Australia declared an interest in a number of potentially high value water resource catchments in the south-west which had marginal but deteriorating salinities but sufficient remnant native forest for reforestation to be an economically viable option. These catchments were the Mundaring, Wellington, Warren, Kent and Denmark (Fig. 2). Clearing controls were placed on these catchments in 1976 and 1978.

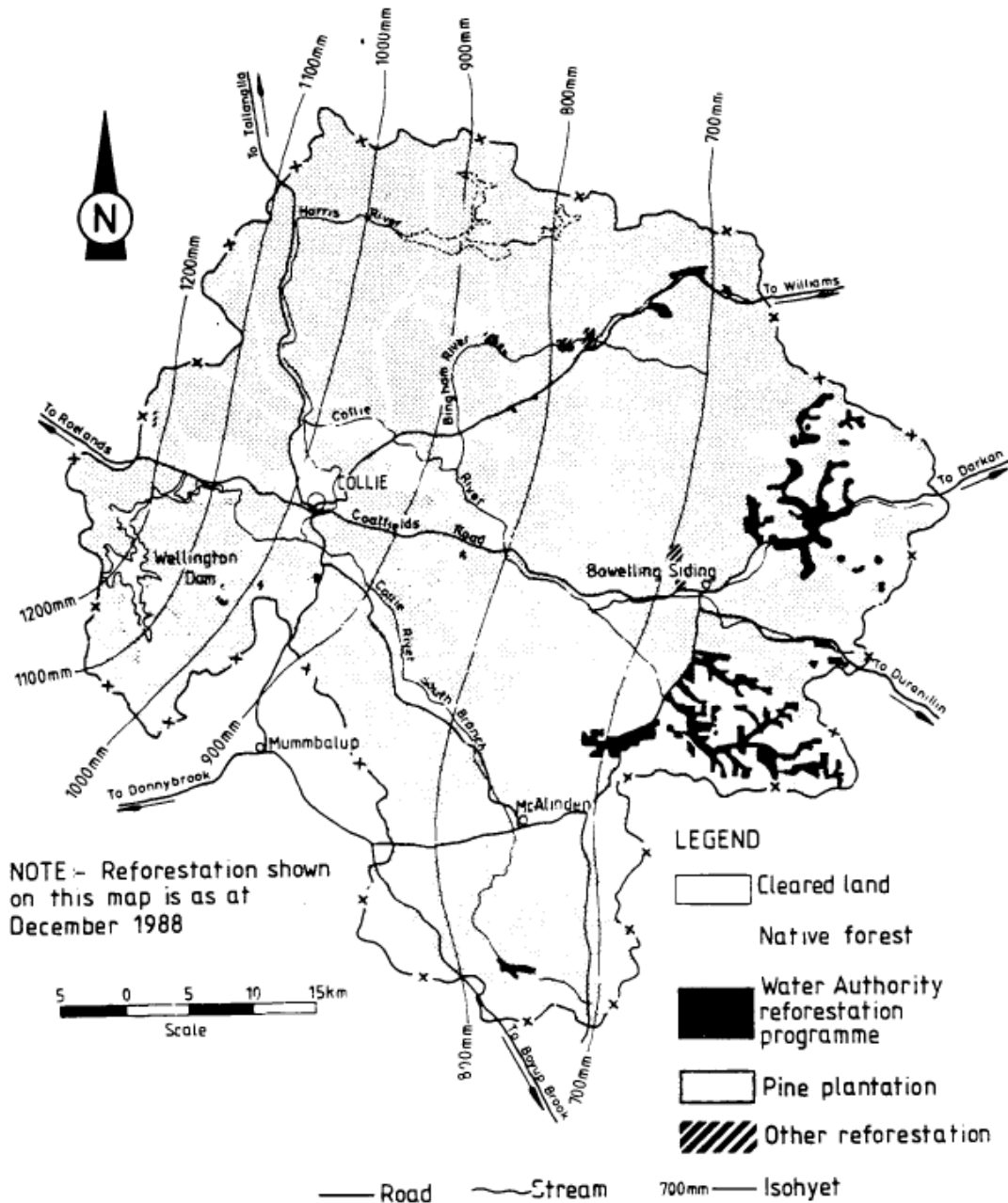
### 9.1 Mundaring Weir

The Helena River feeds Mundaring Weir which in turn is the source of the Goldfields and Agricultural Water Supply Scheme. The Mundaring Weir catchment required relatively little reforestation which is nearly complete. The inflow salinity to the reservoir has stabilised at about 500 mg L<sup>-1</sup> TSS.

### 9.2 Wellington Dam

The Collie River feeds Wellington Dam, the largest reservoir in the south-west and, until recently, the source of the Great Southern Towns Water Supply Scheme as well as coastal plain irrigation. Reforestation was initiated in 1979 and was the first major reforestation project of its type in Australia (17). The objective was to control the inflow salinity to the reservoir which has been increasing steadily since the 1950s.

Clearing controls were imposed in 1976 by which time 26% of the catchment had been cleared, including 60 000 ha in the lower rainfall, high salt hazard portion (Fig. 11). The strategy adopted for reforestation was lower slope and discharge zone planting, covering on average about 30% of the farmland. The land for replanting was purchased directly by the Water Authority as it became available. The plantings so far exert 'control' over about 15 000 ha or 25% of the target area. The simulated effect of the reforestation is illustrated in Fig. 12 which shows predicted inflow salinities without any intervention (about 1800 mg L<sup>-1</sup> TSS), with only clearing controls (about 1150 mg L<sup>-1</sup> TSS) and with clearing controls plus 8000 ha of



reforestation (about 850 mg L<sup>-1</sup> TSS).

Figure 11. The Wellington Dam catchment, showing areas of cleared land and reforestation.

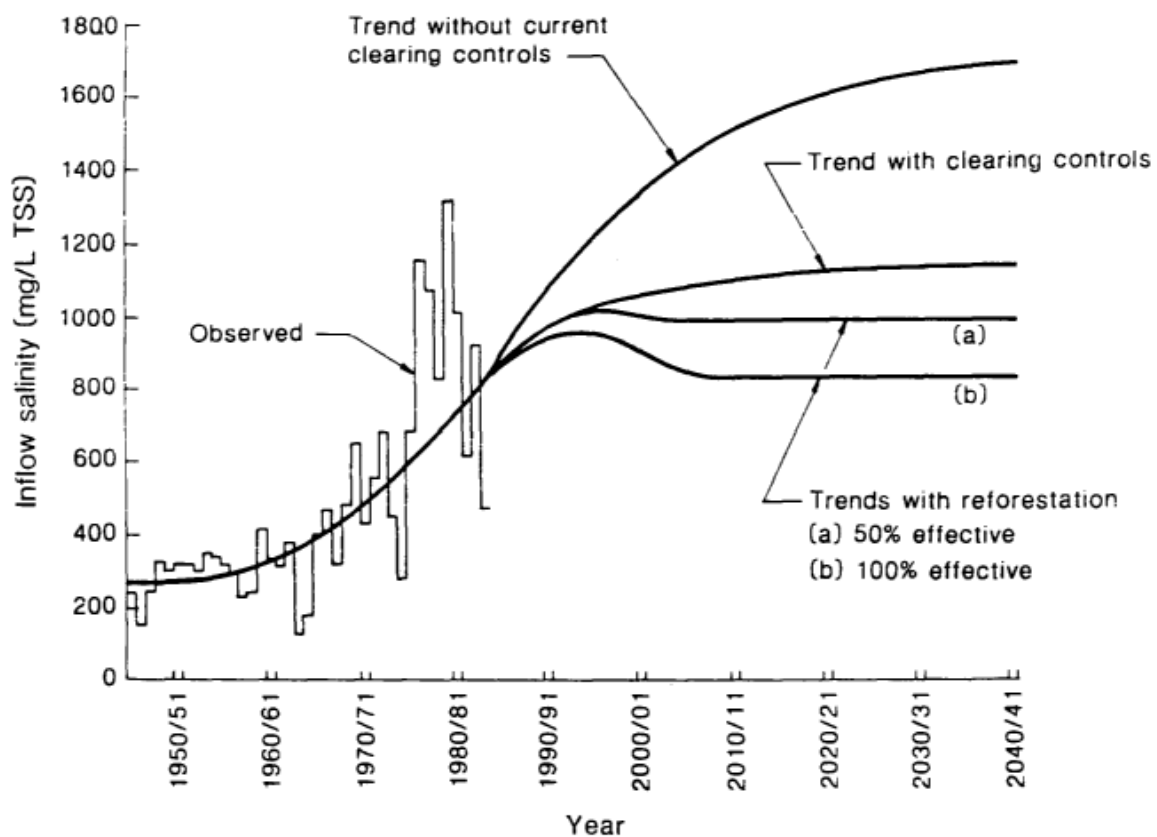


Figure 12. Observed and predicted inflow salinities to Wellington Dam for various salinity control measures.

### 9.3 Denmark River - Integrated Catchment Management

In recent years the concept of Integrated Catchment Management (ICM) has gained popularity. This essentially involves an integrated approach to tackling land and water problems on a catchment basis, involving landowners, communities, industries and relevant government agencies. In the salinity context, ICM promotes the use of a range of options (of which reforestation is one) in developing farm and catchment plans so as to control or reclaim salinised land and water whilst simultaneously maintaining land productivity. This is the approach taken in a joint project between the Western Australian Department of Agriculture, the Water Authority and CALM on the upper Denmark catchment (Fig. 2). Reforestation options with commercial potential were seen as a means of achieving this objective.

## 10. Economic and financial aspects

### 10.1 Development of Commercial Wood Production on Farmland

Traditionally there has been little overlap between production forestry on farmland and tree planting for the rehabilitation of degraded farmland and water resources (6). Production forestry has usually involved State or private investor acquisition of farmland with high rainfall and select soil types for planting with pine species. Land and water rehabilitation has involved the planting of a large range of slow growing tough eucalypts species in drier salt affected areas with little potential for commercial wood production.

The latter has been the approach on the Wellington catchment. By 1990, 6200 ha had been reforested. Total costs in nominal dollars of the reforestation program by the State to 1990 has been \$14.8 M, including outlays on the purchase of land, compensation, direct reforestation costs and research and monitoring. Commonwealth subsidies have been in the order of \$7.7 M. However, this long term approach to rehabilitation was not able to prevent the need for a new reservoir to replace the domestic supply function of the Wellington Reservoir. The Harris Dam was built at a cost of \$42 M (\$1990). To justify ongoing expenditures on rehabilitation, it was estimated that if Wellington Reservoir could re-supply water for domestic use in the future, this represented Net Present Value savings to the Water Authority in the range of \$46M-\$55M (\$1990) based on engineering cost differences (18).

Research into reforestation techniques on the Wellington catchment have identified the potential for trees to achieve the dual objectives of land and stream salinity mitigation and wood production. Several fast growing eucalypts species, in particular *E. globulus*, were found to give commercial yields of pulpwood over short rotations. This species provides high quality pulp and is in strong demand on world markets (5).

## 10.2 Disincentives for Farmers

To generate interest in commercial wood production among mainstream farmers, it is necessary to design initiatives which address the economic and social factors which are likely to prevent the integration of trees within farming activities. The risks and uneven distribution of cost and returns over long rotation periods were identified as major factors discouraging farmer interest in pine plantation forestry in the early 1980s (6). In response, the concept of forestry sharefarming was developed initially for pine plantations and then extended in 1987 to pulpwood species. Under a sharefarming contract the State (or investor) and the farmer agree to share the establishment and management costs of a plantation on the farmer's land and to share the harvest revenue. Between 1988 and 1989, 7000 ha of *E. globulus* were planted by CALM in sharefarming schemes.

It was also recognised that tree crops planted in the traditional plantation form would not be so widely adopted by farmers (5). In 1990 CALM developed the timberbelt sharefarming method with assistance from the National Afforestation Program. This method incorporates agroforestry and sharefarming principles into a form designed to be attractive to the majority of farmers.

A timberbelt is a stand of trees at least several rows wide of any size or shape. It is laid out as an integral part of the farm plan, and designed to give an optimum of wood production and other benefits. Timberbelt sharefarming has been designed to be a commercial operation attractive to both farmers and investors. It is an active joint venture between the farmer and the investor with a flexible sharing of costs, responsibilities and returns.

(20) identified other factors which affect whether a farmer will adopt some form of tree farming. These are: the level of knowledge of tree farming and attitudes to learning about it; how the demands of tree farming match the availability of labour; how the aesthetics of having trees are viewed; and the preference for the traditional farming lifestyle and attitude to change.

## 10.3 Incentives for Farmers

Apart from returns from wood production, other benefits accrue both to the farmer and the community from integrating trees on farm land. These are: shade and



shelter; wind and water erosion control; improved farm landscape and land values; farm business diversification; control of groundwater, water logging, nutrient discharge and salinity; and protection of remnant vegetation. Some of these values have been quantified by research. (27) found that mixed pine/grazing systems in the south west gave an overall gain of 40%. (8) demonstrated that up to 20% of an undulating treeless farm could be planted to treebelts without loss of agricultural production. (39) attributed some of the increase in land values of Victorian farmers participating in the Potter Farmland Plan to improved landscape aesthetics.

#### **10.4 Partnership Approach**

These factors, together with community support for landcare initiatives, are creating a more positive environment for the development of new approaches to catchment management and restoration. Using CALM's Timberbelt Sharefarming Scheme in the upper Denmark catchment, the Water Authority plans to take on the external investor role of providing the funds for implementation and contributing to ongoing management while the farmer provides the land and labour. The scheme has the potential to support existing reforestation operations on the Wellington catchment and be applied on other catchments where the Water Authority has declared its interest.

*E. globulus* is salt-sensitive and is generally being planted on free-draining sites away from salt/waterlogged sites. However, the overall profitability of the scheme makes allowances for up to 20% of plantings to be devoted to non-commercial species on salt affected land. By May 1991, initial negotiations had identified farmer interest in planting 57 ha in the winter of 1991. During the first ten year rotation period, CALM manages and provides advice to both parties. A legal contract ensures that costs incurred by both investor parties are recovered at the time of harvest and any additional returns are divided according to the inputs of each investor. The farmer then manages and receives all of the returns from subsequent coppiced crops. Re-growth from stumps occurs quickly providing for future harvests as well as maintaining the presence of trees for salinity control.

#### **10.5 Financial Evaluation**

Financial analyses have been undertaken on seven farm plans in the upper Denmark. The sensitivity to yield and price was tested at 250 and 200 m<sup>3</sup> of pulpwood per hectare and a received price of \$25 and \$20 per m<sup>3</sup>. With a yield of 250 m<sup>3</sup> ha<sup>-1</sup> and price of \$25 m<sup>3</sup>, internal rates of return for the farmer in years 10 and 20 are 15.2% and 18.4% respectively. The investor achieves a rate of return of 11.4% in year 10. When the yield is reduced to 200 m<sup>3</sup> ha<sup>-1</sup> and price to \$20 m<sup>3</sup>, internal rates of return are for the farmer 6.9% and 12.3% in years 10 and 20. The investor achieves a rate of return of 7.0% in year 10.

#### **Net Benefits**

The timberbelt sharefarming option allows farmers to diversify their farming activities and improve overall productivity. Cash flow problems and aspects of risk are minimised by the partnership arrangement. Management by CALM over the first rotation period aids the farmer in their learning curve about production forestry. Conservative attitudes may be more responsive to change by demonstrated benefits achieved by neighbours. Their tree farming activities also provide off-farm benefits in the form of reducing nutrient discharge to estuaries and salinisation to water resources.

## 11. Conclusions

- Southern Western Australia has extensive and increasing problems associated with rising saline groundwater tables which are causing broadscale stream and land degradation.
- Trees have the potential to control rising saline groundwater and consequently to control land and stream salinisation.
- Selection of tree species will depend on objectives, but there is now an increasing range available which have been tested for varied climatic and site conditions.
- Tree planting is relatively straightforward in free-draining areas away from saline seeps. In saline/waterlogged areas progress is being made on site amelioration techniques and identification and testing of tolerant species, provenances and clones.
- Planting location is an important aspect of any tree planting program. If the objective is to prevent groundwater discharging salts to streams, then the reforestation strategy must include lower slope and discharge zone planting.
- The question of how much tree planting is necessary is again dependent on objectives. To lower groundwater tables by 2 m in 10 years in areas of > 700 mm yr<sup>-1</sup> rainfall requires high density plantations covering 30% or more cleared land. Smaller proportions are required at lower rainfalls. Also smaller areas of reforestation would be necessary if higher water using agricultural systems are implemented.
- Small plantations of eucalypts have been successful in controlling sandplain seeps caused by discharging perched aquifers in low rainfall (300 mm yr<sup>-1</sup>) areas.
- Experimental evidence has shown that reforestation strategies with moderate to high proportions of cleared area replanted have been successful in lowering saline groundwater tables. The rate of groundwater level reduction was found to be proportional to the total reforestation tree cover on the cleared area.
- Operational reforestation for salinity control now has a history of 10 years in the Wellington Dam catchment. Commercial tree planting on farmland for pulpwood production commenced in 1988 and, if directed to salt-affected catchments, has the potential to significantly increase the rate of reclamation. This will be supported by incentives designed to address the financial constraints and social attitudes which are inhibiting factors to production forestry on farmland.
- Reforestation programs and farm planning should now take place in the context of Integrated Catchment Management where the interest of farmers, landowners, the government and community are adequately represented at the catchment scale.
- Reforestation has a number of other benefits including control of nutrient runoff and soil erosion; on-farm shade, shelter and aesthetics; and provision of fauna habitat and corridors.
- At this time of substantial and increasing community support for tree planting, careful research and evaluation should be maintained to maximise benefits.

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# **The role of trees in Providing Shelter and Controlling Erosion in the Dry Temperate and Semi-Arid Southern Agricultural Areas of Western Australia**

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## **1. Introduction**

Development of some forms of land degradation in the agricultural areas of Western Australia is a clear indicator that the level of vegetation on farms is inadequate.

The development of all forms of land degradation is a clear warning that the current agricultural systems are not sustainable.

'Revegetation' and 'vegetation' in this paper refer primarily to trees and shrubs. For particular circumstances, the terms also cover bushes, a range of fodder shrubs (such as salthush), and other woody perennials.

Trees and shrubs are unlikely to solve land degradation by themselves. Changes are also required in land use planning and management. A changed perception of the costs of land degradation amongst some land users appears to be accelerating moves towards revegetation and 'conservation farming'.

There is a broad acceptance in Western Australia of the desirability for revegetation on cleared farmland, and the retention and management of remnant vegetation. Most of this acceptance is in spite of the lack of documented cases showing land conservation and productivity benefits. Although there are good examples of trees lowering watertables, and thus removing surface salting, their economics have not been evaluated. There are even fewer documented examples of windbreaks with benefits on crops and pastures.

The Western Australian Department of Agriculture is, however, committed to revegetation strategies on agricultural land, and evaluation of the physical and economic affects of such strategies [21].

The Department of Conservation and Land Management is committed to retention, regeneration and management of remnant vegetation on farms. This is largely to meet nature conservation goals of the organization, although land conservation is also part of CALM's charter.

## **2. Adequacy of existing vegetation for plant, animal and soil protection**

### **2.1 Clearing and remnant vegetation**

The agricultural region, excluding Shires in the high rainfall South West and in the Pastoral region, covers about 18 m ha. This covers, roughly, the zone between the 600 mm and 300 mm rainfall isohyet (Fig. 1). About 14 m ha of this is cleared, i.e. 79% cleared [1]. This agrees closely with data from the Saltland Survey of 1984-85: In the Agricultural Region, about 13.5 m ha cleared of a total of 17 m ha, i.e. 79%

[25]. However, the total area of establishments includes some Shires with their eastern margins in the less than 300 mm rainfall zone. These more-or-less pastoral areas have not been extensively cleared.

Within the agricultural region of Western Australia, there is a distinct difference in the time since development and the degree of remnant vegetation between the sandplain soils and the heavier soils. Sandplain soils were mostly developed from the 1950s, and the heavier soils were developed before then.

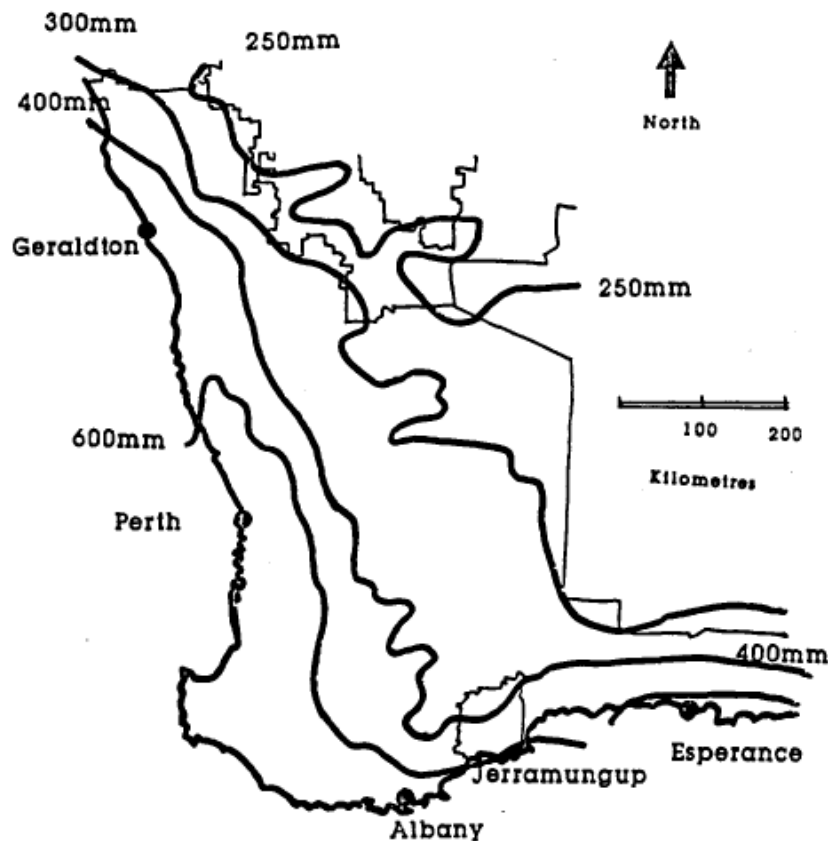


Figure 1. Western Australian agricultural region with rainfall isohyets.

Although there is this big difference in age, there is not as big a difference in the amount and distribution of remnants on farmland in many of these areas. The lighter, later developed soils are favoured for extensive cropping. This, combined with clearing technology, conditions of land release, and a late awareness of the full costs of vegetation removal have led to a high level of cleaning on developed parts of farms in the new areas.

The extent of remnant vegetation in four Shires of the Western Australian Wheatbelt in 1984 [8] is given in Table 1.

**Table 1. The extent of remnant vegetation in four Shires of the Western Australian wheatbelt region in 1984**

	Dumbleyung	Lake Grace	Pingelly	Tammin	
Total Shire area (ha)	255,200	925,000	123,300	108	700
Total area remnant vegetation (ha)	26,578	282,990	17,026	7	642
Remnant vegetation on private land (ha)	16,050	109,132	8,934	5	812
Remnant vegetation on public land (ha)	10,528	173,857	8,092	1	830
% of Shire under native vegetation	10.4	30.6	13.8		7.0
% of freehold land under native vegetation	6.3	11.8	7.2		5.3
% of public land under native vegetation	4.1	18.8	6.6		1.7

The degree of cleaning in several other Shires is shown in Table 2. Several years of Australian Bureau of Statistics (ABS) figures are included to show the variability of this data. Cleaning in some Shires has continued, especially in the more recently released areas; Esperance being notable.

ABS figures at this level are not much use, even on a statistical division, without identifying areas that are not likely to be cleared (natural saline drainage channels, lakes, etc.) and their size and distribution.

**Table 2. Estimates of the extent of remnant vegetation on agricultural establishments (ABS 1986,1988, 1990)**

Shire	% of farmland retained under native vegetation		
	1986	1988	1990
Brookton	9	9.7	13.6
Cornigin	8	7.2	7.9
Cuballing	10	8.7	9.7
Dumbleyung	7	6.3	7.4
Kondinin	11	14.2	11.5
Kuhn	11	10.5	10.7
Lake Grace	13	13.2	13.1
Narrogin	9	9.2	9.5
Pingelly	9	8.7	9.4
Wagin	10	12.2	11.2
Wickepin	10	8.4	9.1
Williams	12	12.3	12.0
West Arthur	17	16.8	16.2

On the first point, estimates of the area of remnants on arable land have been collected [10]. Unfortunately, information on intentions to clean this land was not collected. Esbenshade's data shows, for instance, that to the question "How much land remains to be cleaned that could be suitable for cropping or grazing?", 37% of respondents in Lake Grace said that more than half the remnant native bush could



be cleared. The question itself may have led to some confusion, and the issue of clearing remnants was a sensitive one among the farmers involved in the survey.

Remnant vegetation in the Western Australian Agricultural area is being identified with aerial photography, mapped, and entered into a Geographic Information System (GIS) by the Department of Agriculture. CSIRO and the Department of Conservation and Land Management also have an input to this data. A report on the mapping is expected from the Western Australian Department of Agriculture in July 1991 (G. Beeston, Research Officer, Land Information Assessment Branch WADA, personal communication).

When the GIS data is available it will be possible to give the extent, and potential value of remnants for different 'conservation' goals. This assumes that existing remnants identified by this means have not degraded too far to be of use. Extensive 'ground truthing' will be needed to check actual values.

'Adequacy', as defined in the review paper, could then be determined in terms of vegetation spatial distribution in relation to soil, landform, landuse interactions, and the environmental factors such as wind, rain, hydrology, etc. This type of definition is required in farm and catchment planning, and for the development of larger scale strategies and policy making.

At a pragmatic level, 'adequacy' can be defined in terms of the outcomes of vegetation removal, and the estimated need for revegetation.

### **3. Solving problems with revegetation**

Trees and shrubs planted onto cleaned agricultural land can prevent or solve some land degradation problems. In all cases, other engineering or management techniques also play a role in land conservation but these techniques are not discussed in detail below.

For any given land degradation problem, there will be factors for and against the adoption of revegetation answers. In the absence of good data on the values of replanted and managed trees and shrubs, there will always be an argument against their use. However, the concurrent, multiple values of perennial woody vegetation is a strong factor in their favour.

The design, establishment technology and management of revegetation programs has not reached the same level of refinement as most other agricultural activities. This 'simple' approach to revegetation in agriculture has been the cause of some failures, and the subsequent downgrading of plantings that attempt to optimize the tree-agriculture interface.

Estimates of the current extent, annual cost, and potential extent of the major forms of land degradation in Western Australia are shown in Table 3.

**Table 3. Land degradation in Western Australia: the extent, estimated costs, and potential extent**

Form of land degradation	Estimated area (km <sup>2</sup> )	Estimated annual cost (\$ m)	Potential area (km <sup>2</sup> )
Dryland salinity	4,272	50	23,810
Waterlogging/crops	*5,000	50	**10,000
Waterlogging/past	13,000	40	25,000
Water erosion	7,500	21.3	
Water repellance	50,000	150	?
Soil acidification	5,000	5	105,000
Soil struct. decline	35,000	70	?
Sub-soil compaction	85,000	153	
Wind erosion <sup>+</sup>	40,000	21	96,000
Salinisation of major public water resources <sup>#</sup> on-farm water resources		41	

\*\* In an average season.

.. In a wet season.

+ Documentation is lacking.

# 52% of the divertible surface water is affected by salinity in the SW of WA.

### 3.1 Salinity

Removal of native vegetation, and its replacement with lower water-use crops and pastures, is the major cause of rising saline watertables and the development of secondary salinity of soils. Strategic replanting of trees and shrubs is one of the most important ways of controlling recharge and discharge in Western Australia. This topic is dealt with in another review paper.

### 3.2 Wind erosion

#### 3.2.1 Extent of problem and potential

Given the right (or wrong!) conditions, most of the soils in the Western Australian Agricultural region are susceptible to wind erosion. An estimate by the Department of Agriculture in 1983 [7] was that about 25% of the "16 m ha of cleared agricultural land" needed special attention to prevent wind erosion. Another 40% was estimated [21, 26] to need some management to control wind and water erosion (see Table 3 for quantification of the problem).

Soil surveys at a useful scale do not cover much of the agricultural region. Coastal areas between Geraldton and Esperance have been surveyed, at different intensities, and to about 100 km inland [16].

Sandy surfaced soils, commonly called 'Sandplain' (and characterized by 'Kwongan' vegetation), are particularly susceptible to wind erosion. By analysis of the vegetation it is estimated that the sandplain covers about 117,763 km<sup>2</sup> or 26.9% of the South West Botanical Province [18]. This Province has a rough approximation to the South West Agricultural Region.

#### 3.2.2 Documentation of wind erosion

Wind erosion is known to be widespread in Western Australia, and particular risk factors are associated with erosion events, but 'there is little documented evidence of its occurrence, severity and cost' [16].

An unpublished report in the Department of Agriculture estimated that, in 1986, 500,000 ha was actually affected by wind erosion, and another 10 m ha was susceptible [16].

Anecdotal evidence of dust erosion in the central wheatbelt is widespread, but documentation is not available. Instances of note in 1991 include severe wind erosion in the North-Eastern, Central and South Eastern wheatbelt of Western Australia. The South-Eastern area, to the North of Esperance, was put at risk by the driest spring and summer on record. The Central wheatbelt was affected by a decaying cyclonic low pressure system in May 1991, at a period when many paddocks had been cultivated for crop establishment, and most pastures were bare.

Remote sensing of wind erosion has potential in Western Australia, combined with on-ground monitoring, but the costs have prevented its use (D. Carter, Research Officer, WADA, personal communication).

Anecdotal and photographic evidence is available on the role trees and shrubs have played in particular wind erosion events in Western Australia. Little of this has been properly documented.

### **3.2.3 Jerramungup case study**

An example of an area with some documentation is Jerramungup; situated on the South Coast Sandplain, about 180 km North East of Albany, Western Australia (Fig. 1).

Jerramungup, cleared mostly since the 1950s, has had significant wind erosion in 1969/1970/1971/1980/1981/1983/1984/1986 and instances since then. Wind erosion and the effects of sand movement were particularly bad around Jerramungup in 1980 and 1981, and 1983 and 1984.

About 44,000 ha in 1980 and more than 64,000 ha in 1981 were estimated to have been seriously affected by wind erosion [13]. This was about 7.3% of cleared land, and 18.3% of the cropped area showing evidence of sand blasting. The report estimated that the direct, or cash costs, averaged \$17,900 per farm for 1981 alone. Wind erosion caused an estimated loss of \$1.5 m in the Shire of Shelter and Erosion

Jerramungup in 1981. This estimate does not include the effect on subsequent crop yields, depressed yields on areas not totally destroyed, the cost of clearing roadways and tracks, recovery of fences, and loss of vegetation due to sand abrasion and cover.

Another study in Jerramungup, following severe wind erosion in 1983 and 1984, investigated farmers' management and their perceptions of the causes and methods of reducing wind erosion [14]. The extent and severity of wind erosion in the area was not assessed.

The survey results indicated that farming systems which maintained a good plant cover, minimized wind erosion risk. Farmers in the survey appeared to be aware of the reasons for, and causes of, wind erosion within their control.

Given the extent of erosion in Jerramungup till 1984, and erosion being experienced on the South Coast in 1990/91, many landowners do not appear able to respond to indications of risk on an annual basis.

Conditions leading to wind erosion are very similar in the Esperance agricultural region, about 300 km further East from Jerramungup, and based on the coast.

Farming conditions, soils and winds experienced at high risk times on the Esperance sandplain have led to widespread, severe erosion, but this has not been documented. Significant areas of wind erosion occurred North of Esperance in the autumn of 1991.

### **3.2.4 Agronomic vs tree windbreak control of wind erosion**

Conservation farming techniques to minimize wind erosion have been known for many years. 'Minimum tillage' and stubble management in cropping have been a major extension and research activity of the Western Australian Department of Agriculture for nearly a decade. This reliance on management of crops and annual pastures for wind erosion control could be adequate, if universally practiced, in a 'normal' year.

Severe weather and/or economic factors, combined with less than perfect adoption of appropriate grazing and crop management systems, shows the weakness of relying completely on annual management decisions.

Clover harvesting nearly always leads to soil erosion. On the sands of the South Coast, this erosion is often severe. A few farmers have planted tree windbreaks as an integral part of clover harvesting, but most do not. Guidelines for clover harvesting, to minimize soil erosion, are being prepared by the Department of Agriculture.

Tree windbreaks for prevention of wind erosion would overcome the reliance on short-term management decisions for protection during severe conditions. Combinations of tree and agronomic protection systems are likely to give higher returns over a range of risk conditions.

### **3.2.5 Tree windbreaks for the agricultural region of WA**

Although the design, or engineering, of windbreaks is well understood [24, 6, 4], in practice, especially in the low rainfall areas of Western Australia, there are considerable economic and technical problems in establishing windbreaks on old agricultural land.

Many tree windbreaks have been established on farms between Geraldton, on the North-Western end of the wheatbelt, and Esperance, on the South-Eastern end of the wheatbelt. There is a wide range in the efficacy of these windbreaks. The range is due to both windbreak construction and placement in the farm landscape. Windspeed reductions behind some of these windbreaks have been documented [3; also D. Carter, unpublished data], but the effect on erosion has not been measured directly.

## **3.3 Waterlogging and water erosion**

Revegetation has a minor role in the treatment of these problems on a catchment basis.

The particular nature of Western Australian soils, warm Mediterranean climate, and agricultural practices, means that winter waterlogging and summer to early autumn water erosion is a moderately high risk.

Soil and water conservation earthworks combined with reduced tillage in crop production are the most effective action to prevent water erosion.

Waterlogging is mainly treated with earthworks (on sloping duplex soils) and agronomic options (on flats with limited drainage options). See section 3.4 for more information.

### **3.3.1 Seepage control as a special case**

Waterlogging associated with hillside and sandplain seeps can be effectively treated with trees. Seepage areas are usually also salt affected, and may be a recharge point for the deeper water table. Sandplain seeps account for about 60% of secondary salinity in the Eastern wheatbelt of Western Australia; about 15,000 ha [12].

Reclamation of many seeps has been possible within five to ten years of planting [12]. There is usually a net gain of productive land from revegetating sandplain seeps, and the trees can fill other functions at the same time. Trees on these sites, even in low rainfall country, grow well due to the availability of relatively fresh water in the aquifer. These trees can be part of a windbreak system, shelter and a woodlot.

Control of waterlogging associated with salt is covered in another review paper.

### **3.4 Soil structure decline**

Surface soil and subsoil show evidence of deterioration following removal of the native vegetation.

Major changes in the surface soil that affect agriculture and the development of land degradation are [23]:

- reduced organic matter
- reduction in non-capillary porosity
- reduction of water stable aggregates

Changes in subsoil that affect agriculture and the development of land degradation are [15]:

- closure of vertical water-flow preferred pathways in the otherwise massive subsoils
- reduced macrofaunal populations which provide pore entry at the surface, leading to the subsoil

#### **3.4.1 Role of trees and revegetation**

In particular areas, the use of edible shrubs, deeper rooted crops, perennial pastures and trees, will allow easier water flow into the subsoil. They are also likely to increase soil organic matter, water stable aggregates and macrofaunal populations. Trees by themselves have a limited use for treating soil structure decline, although trees planted for other reasons will ameliorate the problem.

Alley farming with deep rooted shrub species has been suggested as one way of preventing soil structure decline [15]. A few farmers in the agricultural region of WA are trying forms of this system, but not primarily for improvement of soil structure.

### **3.5 Subsoil compaction**

Development of compaction pans, or 'hardpans', are a result of the passage of heavy agricultural machinery.

The lighter soils of Western Australia are particularly susceptible, with significant compaction developing after only three to five crops following clearing [26].

Given that this problem occurs directly under, and as a direct result of agricultural practice on arable land, revegetation has no significant role in treatment.

### **3.6 Water repellence**

Water repellent soils, or soils that resist wetting when dry, can be a major contributing factor to wind erosion. The problem develops most noticeably on sands with a low organic matter content, but also on more clayey soils with a higher organic matter content [25].

It is important to realise that all the currently favoured agricultural systems lead to increasing water repellence.

Tree windbreaks, by protecting soils from wind erosion, have an indirect value in the treatment of water repellent soils. Deep cultivation is one of the methods that can overcome water repellence. This technique is not often used because soils with water repellence are highly susceptible to wind erosion.

### **3.7 Soil acidification**

Soil acidification processes, the extent in Western Australia, the treatment and research needs are discussed elsewhere [11].

Trees, shrubs and perennial grass pastures can prevent further acidification on-site [9], although treatment with agricultural lime is still the preferred ameliorate in most of the State [25]. Trees have little role in the treatment of broadscale acidification.

### **3.8 Degradation of waterways and water resources**

This section refers to drainage lines, creeks, lakes, swamps, and man-made water storage areas on farms within the agricultural area. It does not refer to divertible surface water supplies or potable water catchments.

There are two parts to this degradation:

- (i) Soil erosion and silting
- (ii) Surface discharge of salt or salinization of water supplies

Vegetation buffers for protection of natural waterways and drainage and 'wetlands' are allowed for in the land clearing regulations of the Western Australian Soil and Land Conservation Act 1945-88. Guidelines on clearing have been prepared for each agricultural division.

On much of the agricultural area, clearing or degradation of vegetation adjacent to the above areas has already occurred. Therefore, there is a large potential area for revegetation. However, soil and water conservation earthworks have taken some of the roles of buffer vegetation, i.e. water erosion and silting control.

The nature conservation value of remnant vegetation and revegetation adjacent to these natural 'corridors' will be covered in another review paper, but should be appreciated.

Salinization of on-farm water supplies is from the same cause as land salinity; that is, a rising saline watertable. Strategic revegetation can prevent discharge of saline waters from affecting fresh, surface run-off [25, 20, 22].

Combined earthworks for surface water control, and trees for watertable control, can be used to safeguard farm water supplies. Several farmers in Western Australia have established grade banks or interceptor banks with three or four rows of trees on the downslope. This controls leakage to some extent, and provides windbreaks that roughly follow contours. An extra advantage of this system is that protecting the bank and vegetation is done with the same fence. The potential for this type of revegetation is large.

### **3.9 Livestock exposure and productivity**

There are four main areas of concern where revegetation has a role:

- (i) Post shearing deaths
- (ii) Death of lambs
- (iii) Increased maintenance energy requirements
- (iv) The pasture production/sheep nutritional exposure interaction early in the winter

The agricultural region of Western Australia has a warm to mild Mediterranean climate. This means that there is a distinct dry, hot summer period and a mild to cool, wet winter. Feed availability and quality is highest in spring, and lowest in autumn just before newly germinating pastures become available. Pastures are mostly based on annuals, which germinate with rain about mid-April and senesce in late spring (October to November).

#### **3.9.1 Post-shearing losses**

Low level losses occurring on an annual basis are not well recorded, but are often seen in late summer/autumn shearing in the agricultural areas.

Outstanding losses from adverse weather over a broad area have been documented in some cases. Losses were estimated at 100,000 following a rain-bearing depression in the South West of Western Australia in January 1982 [5]. Average flock loss exceeded 50% in areas where more than 250 mm of rain fell in the two days, but no losses were reported in areas receiving less than 100 mm. The windspeed was estimated to be less than 10 km per hour; had it been greater severe losses would have resulted over all areas, since windspeed is often the major factor in the temperature-rain-windspeed chilling equation. The variable presence or absence of shelter from vegetation or topographical features on different farms, differences in wool cover, and age and condition of sheep would account for much of the reported 0-84% range in mortality experienced.

A number of important points came from the report:

- Under unusual conditions of continuous and prolonged rain which completely wets the fleece (and keeps it wet), vegetation shelter may not reduce mortality
- Sheep use, or fail to use, shelter according to weather conditions, positioning of shelter, and amount of wool cover
- Shelter needs to be of very high quality (canopy cover and a dense windbreak) in severe conditions of prolonged rain and low temperature (and especially where high windspeeds also occur)

Remnant vegetation in grazing paddocks has traditionally been used for shelter [8]. As pointed out in an earlier part of this paper, remnants are scarce in some areas, and many of them have lost their understorey. Also, most of the remnants are unfenced [10] and therefore cannot be used to contain sheep.

Revegetation, in the form of 'livestock havens' [28] would be the most effective way of providing high quality, short term shelter for off-shears sheep. Havens usually have a dense perimeter and less dense centres. They are intended to carry up to 1000 sheep per ha for a few days. On the deeper sand soils of the Western Australian agricultural region, fodder shrub blocks serve the same purpose if there is some tall shelter included.

### 3.9.2 Death of newborn lambs

Information on lamb losses, as a direct result of exposure close to birth, is limited in Western Australia.

Severe lamb losses in Western Australia are usually associated with late breaks to the season combined with poor feed availability. In these circumstances there are losses from direct exposure, starvation and mis-mothering.

An indication of the occurrence of such losses is found in the Esperance Shire statistics [2] (see Fig. 2).

Over the twenty years of information shown, there are four years of moderate to severe lamb losses associated with bad weather during lambing. Individual farmers have told the author that lamb marking in 1981 was often around 10 to 20%. The Shire average was reported to be 48% for that year, and is higher than 70% in a good year.

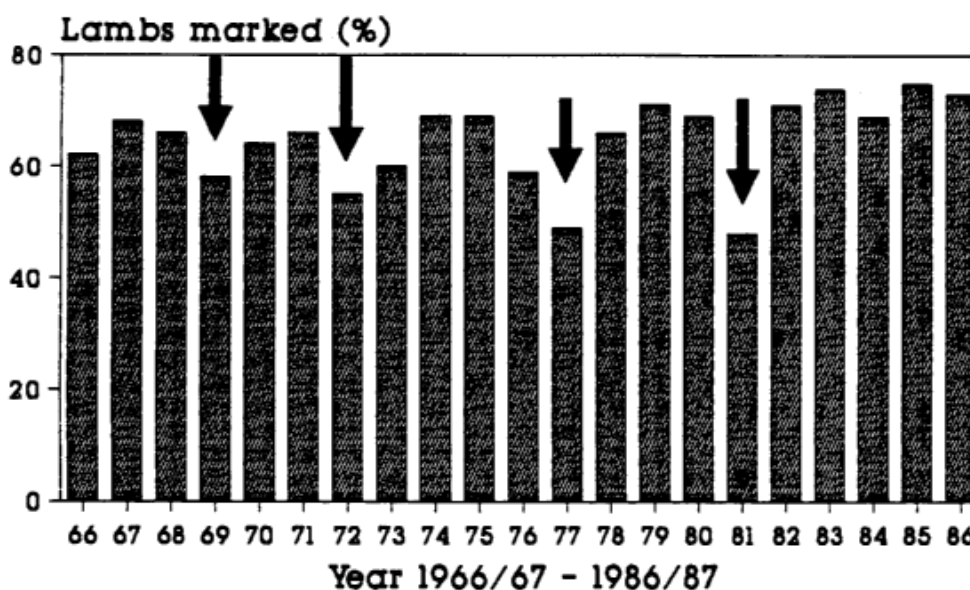


Figure 2. Lambs marked (%) in the Esperance Shire, Western Australia, showing high loss years

## 4. Improvements to productivity and sustainability

The overall intention of revegetation with trees and shrubs is to buffer the adverse affects of variable weather conditions and annual management, and improve economic and environmental sustainability.

Perennial woody vegetation included in farming management will simultaneously fill several roles. When each of the primary reasons for revegetation are integrated into



a farm or catchment plan, the design, establishment and management of the plantings is likely to alter to accommodate other requirements of the site.

Data on the bio-physical effects of revegetation, and relevant interpretation of these data, is needed to assess individual cases. Most of this information is lacking for the drier agricultural areas of Western Australia.

Individual farmers have recorded increases in productivity following revegetation, but very few have been assessed for their net economic value. There is an urgent need to collate and assess this information. There is also an urgent need to establish monitoring sites and trial plots to quantify the value of revegetation.

#### 4.1 Measured plant production behind windbreaks

There are only three sets of information known by the author in Western Australia; collected by the Department of Agriculture and a National Soil Conservation Program project based in the Department of Conservation and Land Management.

- (i) Pasture production behind a 3 m high natural windbreak was estimated by Findlater and Prout (unpublished data, WADA Division of Resource Management Research Summary 1986, pp. 3 1-53). Dry matter production was estimated with an electronic capacitance meter, and a number of other measurements were taken. However, the meter could not be reliably calibrated, and the site showed great variation. The results did not clearly show increased production directly related to the windbreak.
- (ii) Crop production behind a mature, 10.5 to 12.5 m high *Pinus pinaster* windbreak was measured by Negus (unpublished data, WADA Narrogin Office Research Trial Results 1988). Unfortunately, not enough measurements were taken to show the effect of the windbreak in the critical area within four tree heights. The 'open paddock yield' was not measured (i.e. greater than 20 to 30 tree heights away from the windbreak). Also, there were only two replicates measured at 30 m intervals from the windbreak.

Negus interpreted the data to show no gain in yield, and to show a yield reduction close to the windbreak due to competition.

- (iii) Lupin and oat yields behind young *Pinus radiata* were measured by Bicknell and Vincent (unpublished data, National Soil Conservation Program Project, Department of Conservation and Land Management, Esperance, WA) in 1988, 1989 and 1990.

The site is on the property of Garry and Jan English, about 45 km north of Esperance, in a 450 mm rainfall zone. The soils are fine podsolized sand, 3.5 -5.0 m deep over clay (formed over marine sediments). The windbreaks consist of three rows of *Pinus radiata*; rows are about 3 m apart and trees are about 2 m apart within the rows. The belts are about 200 m apart, aligned N-S.

The windbreaks were planted in 1984. In 1988 they were about 5 m high, in 1989 they were 6.5 m, and in 1990 they were 7.5 m.

Lupins in 1988 and 1989 showed a distinct response to windbreaks on the western and eastern sides of the crop. The net yield increase between the N-S windbreaks was about 27% in 1988 (Fig. 3), and 30% in 1989 (Fig. 4). Accounting for the area lost to production under windbreaks, the overall net increase was 19% and 22%, respectively.

Lupins are particularly susceptible to cold conditions and sandblasting in early winter, following germination. Winds at this time of year are usually from the NW (pre-frontal winds). Yield increases on the western side of the paddock are probably due to protection from this wind.

Lupins are also susceptible to flower abortion caused by moisture stress and buffeting. Winds at this stage of development are usually from E to NE. Yield increases on the eastern side of the paddock are thought to be due to protection from this wind.

Oats did not show a response in 1988 (Fig. 5), and showed about a 10% yield increase between windbreaks in 1989 (Fig. 6). Results from 1990 have not been analysed.

Oats were not as responsive as lupins to shelter. The apparent response in 1989 was in an exceptionally wet year. Evaporative cooling interacting with nitrogen deficiency may have reduced yields, and the western windbreak would have given some protection from the problem winds.

#### **4.2 Livestock productivity with shelter and windbreaks**

A trial was established in 1988 by Bicknell (unpublished data, National Soil Conservation Program project at Esperance, WA) to investigate productivity of pastures and sheep behind a pine windbreak. Sheep production differences between plots were not noticeable, even though pasture production was very different between plots. However, plot differences could not be ascribed to the windbreak. Plots closer to the windbreak were also on a deeper sand. This soil had developed a severe non-wetting surface, possibly due to its very low clay content and the regular sheltering of sheep on it.

Pasture production was markedly lower on these non-wetting soils, but sheep liveweights and wool production did not reflect this. The windbreak protection appeared to allow higher sheep productivity from plots closer to the windbreak than would have been expected from the lower pasture production on these plots. Stocking rates used in the trial were high for the district (10 DSE per ha).

There is no further Western Australian data known by the author. Anecdotal information abounds, but is usually confounded by very different feed regimes, flock structure or other factors.

#### **4.3 Tree windbreak potential to control exposure effects on pasture and livestock productivity**

Although evidence is lacking in Western Australia, there is good reason to believe that pasture and livestock production will increase with shelter.

This increase is likely to be higher on the erodible sandplain soils (which are more likely to have non-wetting, soil detachment and saltation in wind events), or very exposed sites anywhere in the agricultural region of Western Australia. Reduction of sandblasting, evaporative cooling and moisture loss from exposed soil should lead to increased pasture growth early in the season. This is the period in Western Australia when feed availability is most critical.

The potential for strategic revegetation to control these exposure losses is very high. Moves by the Land Conservation Districts toward farm and catchment planning using land management units will allow this potential to be realized.

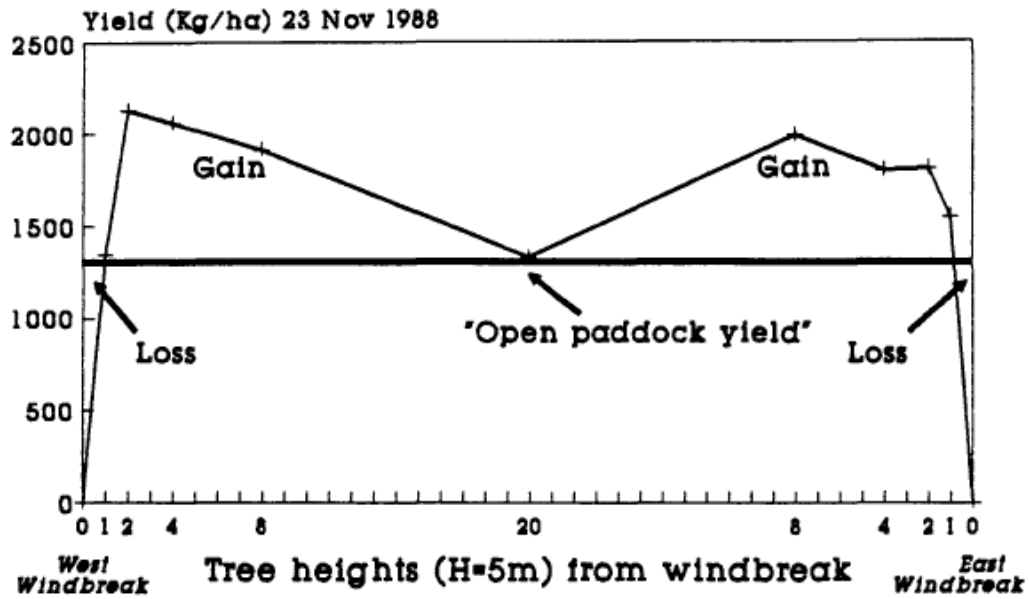


Figure 3. Lupin yield between parallel pine windbreaks in Esperance, Western Australia, 1988 (Property of G. and J. English).

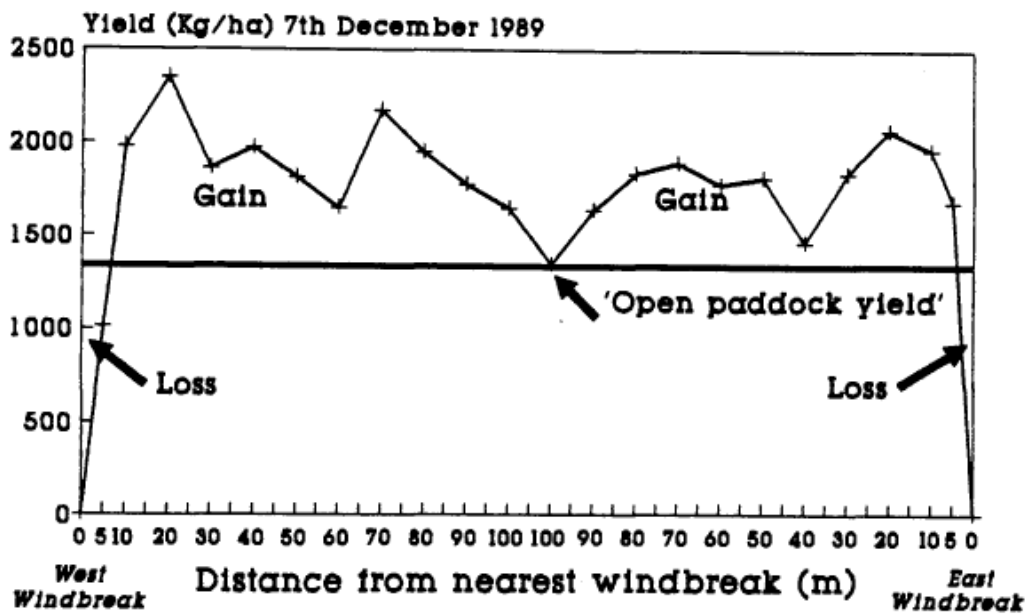


Figure 4. Lupin yield between parallel pine windbreaks in Esperance, Western Australia, 1989 (Property of G. and J. English).

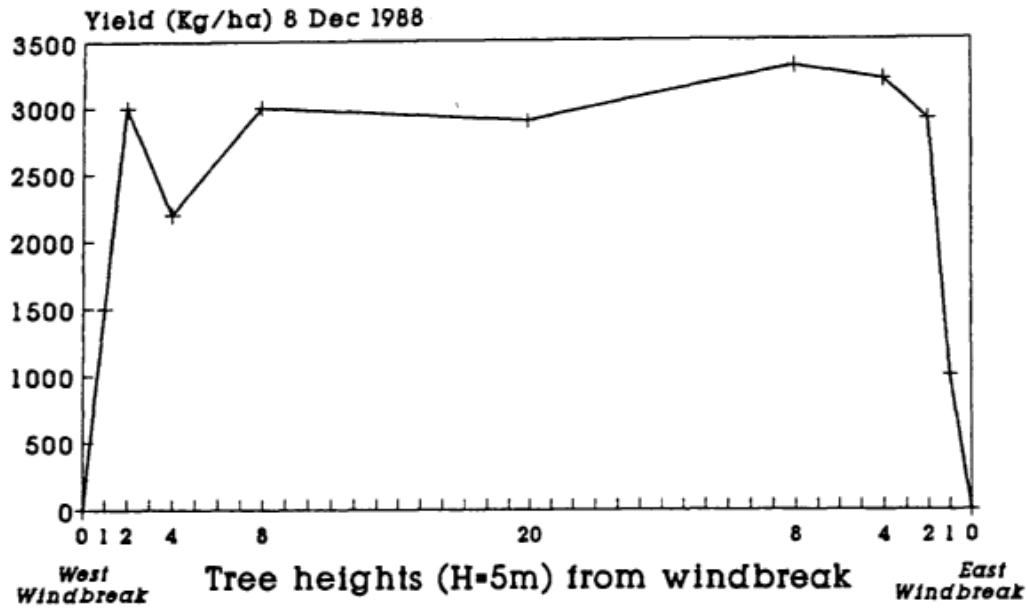


Figure 5. Oat crop yield between parallel pine windbreaks in Esperance, Western Australia, 1988.

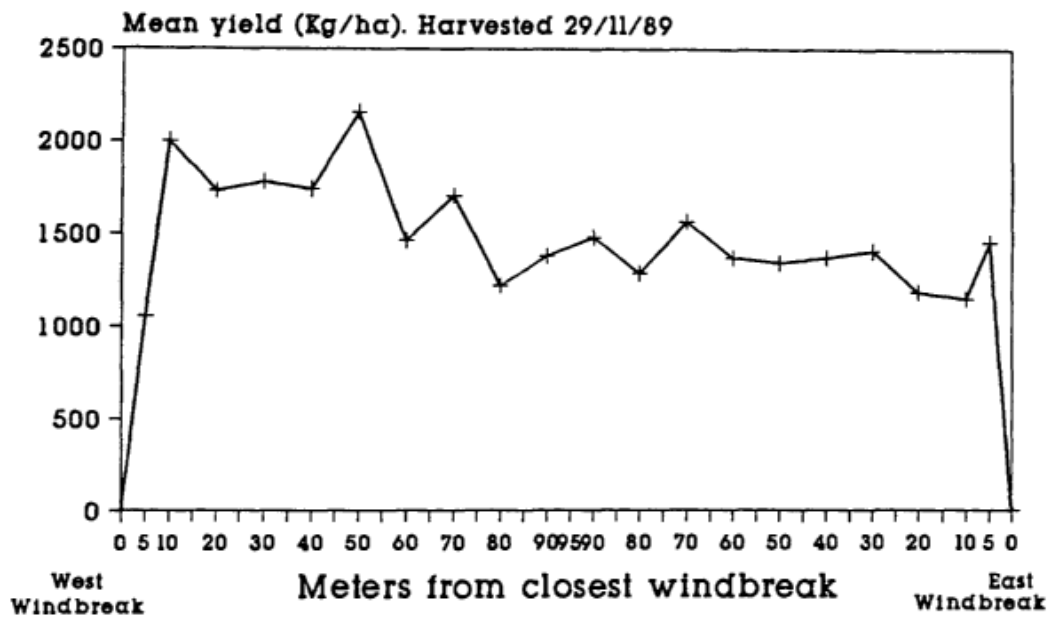


Figure 6. Oat crop yield between parallel pine windbreaks in Esperance, Western Australia, 1989.

#### 4.4 Revegetation requirements

A number of surveys and reports suggest that about 15% of each property should be left under vegetation. In one survey [8], on average, respondents believed that 14% of each property should be left under native vegetation, assuming that all the property was arable. The limitations are that remnant vegetation is often on the non-arable land, and many properties have less than 14% of remnants.

The Land Resource Policy Council of Western Australia [17] suggested that a minimum of 15% of the land be retained or re-established with native vegetation. This was an interim recommendation, until a minimum desirable amount of vegetation could be ascertained.

Clearing guidelines from the Western Australian Department of Agriculture suggest 20% of each sub-catchment be left under native vegetation for land degradation control. The reasoning behind this figure is arguable, as is the requirement in terms of 'native vegetation'.

Greening Australia (WA) suggest that 8-15% revegetation, above the existing area of remnant vegetation, is required for land degradation control [21].

There is very little research evidence to support any given figure for revegetation requirements. For salinity, wind erosion and watertable control, combined with shelter for plants and animals, there appears to be a case for between 5 and 15% revegetation on all cleared land.

The Western Australian Farmers Federation (WAFF) surveyed 234 farmers in 1990 about their tree planting [27]. By extrapolation, WAFF estimated that 23.2 m trees and 1.39 m shrubs were planted in 1990 by farmers. This figure is much higher than estimated from the combined sales of seedlings in the State (W Edgecombe, Rural Adviser, CALM; personal communication).

Assuming that 5% of the agricultural region needs revegetating over the next decade, at an average density of 300 per ha, then 24 m surviving trees and shrubs would be needed each year.

The author estimates that survival of plantings is less than 50%, and that actual planting in the agricultural region has been about 10 m in the last two years. That is, about 5 m surviving seedlings in 1989 and 1990.

Revegetation levels were lower before 1988 across the State. Interest in replanting trees on farms has increased markedly since about 1981. Economic pressures on farmers in 1991 have greatly reduced tree orders to the larger nurseries. This downturn in planting is expected to continue for at least two years.

All these figures are very rough estimates. However, it is possible that revegetation rates need to increase some 4 to 8 times over the highest known revegetation rate, over a period of at least ten years, to achieve land degradation control in the long term.

#### **4.5 Support for revegetation activity**

There are three main factors in achieving increased revegetation:

- (i) Landowner interest and initiative
- (ii) Adequate on-farm resources and off-farm materials supply
- (iii) Technical and organizational support

On the first point; the 1980s have been a very obvious precursor to the 'Decade of Land Care' in the 1990s. Farmer interest in land care is very high, as evidenced by the development and expansion of Land Conservation Districts (LCD's) in Western Australia. Revegetation is a major interest of many of the LCDs.

On the second point; farmers' financial resources for revegetation are currently low. The nursery industry has expanded rapidly over the last five years or so to supply

demand for farm trees. Some of the larger nurseries have also investigated species, seed sources and clones for salt tolerance. Equipment for seedling planting and direct seeding has been developed to cover nearly all requirements in Western Australia.

On the third point; technical and organizational support for farmers' revegetation activities has not been so quick to respond. The main demand has been for advice on species selection, site preparation, early management, and design for revegetation strategies.

#### **4.5.1 Conservation and Land Management (CALM)**

The main nature conservation and forestry authority in the State, the Department of Conservation and Land Management, has until recently had only two Rural Advisers dealing specifically with farm revegetation. A third adviser, based in Perth, was appointed in 1990.

More recently, the three advisers and personnel involved in the Timberbelt Scheme have been formed into the Vegetation and Tree Planting Advisory Service (VATPAS). CALM has a stated policy of providing on-farm advice, and sees the future for expanded commercial and semi-commercial plantings to be on privately held land. A major move by CALM to encourage tree planting as an integrated farming activity has increased effective farmer contact.

#### **4.5.2 Department of Agriculture (WADA)**

The Department of Agriculture's revegetation activity has been concentrated on the use of halophytes (such as saltbush) on dryland, salt affected soils.

Individual research officers and advisers have initiated some on-farm tree programs. Most of these have been for saltland or watertable control, and some have been for windbreaks.

More recently, the Revegetation Technology Group (of the Department's Division of Resource Management) has included a 'perennials and fodder shrub' project for the lower rainfall agricultural areas, funded by the National Soil Conservation Program (NSCP). A Revegetation Development Officer has also been appointed to this Division, to deal mainly with tree and shrub revegetation strategies in catchment and whole-farm planning.

Project Officers, appointed by the WADA to work directly with the Land Conservation District Committees (and funded by the NSCP), have also raised awareness of the need for revegetation and its place in farm and catchment planning. However, very few of these officers have experience or ready access to locally relevant and validated information on revegetation.

Farmer experience continues to be the largest source of information for other farmers, although this experience is not always transferrable between seasons or different land units.

#### **4.5.3 Greening Australia (GA)**

Four 'Community Coordinators', or 'tree persons', are employed by Greening Australia (WA) to coordinate GA programs at the local level. These people also act to raise awareness of the value of revegetation and remnant vegetation. In general, they are not expected to be technical specialists.

Greening Australia also has a Project Officer to centrally coordinate One Billion Tree Program projects, and currently has a NSCP Project person to investigate direct seeding of trees and shrubs (a one year project).

#### **4.5.4 Other organizations with revegetation activities**

Australian Conservation Foundation (ACF); ACF has a Rural Liaison Officer to deal directly with the farming community. Most of this contact concerns the retention, protection and use of remnant vegetation.

Land Management Society (LMS); has membership from farming through to research. Revegetation and remnant vegetation are an integral part of the holistic view of agricultural land use that the Society has. However, LMS does not employ its own officers.

Fodder Shrub Society; has a broad membership, and acts to promote the use of fodder shrubs and encourage research. No independent advisory activity.

Men of the Trees (MOTT); deal mostly with recreational and community plantings. MOTT is starting to have an input to farm tree planting through a nursery scheme to supply and sometimes plant trees on farms. MOTT runs its own nurseries.

Greenhouse Corps; activities are mostly in the higher rainfall areas of the SW of the State. This group organizes training programs for farm and catchment planning, and revegetation contractors.

There are several revegetation contractors that also supply advice on species, design of programs, plans, etc. Their advice is mostly associated contract services, but their staff provide technical input to many open field days.

#### **4.6 Data acquisition and the economics of trees for rehabilitation**

Although it is known that trees can use high levels of water, slow windspeed, give shelter, etc., the value of these to farm scale agriculture is largely anecdotal.

Very few revegetation programs, for land degradation control or increased agricultural productivity, have been documented, and even fewer have used economics to assess the program within the whole-farm plan.

This lack of data and assessment means that we are lacking the means of giving quantitative advice, and the ability to devise economically and environmentally sustainable agricultural systems.

Revegetation is, qualitatively, seen to be the answer to many of Western Australia's land degradation problems. It is vital to collect available data, analyse the biophysical and economic implications, and validate revegetation strategies.

The cost of sustainability could be reduced income in the long term, compared to the current profitability of apparently non-sustainable agriculture. This view was the outcome of an initial assessment of a revegetation-rehabilitation program on the Esperance Downs Research Station, Western Australia. The assessment was carried out using the 'Farmula' software program, developed by the Division of Agricultural Economics and Marketing, Department of Agriculture, Western Australia. This appraisal is at variance with studies in Victoria and South Australia (see reviews by Bird and Bulman). In the absence of a revegetation program the long-term effects of land degradation might also reduce farm income and viability. None of the current models deal adequately, if at all, with this issue.

The expectations of farmers implementing revegetation programs are often exceeded after a certain level of vegetation development. This has been reported by a number of leading Landcare-oriented farmers in Western Australia. The potential productivity, and options for alternative enterprises, has appeared to expand with the expansion of vegetation and other Landcare activities. This potential is hard to build into the usual models of economic assessment.

Many of us have arrived at the point of feeling that revegetation for land conservation is necessary. It is necessary now to document and validate that feeling; to place revegetation activity on a level with other agricultural enterprises and engineering solutions to soil degradation.

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# Management of Native Woody Vegetation on Farms in Western Australia

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## **Abstract**

The paper is to review the relationship between remnant vegetation and agriculture in Western Australia. Farmers and pastoralists currently manage up to 45% of WA or about 112.6 million ha. There are 2 major agroecosystems, agricultural and pastoral with several sub-agroecosystems. Development of these agricultural agroecosystems has meant widespread land clearing and subsequent costly land degradation effects. Remnant vegetation on farms in this agroecosystem is estimated to be about 4.4 million ha or 22%, however this is more commonly 5-12 % in most wheatbelt shires. The distribution of this is highly fragmented, small in size, disturbed and of unknown condition and viability. Publicly owned vegetation remnants are also fragmented and exposed to disturbance, but of greater conservation value because of larger remnant sizes.

The pastoral agroecosystem is comprised largely of native vegetation over an area of 92.7 million ha with relatively little clearing (0.01%). About 22% of the best types of rangelands are degraded and another 20% of rangelands are not used because of low pastoral value and inaccessibility. Up to \$37 million/year in lost production is attributed to land degradation in the agroecosystem. Rangeland inventories and monitoring are already assisting pastoral managers to better manage the resource. Conservation of native woody species in the shrublands region is regarded as the best means of ensuring the pastoral industries future.

Other topics include the value and costs of retaining remnant vegetation, the impacts of excessive clearing on agriculture, and estimated costs of the resultant land degradation. Management issues such as retention, legislation and alternate uses for remnant vegetation are discussed as well as gaps in knowledge and required cooperation of farmers for future conservation and management of remnant vegetation.

## **1. Background**

### **1.1 Introduction**

This paper examines the relationship between remnant vegetation and agriculture in Western Australia and reviews current knowledge on aspects of its conservation and management.

Remnant vegetation is defined here as native woody vegetation left after clearing or after many years of grazing by domestic stock. Native vegetation has been used by landholders since the European settlement of the Swan River area in 1827.

Remnant vegetation and adjacent land at King's Park, in central Perth, was used for grazing of domestic stock, as a source of firewood and building materials and for food production after clearing (Seddon, 1972). By the 1930's agriculture in the

south-west had changed from largely pastoral activity in native vegetation to intensive cereal cropping and pasture improvement which required clearing the native vegetation (Jarvis, 1986). This process of agricultural development in the south-western of WA has resulted in a fragmented landscape that is 'degrading rapidly in terms of both its agricultural potential and its nature conservation value' (Hobbs, 1991).

## 1.2 Agroecosystems of Western Australia

### 1.2.1 Agroecosystem Definition

The dictionary of Ecology, Evolution and Systematics (Lincoln *et al.* 1982) defines an agroecosystem as an agricultural ecosystem. Elliot and Cole (1989) have further defined agroecosystem as 'an interactive group of biotic and abiotic components, some of which are under human control, that forms a unified whole (ecosystem) for the purpose of producing food and fibre. They are intentionally disturbed ecosystems that, through human influences, are being forced into states different to the natural systems which they are derived from.'

A definition of two agroecosystems and five sub-agroecosystems are provided for WA, based on climate, vegetation and landuse. The agricultural agroecosystem may be subdivided into two zones, the wheatbelt (Saunders and Curry, 1990) and the lower south-west (Jarvis, 1986). The pastoralism agroecosystem can be subdivided into three natural regions, the shrubland, north-west spinifex and Kimberley regions. The remainder of the State is arid with less than 250 mm of rainfall unreliably distributed throughout the year (Jarvis, 1986). Descriptions for the sub-agroecosystems are described by Australian Bureau of Statistics [ABS] (1990a and 1990b) in production types and economic terms. Because of common landuse the two major categories are mostly discussed here.

### 1.2.2 Agricultural Agroecosystem

The wheatbelt is a widely used description of the dryer part of the agricultural ecosystem which has 250-600 mm total annual rainfall, falling mostly in the winter months. It is not a well defined natural region and has highly variable soils, climate and vegetation (Gentilli, cited in Saunders and Curry, 1990). As the name suggests most of the State's wheat production is found in the wheatbelt along with a variety of other crops mixed with grazing (mostly sheep) (ABS, 1990b). The original vegetation comprised of a variety of eucalypt woodland types (mostly *Eucalyptus wandoo*, *E. loxophleba* and *E. salmonophloia*) and shrublands (mostly species of the Myrtaceae and Proteaceae families) (Beard, 1979b and 1986).

The lower south-west has higher annual rainfall, between 750 and 1300 mm, also falling mostly in 5 winter months (figure 1). The tall eucalypt forests of karri (*E. diversicolor*), jarrah (*E. marginata*) and tuart (*E. gonmphocephala*) grow here (Boland *et al.* 1984) and support the State's forest industry.



Figure 1. Agroecosystems of Western Australia (Jarvis 1986).

### 1.2.3 The Pastoral Agroecosystem

The Shrubland Region (Holm and Burnside, 1988) comprises the Gascoyne, Murchison, Goldfields and Nullarbor areas. It has an arid to semi-arid climate and lies below the latitude of 23° South and adjacent to the wheat belt along the 250 mm rainfall isohyet. The region experiences occasional lengthy droughts and there are many years when the rainfall is below the average rainfall of 150-250 mm. Summer rains are more common in the north with predominantly winter rains in the south. The region has rich and diverse vegetation types including tree dominated shrublands with perennial grasses and annual herbs (Holm and Burnside, 1988). The most common trees are acacias, particularly mulga (*Acacia aneura*), snakewood (*A. xiphophylla*) and myall (*A. papyrocarpa*). Saltbush shrubs (*Atriplex* spp.) and the introduced buffel (*Cenchrus ciliaris*) and birdwood grasses (*C. setiger*) are important pasture species (Holm and Burnside, 1988).

The NW spinifex region (the Pilbara) lies between the Kimberley region and latitude 23° South excluding arid desert areas (Figure 1) to the east of longitude 122° East where permanent grazing and water are unavailable (Holm and Burnside, 1988). The climate is arid tropical (Beard, 1990) with 7-8 dry winter months and unreliable annual average rainfall of 180-300 mm. Rainfall is normally associated with tropical cyclones in summer. The vegetation is mostly tree and shrub steppe communities characterized by *Eucalyptus* spp. (trees), *Acacia* spp. (shrubs) and *Triodia pungens* and *T. wiseana* (native grasses) (Beard, 1990).

The Kimberley Region lies north of the latitude 20° S and has an arid to semi-arid monsoonal climate (Petheram and Kok 1983) or semi-arid to dry hot tropical (Beard, 1990). The average rainfall ranges from over 1,200 mm near the north coast to less than 400 mm in the extreme south (Beard 1979). The main pastures are native tussock and hummock perennial grasses, with the most favourable pastures of extensive grassy plains adjacent to the major river valley of the Ord, Fitzroy and

Margaret Rivers [Holm *et al.* 1988]. Beef cattle grazing native pastures is the main land use activity in the pastoral regions of the Kimberleys.

### 1.3 Land Tenure in WA

#### 1.3.1 General Tenure

Farmers are responsible for more environment than any other single group with 30% of the earth's land area managed as agroecosystems (Elliott and Cole, 1989). This proportion is much higher in Australia (Barde, 1991) and WA (ABS 1990a p.176) where farmers and graziers manage 45% of land for cultivated agriculture and pastoralism (Table 1). The State of Western Australia is the largest in Australia and covers 252.76 million hectares (DOLA, 1990). Pastoral leases make up the largest tenure being 38.9% of the State with vacant crown land being 32.9% (Table 1). Freehold land is 7.2% with the remainder of the State comprising a variety of reserves and lease types. These reserves are also mostly remnant vegetation and are managed for a variety of purposes by a number of government departments (Table 1) and independent bodies. These purposes include forestry, nature conservation water supply, transport corridors and traditional aboriginal activities.

**Table 1. Major Land Tenure Types in Western Australia (in hectares) data from DOLA, 1990 and CALM, 1990**

Land Tenure Type		Area (hectares)	% State Area
Alienated Land	Pastoral Leases	98,263,924	38.9
	Freehold	18,164,441	7.2
	Other Leases*	7,654,108	3.0
Crown Land	State Forest <i>et al.</i>	2,071,314	0.8
	National Parks	4,854,571	1.9
	Nature Reserves**	10,425,883	4.1
	Other Reserves	27,683,688	11.0
Vacant		83,278,346	32.9
Total area of WA		25,2762,120	100.0

\* Leasehold for purposes other than pastoral.

\*\* Tenures other than Nature conservation.

#### 1.3.2 Pastoral and Agricultural Development

Until the turn of the century, land use in south-western WA was largely forestry and pastoralism, with intensive cultivation close to the major settlements of Perth and later Bunbury. Between the 1840s and 1900 most parts of the State were explored for suitable areas to develop and pastoralism quickly followed. By 1934 pastoral leases were well developed except within desert areas which are not suitable for pastoralism due to inadequate rainfall (Jarvis, 1986). Pastoralism in WA peaked in the late 1930s when extensive drought and rangeland destruction, due to overstocking, reduced the industry substantially (Holm and Burnside, 1988). Pastoral leases now cover 40% of the State or about 100 million ha, and extend from the tropical grasslands of the Kimberley to the arid shrub and steppe of the Nullarbor Plain (Hacker *et al.* 1990). Native vegetation in the pastoral agroecosystems now supports about 2.5 million sheep (8% of State total) and about 850,000 cattle (49% of State total) on leasehold land (WADA, 1989).

Expansion of stock grazing into the 'wheatbelt' was rapid during the late 1800s, but this was quickly replaced by clearing for cropping and improved pastures (Burvill, 1979). Some forest areas were cleared for intensive agriculture, e.g. for dairies and orchards (Jarvis, 1986). This expansion was aided by the development of a railway

network which allowed produce to be transported to ports for the growing export market (ABS, 1990a). Clearing is estimated to have been 0.05 million ha at 1890, 6.5 million ha at 1945 and 13 million ha at 1968 (Saunders, 1989).

## 2. Estimates of remnant vegetation

### 2.1 Quantitative Studies of Remnant Vegetation

#### 2.1.1 Agricultural Agroecosystem

Fourteen per cent of WA is cleared (Table 2), mostly in the agricultural agroecosystem, which supports 12.9 million hectares of crops and improved pastures (ABS 1990b, p 176). Beard and Sprenger (1984) have discussed the distribution of vegetation types for the South-west Botanical Province and have calculated that 65% has been cleared for agriculture and urban development. Woodlands are the most highly cleared (89%) of vegetation types (Smith, 1987) being favoured for agricultural development because of their suitable soils (Hobbs, 1987). Forty-four per cent of high rainfall forests in the lower south-west have been cleared (Beard and Sprenger, 1984) for intensive agriculture (Jarvis, 1986), while the remainder is largely managed for forestry by the Department of Conservation and Land Management (CALM, 1990).

**Table 2. Area of agriculture in WA ('000 hectares) with income \$20,000 and % of remnant vegetation NB areas of remnant vegetation calculated from data in ABS (1990) are underestimated because of the income thresh-hold**

ABS statistical division	Property area ('000 ha)	Uncleared ('000 ha)	% Uncleared	Cleared ('000 ha)	% Cleared
Perth	81.9	20.6	25.2	61.3	74.8
South-West	795.7	1,35.2	17.0	660.5	83.0
L. Gt. Southern	2,840.3	3,83.6	13.5	2,456.7	86.5
U. Gt. Southern	3,416.1	4,01.5	11.8	3,014.6	88.2
Midlands	7,113.1	1,385.2	19.5	5,728.6	80.5
Central	4,203.1	1,822.2	43.4	2,380.9	56.6
South-eastern	1,481.5	228.7	15.4	1,252.8	84.6
<i>Total Agricultural Agroecosystem</i>	19,932.4	4,377.0	22.0	15,555.4	78.0
Central-P	38,793.9	38,791.8	99.995	2.1	0.005
South Eastern-P	15,321.7	15,192.1	99.155	129.6	0.845
Pilbara	14,506.9	14,506.9	100.0	0.0	0.0
Kimberley	24,075.7	24,059.6	99.9	16.1	0.067
<i>Total Pastoral Agroecosystem</i>	92,698.2	92,550.4	99.841	147.8	0.159
Total properties	11,2630.7	96,927.4	86.06	15,703.	13.94

Shire data from the 1988/89 ABS agricultural land-use survey (ABS, 1990b) were used to assess remnant vegetation on farms in south-west WA. Data for cleared land on agricultural properties were subtracted from total area to estimate areas of remnant vegetation for 11 groups of shires (Figure 2). The total estimate of remnant vegetation on farms in the agricultural agroecosystem is 22% or 4.38 million ha (Table 2). This is only an estimate as the ABS clearing data does not include farm infrastructure and based on an income thresh-hold (ABS, 1990b p 174.). Coates (1987) found the 1984 ABS land clearing data to be an accurate estimate for three out of four wheathelt shires, compared to calculations made using a geographic information system (GIS).

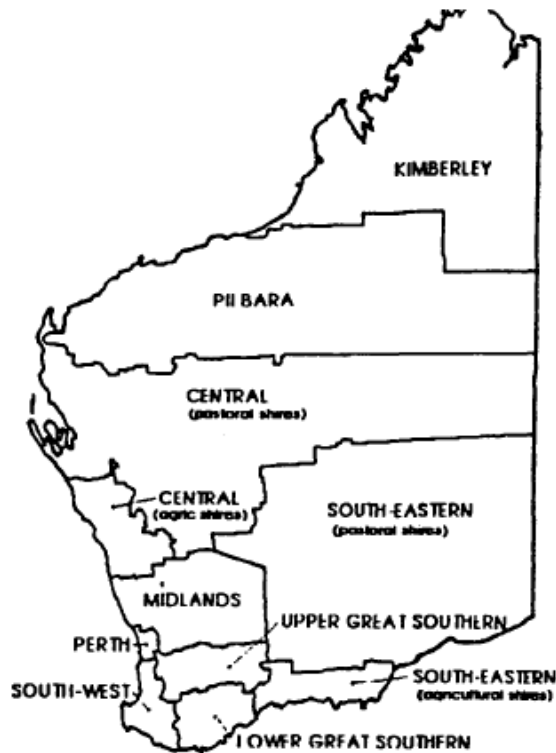


Figure 2. ABS Statistical divisions of Western Australia .

The lowest estimate of remnant vegetation of farms for the agricultural agroecosystem was 11.8% (0.4 million ha) for the Upper Great Southern (Table 2). This is a higher rainfall area of the wheatbelt and there is little vegetation left on farms that could be utilized for agriculture (L. Wardell-Johnson, pers. comm.). The highest areas of remnant vegetation were 1.82 million ha for the Central division and 1.39 million ha for the Midlands (Table 2). Remnant vegetation in the 3 least cleared shires (marginal rainfall areas) in each division was calculated from ABS data (ABS, 1990b p 174) to be 2.1 million ha or 48% of the agroecosystem.

No data are available to estimate remnant vegetation of other tenures in the rest of these divisions and it is therefore difficult to make an overall landscape assessment. Remnants on farms are often connected to other vegetation remnants on roadsides and reserves. Assessment of all remnant vegetation in a district or catchment is vital for future land conservation (Hobbs, 1991). Several studies have measured the area of private and public remnant vegetation in view of this (Beeston and Modowski, 1986; Coates, 1987 and Saunders and Curry, 1989).

An area of 146,000 ha in the wheatbelt in the Midlands division, Figure 2) has been surveyed and found to be 94.3% cleared of native vegetation for agriculture and related infrastructure. The remaining 5.7% vegetation is mostly on farms, highly fragmented (see map p. 3 in Arnold *et al.* 1987) and lower than the estimate of remnants on farms for the Midlands division (Table 2). Eight per cent of remnants are larger than 49 ha while 67% are smaller than 16 ha (Arnold, 1990). Most of the remnants are disturbed, have high edge to area ratios and require special management (Saunders and Ingram, 1987).

Two Department of Agriculture studies of remnant vegetation on private land have used geographic information system techniques to measure remnant vegetation from aerial survey photographs. Coates (1987) studied four wheatbelt shires and calculated total remnant vegetation of between 7 and 30.6% and on-farm vegetation



of between 5.3 and 11.8%. Numbers of remnants for these wheathelt shires < 4l ha ranged between 73.3 and 87.3% (Schofield *et al.* 1989). Beeston and Modowski (1987) studied four south-coast shires and measured total vegetation cover between 36.2 and 87.5% and remnant vegetation on farms between 2.8 and 6.0%. Numbers of remnants for these south-coast shires < 5l ha ranged between 66 and 83% (Schofield *et al.* 1989). Remnant vegetation on farms in both studies was found to be relatively low in shires with the longest histories of agricultural clearing.

Clearing of remnant vegetation in the agricultural agroecosystem has increased since 1985 when a notice of intent to clear (NOI) was first required by the Commissioner of Soil Conservation (Table 3). The peak of clearing in 1988/89 (Table 3) is best explained as part of the 1980s development boom and rumours in some areas of potential clearing bans (Russell, pers. comm., 1990). The trend is most evident in data for clearing on farms in the WADA's Albany Advisory District (Table 3). Details were provided by the Minister of Agriculture in answer to a Question on Notice in the WA Legislative Assembly in 1989 (cited in Schur, 1990). Remnant vegetation on farms in this district in June 1990 was reduced to 32,479 ha, 63% of the July 1985 estimate (Table 3). The total remnant vegetation on farms is estimated to be 3.9% of farmland at June 1990. This is a much lower figure than the average for all shires (13.6%) in the Lower Great Southern (Table 2).

**Table 3. Remnant vegetation on farms and notice of intent to clear for WA agricultural agroecosystem and the Albany district (WADA) between 1986 and 1990 data from ABS (1990), WADA (1990) and Schur (1990)**

NOI reporting years since inception	Remnant vegetation agricultural areas in ha		Remnant vegetation Albany Advisory District (WADA) in ha		
	NOI to clear (% total)	Estimated* on farms at years end	Approved** NOI to clear (% total remn. veg.)	Cumulative approved clearing	On farms at years end
85/86	14,828 (0.3)	4,393,299	1,727 (3.4)	1,727	51,500
86/87	27,202 (0.6)	4,390,683	1,616 (3.2)	3,343	49,885
87/88	33,943 (0.8)	4,385,500	5,183 (11.6)	8,526	44,700
88/89	101,306 (2.3)	4,377,000	8,500 (23.5)	17,026	36,200
89/90	59,211 (1.4)	4,373,279	3,721 (11.5)	20,747	32,479

\* Estimates calculated from total cleared on farms 1988/89.

\*\* Estimates of approved clearing based on NOI to clear data from WADA, 1986, 1987, 1988, 1989b and 1990 and clearing data from ABS, 1990 and reduced to 83% (1986-89 state average from Schur, 1990)

### 2.1.2 Pastoral Agroecosystem

Less than 1% of native vegetation on leases in the pastoral agroecosystem is reported as cleared (Table 2), but not all alienated pastoral lands are suitable for grazing. Rangeland surveys have shown that a significant area of pastoral leases is not suitable for stock grazing (e.g. Payne *et al.* 1988). These rangelands have been assessed as poor or very poor pasture value, are inaccessible or have no watering places for stock or all of these. A total of 0.18 million ha (18.6%) has been classified in this way out of a total area of 0.95 million ha of Surveys throughout the pastoral agroecosystem (Table 4) have classified 18.6% of rangelands in this manner. Estimates of poor/very poor rangelands in the agroecosystem vary between 12 and 25% for the arid rangelands. Estimates of pasture condition varied between 9 and 42% for poor or degraded and between 20 and 64% for good (Table 5).

**Table 4. Estimated Areas (ha) of Leased Rangelands Classes as Poor/Very Poor in the WA Pastoral Agroecosystem data from WADA (1989)**

Pastoral Agroecosystem Zones	Leased Rangelands in 000 ha	Area classed as poor/very poor in 000 ha (%)
Kimberley - non arid	4,395.8	43.9 (1.0)
Kimberley - arid	14,209.9	2,771.0 (19.5)
NW Spinifex and southern shrubland	52,063.6	111,41.6 (21.4)
Goldfields shrublands	18,077.0	2,169.2 (12.0)
Nullarbor shrublands	6,171.7	1,542.9 (25.0)
Total	94,918.0	17,668.6 (18.6)

**Table 5. Rangelands Surveys in the Pastoral Agroecosystem and Areas of Pasture Value and Condition data from Curry and Payne, 1988 Holm and Burnside, 1988**

Region/Reference		Total area	% Pasture Condition		
		million/ha	Good	Fair	Poor
Gascoyne	<i>Wilcox et al. 1972</i>	6.32	32	53	15
West Kimberley	<i>Payne et al. 1979</i>	8.96	20	50	30
Nullarbor	<i>Mitchell et al. 1974</i>	4.74	50	10	40
Ashburton	<i>Payne et al. 1982</i>	9.36	64	27	9
Carnarvon Basin	<i>Payne et al. 1987</i>	7.45	45	32	23
Murchison	<i>unpubl. data</i>	8.00	21	37	42
(cited in Holm and Burnside, 1988)					

\* Level of rangeland degradation.

The vegetation classified as poor/very poor is not degraded from stock grazing (Payne *et al.* 1987 and Payne *et al.* 1987) and represents a significant conservation resource. There are however significant conservation problems in these remote areas, such as grazing by feral animals (Burbidge, 1989) and predation of native animals by foxes and cats (Burbidge and Friend, 1990). However management strategies are being developed to deal with some of these problems in remote conservation areas (Burrows and Thompson, 1990).

## 2.2 Current Condition of Remnant Vegetation

### 2.2.1 Agricultural Agroecosystem

Accelerated land clearing in the WA wheatbelt over the past 50 years has caused landscape fragmentation (Hobbs, 1991) and left remnants of native vegetation of various shapes and sizes on farms and Crown land. The current condition of remnant vegetation in the agricultural areas is not known (WA Parliament, 1990b) and its viability poorly understood (Robertson). Clearing has resulted in habitat loss, species extinction's (Arnold, 1990) and loss of sizable proportions of vegetation types (Beard and Sprenger, 1984). Remnant vegetation (public and private) is prone to altered water regimes and the transfer of organic matter, pesticides and fertilizer from adjacent farmland (Hobbs, 1987). Remnants are also reported to be deteriorating from insect and fungal attack, stock grazing and salinity (Schur, 1989). Combinations of these factors disrupt the internal dynamics of plant and animal communities in remnant vegetation, causing ongoing decline (Hobbs, 1991). Intensive management of this remnant vegetation has been recommended to ensure its survival (WA Parliament, 1990b).

Some research is being conducted in the wheatbelt to assess the impacts of these factors. Many years of sheep grazing has removed most shrub species from woodland understorey and depleted the soil seed bank of useful regeneration

species (authors' unpublished data). Physical disturbance and added nutrients can increase numbers and biomass of annual bushland weeds (Hobbs and Atkins, 1988) and annual weeds can interfere with shrub establishment (Hobbs, 1988).

Two recent studies have assessed disturbance in remnant vegetation. In the CSIRO study of Remnant vegetation near Kellerberrin (See section 2.1.1) was assessed for disturbance (e.g. for discussion of disturbance types see Hobbs, 1987). Out of a total of 531 remnants only 60 were found to be relatively undisturbed (Saunders and Ingram, 1987) and this is attributed to the small sizes of remnants in the area.

The second study was carried out by the author (Pigott, 1990) to assess condition of farm remnants in the 1989 Remnant Vegetation Protection Scheme (see Wallace, 1991 for RVPS details). The application for funding form requires information about the type of vegetation and aspects of disturbance in the remnant. These assessments were checked in the field for 12% of the total applications (Table 6). The study revealed high levels of discrepancy between the real condition of the vegetation in the remnant and that declared in the nomination. A greater number of remnants were found to be more degraded than expected and many of these were less than 30 ha (P. Pigott, unpublished data). A higher proportion of remnants in good condition were found in the RVPS for 3 years (Table 6) than for the Kellerberrin area (see above) although the scheme was established to attract undegraded remnant vegetation for heritage protection.

**Table 6. Statistical details of applications for heritage agreements (fencing subsidies) to the Remnant Vegetation Protection Scheme, 1989-91**

Year	1989	1990	1991
Total number applicants *	336	220	208
Final no. heritage agreements *	110	187	NA**
Total area of bush *	7,855	7,478	6,500**
Funds used for grants *	\$290,000	\$441,000	\$450,000
Propn. undegraded remnants +	46%	76%	75%
Propn. degraded and saltland remnants †	25%	14%	15%
Propn. rejected remnants †, ††	29%	1%	1%

\* Data from C. Hawkins, pers. comm.

\*\* Contracts not finalised, area estimated from eligible 7200 ha with approx. \$450,000 avail.

† Author's unpubl. data.

†† Applications were rejected for not complying with the basic instructions outlined in guidelines accompanying the assessment form (see Wallace, 1991 details)

### 2.2.2 Pastoral Agroecosystem

Assessments of rangeland resources and condition have only been made in recent times jointly by the WADA and DOLA and the following discussion uses data and summaries from their technical reports (WADA, 1989). Rangeland surveys have now covered most of the pastoral agroecosystem (Table 5) and there is now an extensive network of monitoring sites.

Widespread degradation and erosion of the rangelands from overstocking were evident by 1940, exacerbated by bad droughts and feral animals (WADA, 1989). Pressure from pastoralists to examine the rangelands on a scientific basis resulted condition surveys in the late 1950s which have continued to the present throughout the pastoral agroecosystem. CSIRO commenced WA's first detailed and objective surveys of land resources of arid and tropical areas in 1957 in the Wiluna-

Meekatharra area (Mabbutt *et al.* 1963, Speck *et al.* 1964, Stewart *et al.* 1970). Since 1969 WADA and DOLA have jointly conducted a comprehensive program of surveys (Table 5).

Rangeland surveys of the remaining pastoral areas should be completed by the year 2000 (WADA, 1989).

Vegetation degradation in the pastoral regions occurred most rapidly in the early days of pastoral development. Mitchell *et al.* (1988) have reported 40% of pastoral lease on the Nullabor Plain in poor condition largely due to misuse, drought and rabbits in the period between 1955 and 1974. In the NW spinifex zone the misuse of fire and over stocking altered the pasture composition from a mixture of spinifex and perennial tussock grasses to poor quality spinifex pastures only (Payne *et al.* 1988). In the Kimberley lack of watering points away from the river led to intensive grazing along the productive but fragile river frontage alluvial soils (Williams, 1987). Rangelands of high and very high pastoral value have been recorded as highly eroded and degraded in the shrublands region (Payne *et al.* 1982; Payne *et al.* 1987). Favourable vegetation types, access and available watering points were found to be the reasons. The major factor affecting production losses in the pastoral areas is vegetation decline rather than removal. Management strategies are being implemented to promote pasture regeneration. Range Monitoring Sites, although only recently established, show a mixture of responses from improvement to static to some decline (WADA, 1989a).

### **3. Impacts of clearing and overgrazing remnant vegetation**

Clearing of native woody vegetation for agriculture is accepted as the primary cause of land degradation in the agricultural ecosystem of WA. Land degradation and related issues have been extensively discussed by the Western Australian Parliaments' Select Committee on Land Conservation in Agricultural Areas (WA Parliament, 1990a; 1990b). Dryland salinity, waterlogging, water erosion, wind erosion, water repellence, soil acidification, soil structure decline, subsoil compaction, decline of remnant native vegetation, management of the conservation estate, rehabilitation in the mining industry and degradation of waterways were prominent issues. Its recommendations have yet to be published.

Technical and quantitative aspects of land degradation issues in WA have been documented by the WA Department of Agriculture (1989). The area of productive agricultural land lost to the above land degradation classes is estimated to be 20.4 million ha or 4% of land cleared for agriculture. The total cost of land degradation in lost production, has been estimated at \$571 million (1988 data). Aspects of soil and water salinization and revegetation strategies are discussed elsewhere in this proceedings (Schofield *et al.* 1991).

Lost production due to land degradation the pastoral agroecosystem have also been estimated by the WA Department of Agriculture (1989). Based on 1988 market values (40% less in 1991, Coates pers. comm.), lost cattle production in the Kimberley zone is \$8.05 million per annum. Lost annual sheep and wool production from other zones of the pastoral agroecosystem is \$28.95 million (40% less in 1991).

### **4. Benefits of retention and protection of native vegetation**

#### **4.1 Background**

The value and management of remnant vegetation on Australian farms has been discussed by Breckwoldt (1983), Conacher (1984), Thomson (1986), Campbell *et al.* (1988) Robertson (1991) and Wallace and Hobbs (1991). The benefits of remnant

vegetation have also been discussed at a number of scientific conferences (Saunders *et al.* 1987; Saunders *et al.* 1991 and Bartle, 1991). The Select Committee into Land Conservation (WA Parliament, 1990a and 1991b) have investigated the role of remnant vegetation in the context of its review into land conservation in the WA agricultural ecosystem. Remnant vegetation is important for nature conservation (Saunders *et al.* 1987), soil conservation (WA Parliament, 1990b), various community benefits and can improve on-farm production (Bartle, 1991).

#### **4.2 Nature Conservation**

The setting aside of the nature conservation estate in WA is much more recent than most development for agriculture (Wallace and Moore, 1987). Consequently many endangered plant species are only found in farm remnants (Hopper *et al.* 1990 and Moran and Hopper, 1987). The reserve system is reportedly not adequate to fully represent the nature conservation estate (WA Parliament, 1990b) and no studies have been conducted to accurately assess the role of remnant vegetation on farms.

Kitchener *et al.* 1980a and Kitchener *et al.* 1982 have reported that fragmentation and isolation does not explain the distribution of lizards and birds in wheatbelt reserves. Reserve ecology, number of vegetation assemblages but not size, explained species richness in hazards (Kitchener *et al.* 1980a). Area of reserve and habitat variables were the most important factors relating to bird species richness (Kitchener *et al.* 1982).

Mammal extinction in the wheatbelt is thought to be related to the inability of certain species to cope with these landscape changes and man's introduced disturbance regimes (Kitchener *et al.* 1980b). Arnold (1990) has reported that clearing has affected the distribution of macropod species from the Kellerberrin area. Out of 11 macropod species known to occur at the time of European settlement, only 2 are common in the area, 4 are rare or very rare and 5 are locally extinct. Saunders and Ingram (1987) have reported that widespread agricultural clearing of mature salmon gum woodland has led to reduced breeding populations and localised extinctions of Carnaby's cockatoos (*Calyptorhynchus funereus latirostris*). Extinctions and reduced numbers of bird species have been recorded at the regional, district and remnant level (Saunders, 1989) and invasions of bird species from pastoral regions have also been recorded for the wheatbelt (Saunders and Curry, 1990). Lack of stand recruitment in salmon gum on farmland is common throughout its wide distribution in the wheatbelt (P. Pigott, unpublished data). Woodlands are also the most important type of habitat for lizards (Kitchener *et al.* 1980) and both resident and transient species of birds (Kitchener *et al.* 1982).

Wheatbelt wetlands have also been seriously affected by clearing of native vegetation. For example, it is estimated that increasing salinity levels at Lake Toolibin, an important wheatbelt freshwater wetland, will reduce by 50% the numbers of resident and breeding waterbirds species if the lake is not protected from further salinization (Halse, 1987).

#### **4.3 Economic and Social Benefits**

Hobbs and Wallace (1991) have discussed many on-farm economic benefits that can be derived from remnant vegetation. These include seed collection, wildflower picking, ornamental fruits, cutting of fenceposts and firewood. Production benefits reportedly include shade and shelter for livestock (Conacher, 1984), improved crop yields and nectar for and honey bees (Hobbs and Wallace, 1991). Despite widespread anecdotal evidence (e.g. improved lambing rates and improved pasture production), no research and economic analysis has been carried out with remnant

vegetation in WA (D. Bicknell, pers. comm.) as has been done for artificial shelterbelts (Bicknell, this proceedings).

Buchanan (1989) discusses the important social benefits of remnants. Some of these include the preservation of historical and natural heritage sites and as an education and research resource.

Recreation and scenic values also provide important destinations for local and overseas tourists (Bartle, 1991 and Buchannan, 1989).

## **5. Retention costs and alternate uses of remnant vegetation**

### **5.1 Foregone Production**

In WA agroecosystems lost production is normally associated with agricultural and rangeland degradation. Most areas of prime production have been developed to their potential and are not sustainable without continued and increased rehabilitation (Chapters 2 and 3).

Only in new agricultural areas, where farms have not been cleared to expectation, does uncleared remnant vegetation potentially represent lost production (A. Coates, pers. comm.). Farmers are keen to maximise their production by clearing to limits set by the WADA (Anon, 1990) rather than their own judgment. Maximum production is ultimately related to soil type, rainfall and sound farm management and differs throughout WA. No research has been carried out to examine this issue and the value of retaining vegetation. Land release for agriculture from vacant Crown land was placed under moratorium in 1981 because of concerns over the viability of these areas for cultivated agriculture.

In the pastoral agroecosystem much of the best rangelands has a high degree of degradation because of past mismanagement and drought (Sect. 2.2.2). Most land suitable for pastoral activities has been leased and improved production is most likely to come from rehabilitation of degraded rangelands and better management of pastoral areas by individual station managers and Land Conservation District Committee's (LCDC's).

### **5.2 Management Costs**

The clearing and development of new farmland is a relatively expensive investment, especially during recessions. New soil conservation guidelines (Anon, 1990) require the fencing of all newly cleared land and frequently small remnants of bushland are protected by a soil conservation notice (Ibid, Ch.7). Fencing-costs are currently between \$1520/km for electric fencing and \$2210/km for a cattle-proof fencing (C. Hawkins, pers. comm.). The cost of clearing land and firebreaks costs from \$100/hour and upwards depending upon the contractor and machinery. With depressed commodity prices alternate uses of remnant vegetation may be more attractive financially than traditional farm development (Section 4.1.3).

### **5.3 Management for Various Purposes**

The Commissioner for Soil Conservation has recently issued new guide-lines for land clearing after a period of extensive consultation with LCDC's and within the WADA. Clearing maximums are now viewed in context of the remnant vegetation left in the catchment rather than the farm.

Percentages of a catchment that may be cleared are based on the soil type and rainfall area (Anon, 1990), factors which also determine potential farm profitability. This is still an issue in newer farming in the south-east of the agricultural

agroecosystem where land was released in the early 1980s with a view to being cleared to 85%-90% to be profitable (A. Coates, pers. comm.). Parkland clearing or leaving large trees and clearing the understorey, is practiced as a compromise where full clearing would not be allowed (M. Page, pers. comm.). This occurs only in higher rainfall areas where land will be developed for improved pasture only. This strategy is clearly a short-term solution as the trees will eventually die from exposure to stock, chemicals, root ripping and increased insect attack. No research has been done to assess this practice as a form of agroforestry.

There is little research into the value of timber products from forestry on farms, particularly in areas less than 600 mm of annual rainfall. This is regarded as an important small-scale industry for farmers in the future (K. Wallace, submission to WA Parliament, 1990b). A recent wood-chipping project based on farm resources in the lower south-west was not endorsed by the EPA because it was found to be unsustainable (Anon, 1987). Tree crops of Tasmanian bluegum (*Eucalyptus globulus*) are being established to satisfy future land conservation and forest product demands (WA Parliament, 1990).

## **6. Retention and protection of remnant vegetation**

### **6.1 Agricultural Agroecosystem**

There is no specific legislation in WA that protects native remnant vegetation on private land for nature conservation purposes. There are however a number of other pieces of legislation that indirectly confer some protection. Remnants may be protected to prevent land and water degradation on surrounding farmland under the Soil and Land and Conservation Act (1991).

The Act imposes regulations on landowners wishing to clear their native vegetation for any development purpose. This is usually agriculture but may also be an urban/semi-rural subdivision. The landowner must give the WADA (for the Commissioner of Soil Conservation) a notice of intent to clear (NOI) native vegetation. The purpose of this is to allow the assessment of land capability and to ensure that clearing and future use cause minimum land degradation (Hartley, 1990). Guide-lines for assessment of the NOI include land capability, landscape and soil characteristics and potential degradation hazards (e.g. salinity). The area of cleared land in the catchment of the NOI must be no greater than 50-80% depending upon the rainfall zone (Robertson, 1990). Acceptance of an NOI may include management conditions such as retention of some remnant vegetation and fencing newly cleared land. The Commissioner may place under a Soil Conservation Notice (SCN) the land under NOI, to prevent clearing if the landowner does not agree with the assessment (Hartley, 1990). Voluntary protection agreements can be reached with the WADA under Section 16 of the Soil and Land Conservation Act (1991).

The Wildlife Conservation Act(1952) and subsequent amendments protects all wildlife in WA. However only gazetted endangered species are protected on private land. This act is administered by CALM, which maintains endangered plant and animal species records for all land tenures. The landowner is prevented by law of carrying out any activity that threatens a gazetted species. At present this does not protect remnant vegetation surrounding endangered plants or bushland habitat for rare fauna. However, the WA Minister for Environment has recently indicated that the legislation will be changed to protect habitats of rare species (Amalfi, 1991).

Remnant vegetation in high rainfall catchment areas are protected from clearing by the Country Water Supply Act where stream salinisation in a public water supply area would result from such activities. A total of 270,000 ha of remnant vegetation has been protected in 5 lower south-west shires to date (Schofield *et al.* 1989). The

use of the Environmental Protection Act (EPA, 1987) is limited to cases where degradation of agricultural land is deemed to have been caused by an agricultural activity (WADA, 1989).

The RVPS was made available to farmers in the agroecosystem between 1989-1991 (Wallace, 1991). It was successful in establishing heritage agreements for about 22,000 ha of remnant vegetation with the provision of up to \$1.2 million of fencing subsidies (Table 6). This amounts to protection of 0.5% of bushland on farms in the agricultural areas of WA at June 1990. Remnants protected under the RVPS in 1989 and 1990 were equivalent to 7.8% and 12.6% of remnant vegetation cleared on farms respectively (calculated from Tables 4 and 7). The scheme has promoted the protection of remnant vegetation amongst farmers in the agroecosystem, and many who have not entered into agreements have fenced or planned to fence their own remnants (unpublished data).

## 6.2 Pastoral Agroecosystem

Pastoral areas of the State are leased from the crown and are administered by the Minister for Lands through the Pastoral Board. WADA staff prepare presale range condition reports for the Board which may recommend that the Minister for Lands place conditions on lease transfer. This would require the lessee to take action to rehabilitate and manage any significant land degradation. The Commissioner of Soil Conservation can also act where land degradation results from pastoral malpractices (WADA, 1989).

Rangeland surveys (Ibid 2.2.2) provide a comprehensive description of the pastoral resource in terms of land form, vegetation and soils and assess the pastoral potential of the various land systems and pasture communities as well as the effect of grazing. Information on the productive potential of each area and the management problems inherent for each class of land are being used to help station managers and LCD's rehabilitate degraded areas. The WA Rangeland Monitoring System (WARMS) has been developed to measure seasonal changes in plant communities as well as those caused by grazing throughout the Shrubland pastoral Region. An extensive network of 2400 monitoring sites have been set up to collect photographic and quantitative data from repeated observations and provide pastoralists with objective information on change to their pastures. This is already allowing pastoralists and LCDC's to make better management decisions and rehabilitation plans (Holm and Burnside, 1988).

Many regeneration programs are planned through Soil Conservation Districts now operating in most pastoral areas. These districts promote active land involvement in solving the problems of range degradation and provide an avenue through which State and Commonwealth financial assistance can be channeled (WADA, 1989 and Holms 1988). Regeneration work has been carried out on the Fitzroy River frontages in a combined project between local pastoralists and the WADA. The area has responded to destocking and cultivation (Williams, 1987).

There is increasing awareness about the need for conservation management so as to reverse historical downward trends in vegetation decline (WADA, 1989). Curry and Hacker (1990) also conclude that if conducted at appropriately low intensity with proper grazing management pastoral use need not 'violate key conservation objectives and continue to be economically viable.' Recently a voluntary reserve agreement was reached, setting a positive conservation precedent for the pastoral industry. A section of Boolardy Station near Yalgoo, that has been excised from the lease for reference and scientific purposes (Halleen *et al.* 1990). Management will be by CALM with the assistance of the Boolardy Station principals and the Murchison LCDC.



## **7. Barriers to landholder conservation practices**

At the present time (April, 1991) the economic downturn and collapse of rural commodity pricing has meant that many farmers have little money for environmental projects. Reduced orders (down 30%) for tree seedlings at the CALM Nursery at Narrogin in 1991 reflect this, although this may improve with ad hoc tree planting activities later in the year (S. Gorton, pers. comm.). Fencing remnant vegetation, a newer farm conservation strategy, is less likely to be carried out than tree planting because of its perceived lower priority and cost (unpublished data). Landsberg (1991) has reported that farmers give a higher priority to survival (farm viability) than to maintaining farm assets (sustainability).

A number of problems have been highlighted by WADA (1989a) as constraints to overcoming land and water degradation. These include lack of suitable/alternative farming systems, lack of cost/benefit analyses on preventative measures, lack of technical support for catchment planning, poor understanding of benefits of known preventative measures by landowners, lack of incentives to retain and replant vegetation and poor economic circumstances reducing remnant vegetation protection.

Effort is now being put into resolving many of these difficulties with National Soil Conservation Programs (NSCP) and increased WADA landcare effort through the Land Conservation District Committee's (WA Parliament, 1990b). A network of project officers for the wheatbelt have been funded by the NSCP to help farmers form catchment management groups and to provide advice for long-term catchment planning and rehabilitation. This strategy appears to be effective in the initial stages of the project (I. Wardell-Johnson, pers. comm.).

A continuation of the RVPS would be beneficial in continuing to promote the conservation of remnant vegetation on farms as part of a successful fencing grant scheme. Such a scheme may be more effective in depressed times as more consideration is given to government advice and financial assistance. To further assist active management of remnant vegetation CALM Wheatbelt Region has secured Federal *Save the Bush* funding for the preparation and publication of a remnant management manual for farmers.

## **8. Future requirements of remnant vegetation protection**

### **8.1 Legislative changes**

The Land and Soil Conservation Act has recently been amended and new guidelines produced. The Land Act is now under review and changes are proposed relevant to native vegetation on leased pastoral areas. These include liaison between the Commissioner of Soil Conservation and the Pastoral Board in relation to SCN, provision for pastoralists to develop areas of the lease for crop, fodder or horticultural production, increase the Pastoral Board membership from 5 to 7 members including a Government official with appropriate conservation qualifications, regulations to ensure that pastoral leases are well managed so that renewable resources are sustained and the exclusion of areas from the leases for conservation purposes.

### **8.2 Government assistance**

Thomson (1986) has proposed public sector intervention and fiscal incentives to halt land degradation and protect remaining bushland. The Community Landcare Program currently being run by the WA Department of Agriculture fits the former objective. Income tax concessions and deductions are discussed in detail (Thompson, 1987) and more recently by Campbell (1990).

### **8.3 Research needs**

The Select Committee into Land Conservation (WA Parliament, 1990b) reports that research and development is required to maintain and regenerate remnant native vegetation in the agricultural region of WA. The following general areas of research are discussed in greater detail in the report.

- Impacts of agricultural chemicals and bi-products.
- Control of pests and diseases inc. native species.
- Impacts of timber cutting, mining and other income generating activities.
- Effectiveness of various management techniques inc. fire.
- Identification of poorly conserved and rare bushland communities.
- Strategies for conservation on farms at catchment/landscape level.

Some research in these areas is being conducted by CSIRO, the WA Department of Conservation and Land Management, WA Department of Agriculture, WA Water Authority and Main Roads Department in the. Given the limited resources of the research branches of these bodies it is therefore essential that planning and cooperation within and between them be further improved. From this cooperation better research and extension will assist in halting the rapid decline of remnant vegetation and better management in the future.

## **9. Conclusion**

### **9.1 Agricultural agroecosystem**

Remnant vegetation on farms is estimated to about 20% of the agricultural agroecosystem.

However, for many shires the estimate is as low as about 4%. Studies show that total remnant vegetation (all tenures) in many wheatbelt shires is between 5 and 10% of total shire area, is very fragmented and that many remnants are in a degraded condition. Evidence suggests that these shires are overcleared and that widespread land degradation has occurred. The small sizes and declining condition of many remnants of native vegetation, and increasing land degradation in the agroecosystem, indicate that agriculture is not sustainable in its current form. Significant lost production of \$571 million/year has already resulted and the predicted increase in soil degradation will escalate these losses. Continued clearing of native vegetation will result in further land degradation and short-term gains will eventually cost the community in lost production elsewhere and for rehabilitation.

Ecological studies show that much of the remnant vegetation is degraded through exposure to agricultural practices, although some, particularly larger remnants, remain undisturbed. Remnants of native vegetation provide many benefits for the landholder and the local community, including on-farm income from forest products, perceived production improvements and the conservation of wildlife and the landscape. However without active management remnant vegetation will continue to degrade and the value of these benefits will diminish.

Changes to present farming practices and alternative systems are required to ensure that agriculture maintains its importance to the economy. The process of change has already commenced with landcare programs, catchment planning and fencing subsidies for remnants. Farmers place a greater priority on financial survival than maintenance of farm assets (e.g. remnant vegetation). More needs to be done to achieve sustainability in the agricultural agroecosystem.

## 9.2 Pastoral agroecosystem

In the pastoral agroecosystem, remnant vegetation has been utilised as rangelands (about 92.7 million ha) for domestic stock and only minimal clearing (0.16%) has taken place. However past mis-management has resulted in degradation of 18% of rangelands, mostly the best types. Up to 22% of rangelands in some survey areas not good rangelands although these areas may be of value to nature conservation. Most remnant vegetation in the agroecosystem is threatened by overgrazing from feral animals and better management of this is necessary.

Total land degradation is estimated to have cost \$37 million/year in lost production in the agroecosystem, although this is an overestimate in the current (1991) recession. A rangeland monitoring system has shown that de-stocking and reduced grazing pressure has allowed regeneration of much rangeland in the shrublands zone. Landcare groups are also improving land management practices.

Sound ecological management of remnant vegetation (i.e. rangelands) in this agroecosystem is essential for the survival of the pastoral industry. Although the native vegetation is extensively modified, the industry is potentially sustainable with monitoring vegetation changes, improved manipulation of stock and the rehabilitation of degraded areas.

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# Producing Timber From Trees - Options for Farmers in Western Australia

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## **Aim**

The review is to present the latest technical and economic information about producing timber from trees on farms in south-western Australia. The information is to be presented in the context of options for farmers. Thus the review:

1. states the range of timber products which can be produced by farmers
2. assesses the demand for these products
3. lists methods of integrating trees for timber with farming and
4. presents costs and returns of growing the various timber products on farms

## **1. Introduction**

The integration of trees within normal farming practice is seen as a vital element in caring for the land, particularly in the control of soil erosion, nutrient loss and salinity, and the protection of livestock, crops and pastures. Trees also provide a means to diversify farm income where there is a market for the timber products, thus providing a dual benefit from tree planting.

Methods of integrating trees and farming are being developed. They include plantations or woodlots, timberbelts, windbreaks and wide-spaced stands. In most cases trees are one of several strategies used together to combat land degradation. For example, drainage, perennial pastures and trees can be combined to treat waterlogged and saline areas. Timber production is usually secondary to other values.

This paper presents the latest technical and economic information about producing timber from trees planted on farmland. It covers the agricultural land of the South West region of Western Australia (Fig. 1.). The rest of the State has been ignored because there is no planting of trees for timber. The South West region has two climatic zones; wet temperate (> 600 mm/yr rainfall) and dry temperate (300 to 600 mm/yr rainfall).

The timber products discussed in this paper are firewood, chipwood (for particle board), pulpwood (for paper), posts and rails, sawlogs and poles.

## **2. Suitable species and regions**

### **2.1 Suitable species**

Trial plantings of a wide range of species have been established on farmland during the past two decades.

They indicate the species which grow well. Table 1 lists some of species suitable for each timber product.

**Table 1. Suitable species for various timber products**

Product	Suitable Species	Comments
<b>Firewood</b> <i>E. cladocalyx</i> <i>E. camaldulensis</i> <i>E. astringens</i> <i>Cas. obesa</i>	<b>Examples include:</b> (FRI, 1989)	- many species OK
<b>Chipwood</b> <i>P. pinaster</i> <i>P. taeda</i>	<i>Pinus radiata</i>	- mainly <i>P. radiata</i>
<b>Pulpwood</b>	<i>E. globulus</i> evaluated include: <i>E. botryoides</i> <i>E. viminalis</i> <i>E. grandis</i> <i>E. saligna</i>	- others being
<b>Posts and rails</b> <i>E. astringens</i> <i>E. wandoo</i> <i>A. acwininata</i>	<i>P. radiata</i> <i>E. cladocalyx</i> (Cremer, 1990)	- many suitable species
<b>Sawlogs (hardwood)</b> <i>E. globulus</i> <i>E. maculata</i> <i>E. muellerana</i> <i>E. microcorys</i> <i>E. grandis</i>	<i>E. diversicolor</i> <i>E. saligna</i> zone (> 600 mm/yr)	- these species are for wet temperate
<b>Sawlogs (softwood)</b> <i>P. taeda</i>	<i>P. radiata</i> <i>P. pinaster</i>	- species for wet temperate zone
<b>Poles</b> <i>E. diversicolor</i> <i>P. radiata</i> <i>P. pinaster</i>	<i>E. muellerana</i>	- used by SECWA

## 2.2 Area already established

Table 2 shows the approximate area of trees, for each timber product, already established on farmland in WA.

**Table 2. Approximate area (ha) already planted for the various timber products**

<b>Product</b>	<b>Approx. area already planted on farmland (ha)</b>	<b>Comments</b>
<b>Firewood</b>	Unknown	- most plantings of trees on farmland can produce firewood if required
<b>Chipwood</b>	500 ha (?)	- includes only plantings by farmers (not by industry or city-based investors) and only those <16yrs old
<b>Pulpwood</b>	9500 ha	- includes only plantings in which farmers are involved, either on their own or as joint venturers. Does not include plantings on land owned by pulpwood companies.
<b>Posts and rails</b>	Unknown	- many species can produce rails posts and rails. Most need preserving
<b>Sawlogs (hardwood)</b>	400 ha (?)	- limited information on area planted
<b>Sawlogs</b>	750 ha (?)	- greater area than for (softwood) chipwood because includes plantings > 16 years old
<b>Poles</b>	Unknown	- likely to be small area

### 2.3 Regions with potential

Table 3 presents general information about the rainfall limits for producing the various timber products.

Figure 1 shows rainfall isohyets. Sites must also have suitable soils. Whether a market exists has not been considered.

**Table 3. Regions with potential to produce timber**

<b>Product</b>	<b>Region with potential to produce timber</b>	<b>Comments</b>
<b>Firewood</b>	- entire agricultural region	- mostly for on-farm use
<b>Chipwood</b>	- min. rainfall 500 to 700 mm/yr depending on location	- within 100 km of particle board plant
<b>Pulpwood</b>	- min. rainfall 500 to 650 mm/yr depending on location	- within 120 km of processing plant
<b>Posts and rails region</b>	- entire agricultural region	- mainly for on-farm use- <i>E. astringens</i> (mallet) is a proven species in drier regions for posts and tool handles
<b>Sawlogs-hardwood</b>	- mm. Rainfall 450 to 700 mm/yr depending soil type and stand density	- specialty timber is a possibility in drier regions although a market not identified
<b>Sawlogs-softwood</b>	- mm. Rainfall 450 to 700 mm/yr depending on location and stand density	- soil type, species and stand density important (CALM, 1987a)
<b>Poles</b>	- mm. Rainfall approx. 700 mm/yr	

The value for farmers in producing sandalwood and specialty timbers needs to be determined. Sandalwood in particular appears to have potential. Although growth rates are slow there is an established industry and \$3000 per tonne is paid.

### **3. Management**

#### **3.1 Ways of laying out trees on farmland**

The layout of trees on farmland is flexible. This means that trees can be arranged in ways that fit with the overall requirements of the farm, i.e.. as part of a whole-farm plan or even a whole-catchment plan. The main ways of laying out trees are in plantations, timberbelts, windbreaks and wide-spaced stands.

##### *3.1.1. Plantations*

Trees can be planted in plantations or woodlots on selected parts of the farm. Suitable sites include for example areas which are out of the way and inconvenient to graze or crop and areas on lower slopes to combat salinity.

##### *3.1.2. Timberbelts*

Timberbelts are essentially plantations except they are long and thin [commonly 5 to 10 rows wide]. From a farming point of view their main advantage is that they can be

arranged in ways that are appropriate to the needs of the farmer. For example, belts of Bluegums can be established around paddock boundaries to provide shelter as well as a return from pulpwood.

### 3.1.3. *Windbreaks*

Windbreaks differ from timberbelts in that they are only 2 or 3 rows wide. If the purpose of the windbreak is to produce high quality sawlogs, the trees need to be pruned or trimmed. This is because most of the trees in a windbreak are 'edge trees' and will develop large branches if left untended. Large branches reduce timber quality. Bushy species are often needed to provide low shelter.

Increases in crop yields of more than 20% overall have been measured in windbreak studies in the Esperance region (see paper by D. Bicknell in these proceedings).

### 3.1.4. *Wide-spaced stands*

Trees can be widely-spaced so that pasture and crops will grow under them. The arrangement is flexible and can range from a parkland style with trees in single rows to strips of several rows separated by wide pastured bays (Moore, 1990). The latter arrangement makes it easier for the farmer to carry out agricultural activities such as cropping. The density of trees is also flexible and can be set to provide the desired balance between tree and pasture production.

Anderson *et al.* (1988) reported an average carrying capacity with sheep of 42% under 100 pine trees/ha over a 30 year rotation compared with that in open pasture.

## 3.2 **Managing trees for timber**

The way a particular stand needs to be managed depends on the timber product to be produced and the capacity of the site to grow trees, i.e. rainfall, and type and depth of soil. Thinning is necessary in dense stands to make space for crop trees to grow. In regions of low rainfall or where the depth of soil is shallow there is a risk of death from drought if stands are too dense.

Thinnings can be either left to lie on the ground or used for firewood, chipwood, pulpwood, or posts and rails. These products can be used either on or off the farm.

Close spacing of trees restricts growth of branches and therefore pruning is usually unnecessary. However in open stands branches become large and reduce timber quality. Therefore trees require a higher level of tending, especially pruning (CALM, 1987(b)), to achieve the required quality. Open stands concentrate on producing fast grown, high quality timber.

Trees grown for timber in narrow windbreaks need to be managed as open grown trees. Pruning and trimming techniques have been developed to maintain shelter and to produce timber from pine windbreaks (Moore, 1986).

Although growing trees at wide-spacing requires more work, there are some significant benefits. Farmers can continue to obtain an income from the land by grazing or cropping amongst the trees. Greater overall productivity is another important benefit of tree/pasture combinations. Anderson *et al.* (1988) reported 30% greater productivity with the combination of pines and grazing compared with grazing alone in a 700 mm/yr rainfall zone. Wide-spaced trees are also effective at lowering water-tables on a local basis which makes it an important strategy for helping to combat salinity (Schofield *et al.* 1989).

Spacing trees out also makes it possible to grow sawlogs in areas too dry for plantations, i.e. in regions with < 700 mm/yr rainfall (Moore, 1990). In this zone land

degradation is often severe and tree planting is most urgently needed to control soil erosion by wind and to combat salinity and waterlogging.

The potential to produce sawlogs at wide-spacing declines with rainfall. About 450 mm/yr is considered the lower limit for commercial production of sawlogs at wide-spacing (CALM 1987a). There has been no experience with producing timber from wide-spaced trees in zones with < 450 mm/yr. It is likely that most timber produced in this way would be used on the farm.

Table 4 describes tree management required for each timber product.

**Table 4. Tree management required for timber products**

<b>Product</b>	<b>Tree Management Required</b>
<b>Firewood</b>	<ul style="list-style-type: none"> <li>- subsequent crops from coppice growth</li> <li>- no tending required</li> <li>- firewood can be a by product of thinning</li> </ul>
<b>Chipwood</b>	<ul style="list-style-type: none"> <li>- no tending required</li> <li>- normally produced at 8 to 14 years by thinning from about 1200 trees/ha down to about 450 trees/ha</li> </ul>
<b>Pulpwood</b>	<ul style="list-style-type: none"> <li>- density at planting ranges from 1660 to 830 trees/ha depending on rainfall and soils</li> <li>- no tending required apart from applying fertilizer, especially on sands</li> <li>- clearfelled at 8 to 12 years</li> <li>- second crop from coppice</li> </ul>
<b>Post and rails</b>	<ul style="list-style-type: none"> <li>- branch size needs to be controlled, especially with Pinus species. This can be achieved either by growing trees in dense stands (1500+ trees/ha) or by pruning</li> <li>- posts and rails can be produced as a by-product of thinning</li> </ul>
<b>Sawlogs - hardwood</b>	<ul style="list-style-type: none"> <li>- planting density can range from 400 trees/ha for open stands with pasture to 1600 trees/ha for plantations or woodlots</li> <li>- thinning to a crop of 100 to 400 trees/ha depending on site quality and aims</li> <li>- pruning necessary where tree growth is fast (e.g. in open stands, in windbreaks and on fertile soils)</li> </ul>
<b>Sawlogs-softwood</b>	<ul style="list-style-type: none"> <li>- planting density can range from 400 trees/ha) for open stands with pasture to 1600 trees/ha for plantations or woodlots</li> <li>- thinning to crop of 100 to 500 trees/ha depending on site quality and aims</li> <li>- pruning necessary where tree growth is fast</li> </ul>
<b>Poles</b>	<ul style="list-style-type: none"> <li>- planting density of 1000 to 1600 trees/ha</li> <li>- thinning to about 300 to 600 trees/ha</li> </ul>

#### 4. Costs and returns

In determining the cost of producing timber on farms, it is important to identify the primary reason for planting trees. In many cases this may not be for timber production but rather for such objectives as controlling wind erosion or combating salinity. The cost of producing timber from trees planted for these other purposes may then consist solely of managing, harvesting and distributing. Therefore

producing timber can be very profitable because establishment costs are carried by the other intended uses.

The cost of establishing trees using seedlings can range from \$500 to \$1100 per ha depending on factors such as type of land, amount of site preparation required and planting method and density. The cost of fencing is an additional cost which can be substantial. For instance, a timber-belt of 10 rows could cost more than \$350/ha of tree area to fence on both sides.

The cost of managing trees varies greatly depending on the product; producing pulpwood, for instance, requires little management whereas to produce sawlogs a considerable amount of thinning and pruning may need to be carried out. Farmers can often cover most of the establishment and management costs themselves by supplying their own labour and machinery at times when these are underused.

The cost of harvesting varies little between species and products. It makes little difference to a logging contractor whether the logs being harvested are hardwood or softwood, sawlog or chipwood. Variations in harvesting costs usually reflect available volumes per hectare, average size of each log, and amount of preparation logs require to make them acceptable to the buyer. The cost of harvesting, that is felling, extracting and loading on a truck, can range from \$10 to \$15 per m<sup>3</sup>. Log transportation costs an additional \$1 to \$1.50 per m<sup>3</sup> per 10 km. Stumpage is the price paid to the grower for the standing tree. It is calculated on the basis that the buyer pays the cost of harvesting and transporting.

Net Present Value (NPV) is the value of timber sold less the cost of producing it, expressed in present day terms to allow for the fact that a dollar in the future is worth less than a dollar now. NPVs have been calculated for projects based on each of the above timber products. It has been assumed that 30 years is the length of projects and that the cost of fencing can be ignored. There is insufficient space to go into more detail in this paper.

It is acknowledged that whilst NPVs are central to evaluating the suitability of investments there are other factors, such as environmental benefits and pattern of cash flow, which people need to consider.

#### **4.1 Firewood**

The yield of firewood can range from 2 to 15 tonnes/ha/annum over 10 years and prices paid for dry firewood delivered to Perth range from \$60 to \$100 gross per tonne (Edgecombe, pers. comm.).

Net Present Values for firewood have been calculated (Table 5) assuming a yield of 70 tonnes per ha after 10 years, harvesting costs from \$10 to \$15/m<sup>3</sup> and the transport costs from \$1 to \$1.50/tonne/10 km. The distance to market was assumed to be 100 km.

The calculations of NPV were made for a 30 year period - three 10 year cycles. Coppice, that is growth from the stumps of harvested trees, was used to produce the second and third crops. Therefore it was assumed that there would be no additional establishment costs. Coppicing the trees would also ensure that environmental benefits are maintained. Remember, it is assumed that initial tree establishment costs are offset by benefits other than timber values.

**Table 5. Range in Net Present Values for firewood over a 30 year period (3 rotations of 10 years).**

Discount Rate	Net Present		Values (\$/ha)
5%	\$1,638	to	\$2,897
7%	\$894	to	\$1,941
9%	\$394	to	\$1,295

The variation in Net Present Values is due to the range in harvesting and transport costs and especially to the range in prices paid.

A study near Esperance (600 mm/yr) assessed the amount of firewood in a 25 year old two row *E. cladocalyx* windbreak (Bicknell 1990, pers. comm.). Firewood was measured at more than 1.0 tonne per tree. At a nett value of \$10 per tonne on the farm, this is \$2000 per kilometer for a single row only. The second row would be left to maintain shelter until the first row had regrown. The second row could then be harvested.

#### 4.2 Chipwood (logs for making particle board)

There is some potential for farmers with pine plantations within 100 km of the particle board plant near Bunbury to sell thinnings at about 12 years of age for chipwood. The volume of chipwood obtained by such a thinning ranges from 40 m<sup>3</sup>/ha to 80 m<sup>3</sup>/ha. The current stumpage is \$8.39/m<sup>3</sup>. Assuming none of the costs of establishing and managing the plantation are assigned to the cost of producing chipwood, the Net Present Value of chipwood at 12 years for a discount rate of 7% ranges from \$148 to \$297/ha.

#### 4.3 Pulpwood

The cost to a farmer to establish Bluegums can range from \$500 to \$1,100 per hectare (Bartle, 1991). Under sharefarming schemes there are additional costs such as site evaluation and legal fees. The volume of pulpwood ranges from 150 m<sup>3</sup>/ha to 350 m<sup>3</sup>/ha after 10 years depending on the site.

Annuities paid by the Department of Conservation and Land Management (CALM) under its Hardwood Plantation Sharefarming Scheme range from \$70 to \$220 per hectare plus a percentage of the final clearfell revenue ranging from 4% to 10%. These annuities are for a 20 year contract and are based on a stumpage of \$25/m<sup>3</sup>.

The Timberbelt Sharefarming Scheme, an alternative scheme to encourage plantings of Bluegum for pulpwood, has a 10 year contract. Under this Scheme the landowner and CALM share returns at harvest, based on their respective inputs (Bartle, 1991). Net Present Values for farmers have been estimated to range from \$902 to \$3277 per hectare for a discount rate of 7% and based on a stumpage of \$20/m<sup>3</sup>. (A lower stumpage is used because haulage distances are generally greater than for the Plantation Sharefarming Scheme.) The calculations of NPV assumed a 30 year project with harvesting of 3 crops. The second and third crops would be grown from coppice. The range in NPVs for three discount rates are presented in Table 6.



**Table 6 Range in Net Present Values for farmers producing Bluegum pulpwood under a CALM Sharefarming Scheme**

Discount Rate	Net Present		Values (\$/ha)
5%	\$1520	to	\$4972
7%	\$902	to	\$3277
9%	\$514	to	\$2184

This variation in NPVs is due to the wide range in yields of pulpwood on different sites in the > 600 mm/yr rainfall zone.

\* The 1991 Bunnings prospectus uses a stumpage of \$21.50/m<sup>3</sup>.

#### 4.4 Posts and rails

The yield of posts from thinning a pine plantation at about 11 years can range from 10 to 40 m<sup>3</sup>/ha. The stumpage for pine posts ranges from \$16.35/m<sup>3</sup> (posts <1.8 m) to \$23.75/m<sup>3</sup> (posts > 1.8 m). Assuming none of the costs of establishing and managing the plantation are assigned to the cost of producing posts and rails the Net Present Value, at 11 years and for a discount rate of 7%, ranges from \$76 to \$380/ha.

An alternative approach would be to grow the plantation for posts and rails only. Net Present Values have been calculated for a plantation planted with 1666 trees/ha and clearfelled at 11 years. The yield of posts was assumed to range from 109 to 150 m<sup>3</sup>/ha. Establishment and management costs were included. Table 7 presents the range in Net Present Values calculated for a 33 year period (3 rotations of 11 years).

**Table 7 Range in Net Present Values for a pine plantation clearfelled for posts and rails on an 11 year cycle**

Discount Rate	Net Present		Values (\$/ha)
5%	\$462	to	\$2039
7%	\$125	to	1325
9%	\$94	to	\$849

The 25 year old *E. cladocalyx* windbreak near Esperance mentioned earlier produced strainer posts in addition to firewood. More than one per tree was obtained on average. With on-farm treatment (cold creosote) the farmer estimated they were worth at least \$10 net per post - that is \$2000 per km for one row of trees.

#### 4.5 Sawlogs (hardwood)

Information about the costs and especially the returns for hardwood sawlogs on farmland is limited. There are many plantings by farmers but most are small in area, and trees have not yet reached a millable size. The stumpage for young hardwood sawlogs ranges from \$14/m<sup>3</sup> to \$34/m<sup>3</sup> depending on size and grade of logs (CALM, 1991a).

There is yield data for 10 year old *E. globulus* and *E. saligna* grown at wide-spacing (150 trees/ha) on pasture. By 15 years of age the average log volume per tree is

estimated to be 0.87 m<sup>3</sup> for *E. globulus* and 0.57 m<sup>3</sup> for *E. saligna*. Logs of this size are large enough to be milled using the VALWOOD process for young sawlogs (CALM, 1989).

Net Present Values were calculated using stumpages for two grades of log; first grade (\$34/m<sup>3</sup>) and second grade (\$25/m<sup>3</sup>). Agricultural production was ignored. The calculations were made for a 30 year period - 2 cycles of 15 years. The range in Net Present Values is presented in Table 8.

**Table 8. Range in Net Present Values at various discount rates for 15 year old *E. globulus* and *E. saligna* sawlogs grown at wide-spacing**

Discount Rate	Net Present Values	(S/ha)	
	<i>E. globulus</i>	<i>E. saligna</i>	
5%	\$1,098 to \$1,922	\$309 to	\$848
7%	\$817 to \$1,427	\$233 to	\$633
9%	\$513 to \$933	\$54 to	\$368

#### 4.6 Sawlogs (softwood)

The cost to establish and tend pine plantations for sawlogs on farmland can range from \$1,540 to \$1,770 per ha (CALM estimates 1990). The breakdown of these costs is presented in Table 9.

**Table 9. Cost of establishing and tending plantations of *P. radiata* on farmland**

Year	Operation	Cost (\$/ha)
0	roads and fire-breaks	180-190
0	Plants	90
0	planting and weed control	200-280
0	Fertiliser	75
3	scrub control	45-65
5	low prune and cull	280-315
7	high prune	280-335
10	Fertiliser	225
31	clean up debris	135-160
0-31	annual maintenance	32

The volume of sawlogs from plantations of *P. radiata* over a 30 year rotation ranges from 185 and to 340 m<sup>3</sup> per ha (CALM estimates 1990) depending on site quality and standard of plantation management. This includes all classes of sawlogs.

The volume of sawlogs from pine windbreaks on the Esperance Sandplain (rainfall of 450 to 600 mm/yr) has been estimated to range from 140 to 220 m<sup>3</sup>/ha after 30 years (data adapted from Moore, 1986). This is for a 3 row windbreak in which 200 trees/ha are pruned to 6 m (see Table 11). The variation in yield is due to differences in soil type and rainfall. Greater yields would be obtained from windbreaks growing on more fertile soils and with higher rainfall (> 600 mm/yr).

The volume of radiata pine sawlogs from a wide-spaced stand of 150 crop trees per hectare, thinned to 75 trees per hectare at 20 years and clearfelled at 30 years, has been estimated to range from 130 m<sup>3</sup>/ha to 380 m<sup>3</sup>/ha depending on soil type and rainfall (Anderson *et al*, 1988).

Typical regimes for these 3 different ways of growing softwood sawlogs and the likely range in yield of sawlogs are presented in Table 10.

**Table 10. Typical regimes for producing softwood sawlogs in plantations, windbreaks and wide-spaced stands and likely range in total volume of sawlogs produced**

Regime (m <sup>3</sup> /ha)	Volume of Sawlogs
Plantation	185 to 340 m <sup>3</sup> /ha
- plant 1333 trees/ha (3 m x 3 m)	
- thin to 500/ha (about 12 yrs)	
- thin to 250/ha (about 18 yrs)	
- thin to 125/ha (about 24 yrs)	
- clearfell (about 30 years)	
Windbreak	140 to 220 m <sup>3</sup> /ha
- plant 1333 trees/ha (3 m x 3 m) in a 3 row belt	(1 ha is approx. 1 km)
- prune 200 trees/ha to 6 m(during years 5 to 10)	
- trim remainder (optional)	
- clearfell (about 30 years)	
Wide-spaced	132 to 390 <sup>3</sup> /ha
- plant 600 trees/ha (10 m x 1.6 m)	(total of both harvests)
- cull to 150/ha (4 to 7 years)	
- prune to 8 to 10m (4 to 10 yrs)	
- thin 75/ha for sawlogs (20 yrs)	
- clearfell (about 30 years)	

Stumpages for pine sawlogs within about 100 km of a mill are presented in Table 11 (CALM, 1991).

**Table 11. Stumpages for softwood logs**

Product	Stumpage (\$/m <sup>3</sup> )
veneer logs	\$74
1st grade sawlogs	\$60
2nd grade sawlogs	\$39
3rd grade sawlogs	\$26

Net Present Values (Table 12) have been calculated for softwood sawlogs from plantations, windbreaks and wide-spaced stands using yields summarised in Table

10 and stumpages presented in Table 11. Costs have been derived from work carried out at study sites. In the case of windbreaks and wide-spaced stands the effects on agriculture, such as shelter and returns from grazing have been ignored. These must be included to complete the analysis. For example, the windbreak should increase grazing returns while widely-spaced trees will reduce grazing returns. The cost of fencing the windbreak was assigned to the agricultural enterprise.

**Table 12. Range in Net Present Values of softwood sawlogs from plantations, windbreaks and wide-spaced stands**

**Net Present Values (\$/ha) for discount rates.**

Regime	5%	7%	9%
Plantation	\$1474 to \$5195	\$478 to q\$2749	-\$91 to \$1341
Windbreak	\$662 to \$2338	-\$87 to \$1055	-\$478 to \$347
Wide spaced	\$753 to \$4285	\$125 to \$1956	-\$223 to \$907

#### 4.7 Poles

The cost of producing poles is similar to that for sawlogs (previous section) except the length of the rotation is less.

The stumpage for both hardwood and softwood poles is \$74.90/m<sup>3</sup> (CALM 1991). Thus producing poles could be a lucrative option for farmers where there is a market within a distance of 120 km. However there is insufficient data on yield of poles to calculate Net Present Value.

#### 4.8 Summary of Net Present Values

Net Present Value and Equivalent Annuity for an 'average' site and under a 'best-bet' regime have been calculated for some of the timber products. They are presented in Table 13.

**Table 13. Net Present Value and Equivalent Annuity for timber products on an 'average' site under a 'best-bet' regime at 7% discount rate**

Product	Net Present Value (\$/ha)	Equivalent Annuity (\$/ha)
Firewood	\$894	\$70
Pulpwood	\$1,496	\$118
Posts and rails (pine)	\$512	\$40
Sawlog (hardwood) widely-spaced	\$817	\$64
<i>E. globulus</i>		
Sawlog (softwood) plantation	\$1,230	\$98
windbreak	\$343	\$27
widely-spaced	\$1,040	\$83

NOTE: Cost of fencing not included.

## **5. Incentives and disincentives**

There are incentive schemes for growing two of the timber products discussed in this paper; softwood sawlogs and Bluegum pulpwood.

The Department of Conservation and Land Management has a Softwood Sharefarming Scheme to encourage landowners to participate in a joint venture to grow softwood. Under the Scheme the landowner leases the land to CALM, CALM plants and tends the trees and the landowner receives an annuity plus a share of the returns at clearfelling.

Annuities range from \$100 to \$160 per hectare depending mainly on the expected productivity of the site. Farmers can increase their annuity by contributing more, such as planting and tending the trees. The landowner also receives a share at the final harvest, i.e. 5% of his total share in the venture.

Both CALM and Bunnings Tree Farms have joint venture schemes to encourage the growing of Bluegums for pulpwood on farming land. The Bunnings Scheme involves leasing land from farmers. Landowners receive an annual rental from \$100 to \$140 per ha, depending on anticipated growth rates, plus 5% of the income at harvest.

CALM has used two schemes; Plantation Sharefarming and Timberbelt Sharefarming, but only the latter is current. The Plantation Sharefarming Scheme has a 20 year contract and landowners are paid an annuity ranging from \$70 to \$220 per ha. They also receive a percentage of the final clearfell revenue ranging from 4% to 10%.

The Timberbelt Sharefarming Scheme provides the landowner with a share of the returns when the trees are harvested, based on the respective inputs of CALM and the landowner. Timberbelts are integrated into the overall farm plan. Thus they aim to provide benefits such as shelter and control of waterlogging and salinity.

Under all schemes CALM and Bunnings normally do the work associated with establishing and tending the trees. The landowner is responsible for fencing and maintenance of firebreaks.

## **6. Harvesting**

There is scope for growers to harvest their own trees and so increase the return they receive. Ordinary farm equipment can be used to fell and stack many timber products, especially logs for chipwood and pulpwood, and posts and rails. For example a farmer with a small plot of Bluegums may obtain greater returns if he harvests the trees himself and stacks them beside the road ready to be collected.

There is also potential for farmers to have logs milled on the farm. There is a range of types of portable mills available for purchase. Contractors with portable mills are operating in many districts. On-farm milling avoids the expense of transporting whole logs. It therefore has the potential to increase profitability for farmers especially those a long way from a mill or with limited numbers of logs.

Simple low cost techniques for preserving posts and seasoning timber on farms are also available.

Farmers need to plan harvesting so that environmental benefits are maintained. For example, harvesting can be carried out in a staggered manner around the farm to produce a mosaic pattern of old and young trees. Harvesting can also be spread out over time, thus ensuring that there is always a high proportion of well developed trees on the farm.

## 7. Marketing

Having a buyer is obviously essential to getting a return from timber. It therefore pays to investigate the market prospects before investing heavily in trees.

Table 14 summarizes information about the marketability of the various timber products from farms in Western Australia.

**Table 14. Marketability of timber from farms in Western Australia**

Product	Marketability
Firewood	<ul style="list-style-type: none"> <li>- limited markets</li> <li>- some demand close to centres of population</li> <li>- scope for on-farm use</li> </ul>
Chipwood	<ul style="list-style-type: none"> <li>- a market exists within 100 km of Bunbury</li> </ul>
Pulpwood	<ul style="list-style-type: none"> <li>- strong demand</li> <li>- plantations on farmland in the &gt; 600 mm/yr rainfall zone likely to be main resource in the future</li> </ul>
Posts and rails	<ul style="list-style-type: none"> <li>- limited markets</li> <li>- scope for on-farm use</li> <li>- some potential to develop markets within local farming regions, even in areas of low rainfall</li> </ul>
Sawlogs -hardwood~	<ul style="list-style-type: none"> <li>- uncertain markets</li> <li>- this could change as supply of logs from State Forest is reduced further</li> <li>- demand depends on industry adopting new milling technology (e.g. Valwood Process)</li> </ul>
Sawlogs -softwood	<ul style="list-style-type: none"> <li>- strong demand</li> <li>- established mills can service most of the area which receives &gt; 600 mm/yr of rain</li> </ul>
Poles	<ul style="list-style-type: none"> <li>- likely to be strong demand by SECWA</li> </ul>

## 8. Integrating with farming - other values

Trees are often grown on farms as an integral part of maintaining farm viability and productivity rather than just for timber alone; i.e. as a vital part of plans for the whole-farm. In this context, harvesting trees for timber can be a bonus, on top of all the other benefits provided while the trees were growing.

It's important to consider the other benefits when assessing information on the costs and benefits of producing timber.

Other review papers prepared for the conference detail the environmental benefits of using trees on farms.

## 9. Research

Table 15 lists aspects which need to be researched for each timber product on farms.

**Table 15.**

<b>Products</b>	<b>Main Research Needs</b>
Firewood	- determine yields of firewood for a range of species and sites - carry out cost/benefit studies
Chipwood	- research program underway
Pulpwood	- evaluate mixtures of species (e.g. Bluegums and Karri for pulpwood and sawlogs)
Posts and rails	- determine yield and quality for a range of species, sites and silvicultural regimes, especially in regions with < 600 mm/yr rainfall
Sawlogs - hardwood	- determine yields and test provenance's - evaluate species in regions with < 600 mm/yr - carry out cost/benefit studies
Sawlogs - softwood	- research program underway - broaden studies to include arrangements such as windbreaks and timberbelts
Poles	- determine likely yields - evaluate a range of species - carry out cost/benefit studies

Other general research needs include:

1. Determining the yield and suitability of timber of some species indigenous to the < 600 mm/yr rainfall zone (e.g. *E. loxophleba* - York Gum)
2. Developing a system for storing and accessing information about tree species
3. Determining whether there is value in producing specialty timbers and sandalwood in both > 600 mm/yr and < 600 mm/yr rainfall zones and
4. Determining the integrated value (\$) of re-vegetating farms

## 10. Conclusion

Farmers in the wet temperate zone have two timber products with strong markets; softwood sawlogs and Bluegum pulpwood. Lease and joint venture schemes for

these products are available for farmers who want financial assistance and market security. Farmers can finance their own tree plantings for these products. There is also scope for farmers to produce chipwood, posts and rails, poles and hardwood sawlogs but markets are limited and less certain. Growing firewood, sawlogs, and posts and rails for on-farm use is an important option.

With our current knowledge, firewood, posts and rails are the timber products of value for farmers in the dry temperate zone. These products would be mainly for on-farm use. There is some potential to grow sandalwood and specialty timbers. Sawlogs grown in wide-spaced arrangements is also a possibility.

Thus farmers in the South West Western Australia have opportunities to plant trees which can either produce a timber product for sale or for use on the farm. This means that tree planting can provide dual benefits - care for the land and diversified income.

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