Agroforestry : integration of trees into the agricultural landscape

P R. Scott

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Agroforestry - Integration Of Trees Into The Agricultural Landscape

P.R. Scott

Resource Management Technical Report 102
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Summary

This publication is the proceedings of a seminar on “Agroforestry” held on August, 4, 1989, jointly organized by the Western Australian Agroforestry Working Group and the Resource Management Division of the Western Australian Department of Agriculture. It was held at the Department of Agriculture and aimed at Government employees and private farm consultants involved in revegetation.

The problems of revegetation are broad and complex. Several disciplines and numerous motives for wishing to incorporate trees in the landscape are involved. The motives are becoming increasingly clear, but the disciplines are still largely constrained by invisible boundaries to “areas of expertise”. It is hoped that this seminar went some way to eliminating those boundaries. As they are reduced the way will be open for the integration of trees on farms to be efficient, cost-effective and productive.
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1. Agroforestry with Widely Spaced Trees (Pines and Eucalypts) and Grazing

The Objectives

The objectives of systems developed in Western Australia are to produce high quality timber and pasture, to lower groundwater levels and to provide shelter for stock.

Biological Considerations

In dense monocultures of pines, eucalypts or other tree species there is direct competition for light, nutrients and water between trees which affects growth rates and influences tree form.

In agroforestry, where widely spaced trees and pastures are grown together, the competitive interactions are more complex. There is competition between trees, between the trees and the pastures and within the pastures. There are also some ways in which the trees and pastures complement one another.

Foresters have been known to say that ‘trees and pastures don’t mix!’ . Certainly, in agroforestry this is true for the first year or two when vigorous pasture growth can overtop small seedlings and deplete soil moisture, with fatal results for many of the seedlings. Therefore, it is essential to eliminate this competition by killing or removing pasture close to the seedlings. From year two on, there seems to be little effect of competition for moisture between the trees and the pasture in medium and high rainfall areas. The tree cover reduces evaporation losses from the pastures through lower wind speeds, higher humidity and lower day-time temperatures, with the result that soil moisture is higher in the pasture root zone under pine agroforestry stands than in open pastures (Anderson and Batini 1979). Pastures remain green for a week or two longer under trees and are less affected by frost. However, in late spring, pastures do wilt a few days earlier around the base of large trees. Some eucalypts are known to be incompatible with pastures or crops because of their heavy demands on water in the top soil. Allelopathic effects of Eucalyptus camaldulensis on pastures have been reported (del Moral and Muller 1970).

Competition for nutrients is not a problem between trees and pastures in agroforestry. The annual fertilizer applications necessary for good pasture growth are more than adequate for the trees and nitrogen fixed by pasture legumes is available to the trees.

The main competition is for light and it becomes increasingly significant with increased tree density and age. With young pines, regular pruning to 55-60% of tree height is recommended in agroforestry (booklet available) and this keeps each crown quite small. The shade from each tree moves during the day allowing each area of pasture direct sunlight for about 80% of the day. A small reduction in photosynthesis may result but benefits to pasture growth associated with the protection provided by a partial canopy may compensate. Later in the rotation, after pruning has been completed, the tree crowns extend (and perhaps merge) with shading increasing and pasture growth and livestock carrying capacity decreasing (Table 1).
Table 1 Light coverage by debris and sheep carrying capacity of pastures under pines

<table>
<thead>
<tr>
<th>TREES ha⁻¹</th>
<th>% LIGHT TO PASTURE</th>
<th>RELATIVE SHEEP CARRYING CAPACITY</th>
<th>% DEBRIS ON PASTURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>100</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>75) (a)</td>
<td>85</td>
<td>88</td>
<td>12</td>
</tr>
<tr>
<td>150) (a)</td>
<td>71</td>
<td>85</td>
<td>21</td>
</tr>
<tr>
<td>225) (a)</td>
<td>59</td>
<td>75</td>
<td>27</td>
</tr>
<tr>
<td>0</td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>35 (b)</td>
<td>45</td>
<td>66</td>
<td></td>
</tr>
<tr>
<td>70) (b)</td>
<td>23</td>
<td>54</td>
<td></td>
</tr>
<tr>
<td>120) (b)</td>
<td>14</td>
<td>36</td>
<td></td>
</tr>
</tbody>
</table>

Note  (a) Trees aged 8 years.
(b) Trees aged 24 years.

Between trees, competition is minimal for the first few years at the spacings used in agroforestry. Table 2 indicates diameter growth of pines only being reduced at densities exceeding 200 trees ha⁻¹ by year 8 (Anderson et al. 1988). As the trees grow older, with root systems and crowns merging, competition increases and occurs at lower densities. Despite this, individual trees in agroforestry stands, having extra light, nutrients and water available, reach a specified diameter several years sooner than those in plantations.
Table 2: Average annual diameter increments of *P. radiata* at various stand densities and times

<table>
<thead>
<tr>
<th>TREE DENSITY (TREES ha⁻¹)</th>
<th>AVERAGE ANNUAL DIAMETER INCREMENT (CM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>3.25 a)</td>
</tr>
<tr>
<td>100</td>
<td>2.90 a)</td>
</tr>
<tr>
<td>200</td>
<td>2.85 a) Year 8</td>
</tr>
<tr>
<td>400</td>
<td>2.00 b)</td>
</tr>
<tr>
<td>35</td>
<td>2.7 )</td>
</tr>
<tr>
<td>70</td>
<td>2.1 ) Year 18-22</td>
</tr>
<tr>
<td>135</td>
<td>1.7 )</td>
</tr>
</tbody>
</table>

Table 3, modified from Malajczuk et al. (1984) indicates that the combined production from the agricultural and the forestry component in agroforestry is greater than 100%. That is, total productivity is increased because the two components are not totally in competition.

Table 3: Summary of agroforestry yield data

<table>
<thead>
<tr>
<th>SCENARIO</th>
<th>ROTATION LENGTH (YEARS)</th>
<th>SAWLOG YIELD (% OF PRODUCTION IN A PURE FORESTRY SITUATION) (x)</th>
<th>AGRICULTURAL PRODUCTION (% OF PRODUCTION IN A PURE AGRICULTURAL SITUATION) (y)</th>
<th>TOTAL PRODUCTIVITY (x + y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural</td>
<td>25</td>
<td>53</td>
<td>65</td>
<td>118</td>
</tr>
<tr>
<td>Emphasis</td>
<td>30</td>
<td>71</td>
<td>61</td>
<td>132</td>
</tr>
<tr>
<td>Forestry</td>
<td>35</td>
<td>70</td>
<td>48</td>
<td>118</td>
</tr>
<tr>
<td>Emphasis</td>
<td>30</td>
<td>93</td>
<td>42</td>
<td>135</td>
</tr>
</tbody>
</table>

Tree form suffers at wide spacings. The trees tend to spread out and develop heavier branches which must be removed while they are small. Strict adherence to a frequent
pruning schedule is essential or pine log values can be seriously reduced. Pruning costs also rise if branches become large and more pasture is covered by larger branches when pruned. Eucalypts require less pruning than pines but improvement in form can be achieved by pruning some trees.

In pine agroforestry, it is necessary to cull about four inferior trees out of every five planted. This, and the pruning of branches produces debris which covers some pasture making it inaccessible to livestock. There is a close inverse correlation between the numbers of livestock carried and the amount of debris on the pasture (Table 1). In the first twelve years of the rotation it is the amount of debris on the ground that limits livestock carrying capacity. Later, the debris breaks down and the effect of debris on pasture growth is lessened. However, as this occurs, the tree crowns are growing larger and shading will limit pasture growth and hence livestock numbers. It is commonly accepted that the availability of shade in summer however, can also improve stock performance (Bird et al., 1984).

Debris, however, does have some positive values. Young green needles have feed value for livestock and, when eaten some of the nutrients are quickly recycled via the faeces. The debris provides shelter for freshly shorn sheep and new born lambs.

**Costs and Returns**

The costs of establishing and tending the trees will vary from farm to farm depending on the conditions and the particular methods used but the range is between $8-b per crop tree (1987 estimate). Delaying tree tending invariably results in increased costs and lower returns from both grazing and timber. Table 4 illustrates a recommended schedule of tasks and likely costs for a typical pine agroforest.
### Table 4 The main tasks involved in establishing and tending a typical pine agroforest and the approximate costs (1987 estimates)

<table>
<thead>
<tr>
<th>AGE OF TREES (YEARS)</th>
<th>OPERATION</th>
<th>COST $/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Ripping (lines 10 m apart)</td>
<td>$15 (i)</td>
</tr>
<tr>
<td></td>
<td>Weed control (strips 1.5 m wide, 10 m apart)</td>
<td>$15</td>
</tr>
<tr>
<td></td>
<td>Cuttings (400/ha @ 0.20cents each)</td>
<td>$80 (ii)</td>
</tr>
<tr>
<td></td>
<td>Planting</td>
<td>$22 (iii)</td>
</tr>
<tr>
<td></td>
<td>Fertilizing - 150 g Super CuZn per tree</td>
<td>$8</td>
</tr>
<tr>
<td></td>
<td>materials</td>
<td></td>
</tr>
<tr>
<td></td>
<td>application</td>
<td>$14</td>
</tr>
<tr>
<td>4</td>
<td>Culling to leave 200 trees per hectare</td>
<td>$14</td>
</tr>
<tr>
<td></td>
<td>Pruning of 200 trees per hectare</td>
<td>$36</td>
</tr>
<tr>
<td>5</td>
<td>Pruning of 200 trees per hectare</td>
<td>$72</td>
</tr>
<tr>
<td>6</td>
<td>Culling to leave 133 trees per hectare</td>
<td>$7</td>
</tr>
<tr>
<td></td>
<td>Pruning of 133 trees per hectare (with “Squirrel”)</td>
<td>$133 (iv)</td>
</tr>
<tr>
<td>7</td>
<td>Culling to leave 100 trees per hectare</td>
<td>$6</td>
</tr>
<tr>
<td></td>
<td>Pruning of 100 trees per hectare</td>
<td>$100</td>
</tr>
<tr>
<td>9</td>
<td>Pruning of 100 trees per hectare</td>
<td>$100</td>
</tr>
<tr>
<td>11</td>
<td>Pruning of 100 trees per hectare</td>
<td>$100</td>
</tr>
<tr>
<td></td>
<td><strong>TOTAL COST OF TREE OPERATION</strong></td>
<td><strong>$726</strong></td>
</tr>
</tbody>
</table>

**Notes:**

*Based on contract price of $35/ha.*

*Seedlings are an alternative to cuttings. They cost less (about 70 each) but more need to be planted (about 600/ha).*
Based on hand planting rate of 1,500/day and a wage rate of $10/hour.

Based on a hire rate of $10/hour for the “Squirrel”, $10/hour for operator and pruning rate of 20 trees/hour.

The tasks involved are very similar for an agroforest with widely-spaced eucalypts. The main difference is that, because eucalypts tend to have smaller branches than pine, fewer prunings are necessary. Instead of having to prune about six times as with pine, eucalypts can be pruned to the same height with three prunings. This reduces costs substantially.

The likely returns from timber in a pine agroforest are shown in Table 5. The returns are presented for two species of pine (P. radiata and P. piriaster), two densities of trees (75 and 150 trees per hectare), and for two harvesting regimes (thinning and clearfelling and clearfelling only).
### Table 5. Likely timber returns from various agroforestry regimes

<table>
<thead>
<tr>
<th>SPECIES</th>
<th>REGIME</th>
<th>AGE (YEARS)</th>
<th>RETURNS FROM SAWLOGS</th>
</tr>
</thead>
<tbody>
<tr>
<td>p. radiata</td>
<td>75 trees/ha</td>
<td>30</td>
<td>6,000 to 9,000</td>
</tr>
<tr>
<td></td>
<td>150 trees/ha</td>
<td>30</td>
<td>10,000 to 15,000</td>
</tr>
<tr>
<td></td>
<td>75 trees/ha</td>
<td>20</td>
<td>1,300 to 1,900</td>
</tr>
<tr>
<td></td>
<td>- thin 40 trees/ha</td>
<td>30</td>
<td>3,300 to 5,000</td>
</tr>
<tr>
<td></td>
<td>- clearfall 75 trees/ha</td>
<td>30</td>
<td>4,600 to 6,900</td>
</tr>
<tr>
<td></td>
<td>150 trees/ha</td>
<td>20</td>
<td>2,000 to 3,000</td>
</tr>
<tr>
<td></td>
<td>- thin 75 trees/ha</td>
<td>30</td>
<td>5,000 to 8,000</td>
</tr>
<tr>
<td></td>
<td>- clearfall 75 trees/ha</td>
<td>30</td>
<td>7,000 to 11,000</td>
</tr>
<tr>
<td>p. pinaster</td>
<td>75 trees/ha</td>
<td>30</td>
<td>5,400 to 8,100</td>
</tr>
<tr>
<td></td>
<td>150 trees/ha</td>
<td>30</td>
<td>13,000 to 15,500</td>
</tr>
<tr>
<td></td>
<td>75 trees/ha</td>
<td>20</td>
<td>1,040 to 1,500</td>
</tr>
<tr>
<td></td>
<td>- thin 40 trees/ha</td>
<td>30</td>
<td>3,600 to 5,400</td>
</tr>
<tr>
<td></td>
<td>- clearfall 75 trees/ha</td>
<td>30</td>
<td>4,640 to 6,900</td>
</tr>
<tr>
<td></td>
<td>150 trees/ha</td>
<td>20</td>
<td>1,900 to 2,800</td>
</tr>
<tr>
<td></td>
<td>- thin 75 trees/ha</td>
<td>30</td>
<td>6,700 to 10,000</td>
</tr>
<tr>
<td></td>
<td>- clearfall 75 trees/ha</td>
<td>30</td>
<td>8,600 to 12,800</td>
</tr>
</tbody>
</table>

Returns are based on a stumpage price (price of standing trees) of $32.76 per m³ for 20 year old trees and $50.21 per m³ for 30 year old trees.

It is assumed that only the 10 metre pruned section of the tree is saleable.
Pines or Eucalypts

Research of widely-spaced tree systems has broadened to include eucalypts. There are three main reasons for this:

farmers have shown a preference for eucalypt agroforestry compared with pine agroforestry;

there is a need to extend wide spaced agroforestry to sites unsuitable for pine; and

the demand for high quality hardwood sawlogs is likely to increase strongly.

The management of eucalypt agroforestry is essentially the same as for pine agroforestry. As mentioned in the section on tasks and costs, it appears that pruning costs are likely to be significantly less for eucalypts than for pine.

There is some uncertainty about markets for smaller fast-grown eucalypt sawlogs at the moment. However, a research programme at the Wood Utilisation Research Centre near Harvey is successfully developing techniques for sawing and seasoning this product (CALM, 1989). Therefore growers of high quality hardwood logs in an agroforest should be able to sell their product.

Economics

Many studies of pine agroforestry systems in Australia and New Zealand have found that the financial returns compare very favourably with those from agriculture. (Gisz and Sar 1980, Garland et al. 1984, Malajczuk et al. 1984, Arthur-Worsop 1985). Some early studies appear to have limitations caused by a lack of data. More recent evaluations however, using comprehensive data, generally confirm the soundness of earlier estimates. In Western Australia, studies by Malajczuk et al. 1984 and 1989 (in preparation) have been based on local data. These have shown agroforestry to be much more profitable in the long term than grazing enterprizes alone in the high and medium rainfall regions of the State, at sensible rates of return (5-9% after inflation).

The cash flow and labour requirements of agroforestry are different to those of agriculture. There are demands for capital and labour during the first 8-10 years of the rotation and a reduced income from grazing until timber is harvested. These demands can be reduced by establishing a sequence of agroforestry plantings over a 25-30 year period rather than one or two very large plantings. Experience gained with early plantings should also improve the efficiency of later projects.
Environmental Considerations

Agroforestry systems have the potential to help prevent or ameliorate land degradation as well as providing a good environment for livestock and other fauna. The combined presence of trees and debris can reduce wind speeds by about one third, depending on stand density. This effect and those of tree roots binding the soil and debris providing cover, together substantially reduce risks of soil erosion.

The combination of trees and pastures lowers groundwater levels (Schofield et al. 1989) and may reduce waterlogging. A mean draw-down of 1.8 m has been recorded among eight year old pines ranging in density from 75-225 trees ha⁻¹. It is expected that this effect will increase as the tree canopy becomes more complete.

Where to From Here?

The implementation phase of agroforestry involving wide spaced trees in combination with grazing or cropping, has been reached. Firm guidelines on how to establish and tend an agroforest and the associated costs are available (CALM 1987). Data on costs and returns for pine agroforestry have been used in economic studies for the Manjimup region (Malajczuk et al. 1984) and for the medium rainfall zone (Malajczuk et al. 1989). Both economic studies concluded that pine agroforestry can be a profitable enterprise compared with conventional agriculture. It has been found that wide spaced stands of trees can lower groundwater tables by 1.8 in in eight years. Agroforestry therefore, is a practical and economic option for controlling salinity.

Demonstrations of agroforestry, particularly in the high rainfall zone, have been established on both private and public land. Further demonstrations are required on a sub-catchment basis in the 500-700 mm rainfall zone where controlling salinity is an important objective. A submission for NSCP funds to establish demonstrations of agroforestry as part of high water use farming systems has been prepared by the Department of Agriculture.

In addition, it is now time to consider government assistance to farmers for establishing agroforests. Possible schemes include grants or low interest loans. Because of the nature of agroforestry, compared with plantation forestry, it is considered important that the farmer be the manager of both the trees and the agricultural component. Therefore the established share farming scheme is not considered suitable. A strong advisory service would be needed to support any financial assistance scheme.
References


Malajczuk, G., Anderson, G., Hyde, C. and Moore, R. An economic study of pine agroforestry in the 500 mm to 700 mm rainfall zone of the south West Western Australia. In prep.

2. Effects of Trees on Saline Groundwater Tables

Abstract

Land and stream salinization in southern Western Australia has now reached a state where 4,430 km² of agricultural land has become salinized and less than 50% of streamflow remains fresh. Salinization 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 covering at least 30% of farmland in areas with rainfall exceeding 700 mm/yr. A smaller percentage of planting may be effective 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. 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.

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 saline groundwater tables. Land and water salinization 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 reforesting farmland. This paper summarizes our current status of knowledge of this management option.

Saline Groundwater Problems in Western Australia

The relationship between salinity problems in Western Australia and groundwater was first noted by Wood (1924). He suggested that the killing of trees allows considerably more water to percolate to groundwater which will then rise to the surface bringing salts with it.

To verify this hypothesis, the government established a research programme in which the whole process from forest clearing to development of salinity would be carefully monitored. From these experiments it was clearly established that a permanent rising saline groundwater was the principal cause of land and stream salinity (Peck and Williamson, 1987; Schofield et al., 1988). The one notable exception is sandplain seeps in the eastern and northern wheatbelt which account for about 60% of dryland salinity in these areas. In the deep sandplain soils, throughflow in the perched aquifer causes saline seeps (George, in press) although, even in this case, underlying saline groundwaters are known to be rising and will cause additional problems in the decades ahead.
Results from two of the forest clearing experiments are shown in Figures 1—4. In the case of the Wights catchment (rainfall 1,200 mm/yr), groundwater levels rose fast following clearing (Figure 1) and the small initial discharge zone (seep area) expanded rapidly (Figure 2). After seven years the groundwater discharge zone covered 18% of the catchment area, since when it has stabilized (Ruprecht and Schofield, 1989). For Lemon catchment, in a 750 mm/yr rainfall area, the groundwater table was initially 16 m below the valley floor and it took 13 years following clearing for the water table to reach the ground surface and cause salinity problems (Figures 3 and 4). This delay from clearing to development of seeps is typically observed by farmers across the south—west, with delays increasing as one goes further inland to lower rainfall areas. In fact the full effects of clearing on salinity will not be felt in the wheatbelt for tens to hundreds of years (Anon. 1988).

Rising saline groundwater tables have had a devastating effect on stream salinities. By 1985 only 48% of the total divertible surface runoff of the south-west remained fresh. All the major inland rivers have become saline. In the 1970s clearing control measures were introduced on five important water resource catchments. Despite this action the salinities of four of these catchments have continued to increase rapidly (Figure 5).

Land salinization caused by rising saline groundwater tables also has been increasing rapidly. In the first survey in 1955, 73,000 ha or 0.5% of cleared land in Western Australia had become salinized. By 1989 this had risen to 443,000 ha or 2.8% of cleared land (Australian Bureau of Statistics, pers. comm. 1989). The rate of increase of land salinization since 1955 has been 10,870 ha/yr but since 1979 has been 17,900 ha/yr (Note that differently phrased census questions mean that the results may not be strictly comparable).

Salinization in south-west Western Australia has now reached a point where it is significantly affecting land and water resources. Our principal and most cost-effective method of bringing salinity under control is reforestation (tree planting). Research over the last 15 years (Schofield et al., 1989) now affords a reasonable description of the mechanisms and potential of this management option.
Figure 1. Groundwater response to clearing of Wights catchment, compared to native forest.

Figure 2. Growth of groundwater discharge area (seep) for Wights catchment following clearing (after Ruprecht and Schofield, 1989). Shaded areas indicate the extent of the waterlogged/saline areas in the year specified by the numbers.
Figure 3. Groundwater response to clearing of Lemon catchment, compared to native forest.

Figure 4. Rising groundwater levels in the valley following clearing of Lemon catchment.
Figure 5. Stream salinity trends of potential future potable water supply catchments.
How Do Trees Affect Groundwater Tables?

The action of trees on groundwater has often been described as ‘pumps’ (Greenwood, 1978). While this description may be appealing to engineers or farmers, it is not correct and in some cases may be misleading. Trees do not act like pumps. Pumps can be designed to withdraw water of any quality from an aquifer at a set rate, day and night, summer and winter. Trees do not behave like this, but they do have several properties which affect the groundwater table.

The behaviour of trees in relation to groundwater is shown schematically in Figure 6. There are two main ways in which trees influence the water table:

- by reducing groundwater recharge; and
- by consuming (transpiring) groundwater.

Groundwater recharge control by trees

Groundwater recharge may be considered as the movement of water from the atmosphere (rainfall) through the unsaturated soil zone to the groundwater table. The greater the groundwater recharge, the more the water table is likely to rise. Trees can reduce groundwater recharge by: (a) evaporation of water intercepted by their crowns; and (b) transpiration of water from the unsaturated zone.
Interception loss is the capture of rainfall by tree foliage, branches and stems and its subsequent evaporation from the wet surfaces. This means that some rainfall will not reach the soil surface and consequently less will be available for groundwater recharge. Interception loss is particularly significant for tall, rough surfaces like trees. Interception loss for eucalypts ranges from 10-25% of rainfall (Feller, 1981). For pine plantations near Perth, interception loss was found to increase with stand density (basal area), from 10% at 7 m² ha⁻¹ to 26% at 25 m² ha⁻¹ (Butcher, 1977). Interception loss from plantations increases as the trees grow and their canopies and leaf areas increase (Schofield, 1984).

Transpiration is the extraction of soil water by roots, movement of that water to leaves and evaporation to the atmosphere through stomates. Tree transpiration reduces groundwater recharge by extracting water from the unsaturated zone. Groundwater recharge occurs both as matrix flow (flow between soil particles) and preferential flow (flow down old root channels and other macroscopic structures). Matrix flow is slow and trees, with their deep roots, are effective in transpiring this water, particularly during summer. Preferential flow is fast (Johnston, 1987) and trees are less effective in transpiring this water before it recharges the groundwater.

Annual crops and pastures are not as good as trees at extracting water from the unsaturated zone. This is for two reasons: firstly traditional crops and pastures have relatively short roots and cannot extract much water below about one metre; secondly these plants die off around November and do not continue to transpire and deplete the unsaturated zone during summer. The much greater soil water depletion beneath reforestation, compared to pasture, is demonstrated in Figure 7.

**Groundwater use by trees**

Trees can also influence groundwater tables by consuming groundwater ‘directly’. This can occur in two ways: (a) extraction of water from the capillary fringe; and (b) extraction of water from within the saturated zone.

The capillary fringe is the area immediately above the water table in which groundwater is drawn up by capillary forces. The capillary fringe may be saturated close to the water table but its water content decreases with increasing distance from the watertable and is consequently well aerated. As such, trees with roots penetrating to the capillary fringe can readily utilize this water. Transpiration of the capillary water leads to a continuous movement of groundwater into the capillary fringe.

Groundwater extraction can take place by trees specifically adapted to transpiring water when their roots are in saturated soil. These trees are called phreatophytes. There is little information on phreatophytic water use under field conditions despite common reference to this mode of water extraction.

One observation that appears to be well known but is little tested is that a tree’s ability to extract groundwater diminishes with increasing depth. Greenwood (1986) cited experimental evidence of van Hylckama (1974) which showed decreasing water uptake of the phreatophyte *Tamarix pentandra* with increasing depth. Reasons for groundwater uptake decreasing with depth include decreasing root density, increasing soil bulk...
density (affecting root penetration), decreased oxygen level and greater gravitational potential difference (i.e. more effort required to lift the water against gravity).

A second often cited observation is that groundwater extraction by trees decreases with increasing groundwater salinity. Salts in water have the property of imparting the so-called osmotic potential which acts against water absorption by roots. For an increase in total soluble salts (TSS) of 1,000 mg L$^{-1}$, osmotic pressure increases by about 0.75 bar (Borg & Giles, 1988). The effect of this on the transpiration of several eucalypts can be determined from Figure 8, which shows the relationship between leaf conductance and leaf water potential. Leaf water potential must typically be several bars lower than the soil water or groundwater potential to allow transpiration. As groundwater salinity increases, water potential becomes more negative, leaf conductance declines and transpiration falls. For a groundwater salinity of 10,000 mg L$^{-1}$ TSS (7.5 bars osmotic potential) all species in Figure 6 could transpire close to their maximum. However, at 30,000 mg L$^{-1}$ TSS (22.5 bars osmotic potential) E. saligna would no longer use groundwater, and the groundwater usage by the other species would be significantly reduced.
Figure 7. Annual maximum and minimum soil water profiles for pasture and E. globulus (data supplied by E.A.N. Greenwood from CSIRO study at Bannister).
Figure 8. Relationship between leaf conductance and leaf water potential for some species in Stene's Arboretum (after Hookey et al. 1987).

Summary

Trees can influence groundwater levels in several ways. They do not act like pumps but respond to climatic and soil conditions. Trees exert influence both by reducing recharge and extracting groundwater. The absolute and relative magnitudes of these processes are difficult to measure and, anyway, vary significantly between species and site conditions. Trees provide a flexible form of land and water management but are difficult to use as a precise engineering tool. Some of the common questions asked about tree planting are discussed in the next section in relation to the environment of south-west Western Australia.
Reforestation to Control Groundwater - Some Common Questions

Which species?

Three criteria are often quoted when choosing tree species:

- adaptation to site conditions
- high water use
- multiple use

Adaptation

This is the first and primary criterion which must be satisfied by all species to survive and flourish. 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 provenances and cloning superior individuals for tolerance to waterlogging/salt affected conditions typical of most saline seeps in the south-west is being carried out in Western Australia (van der Moezel et al., 1989). Species identified so far include swamp sheoak (Casuarina obesa), salt river gum (E. sargentii), river red gum (E. camaldulensis) and swamp yate (E. occidentalis). Even these species; however, often require special establishment techniques in the most severe sites.

For well drained soils, away from saline seeps, a wide range of species are adapted.

Water Use

Knowledge of the water use capacity of species for a range of planting conditions could allow trees to be selected for high water use such that control over groundwater could be maximized or area of reforested agricultural land minimized. A number of measurements of tree water use have been made for farm plantations (e.g. Greenwood et al., 1985; Hookey et al., 1987). These measurements have shown that 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 raking of species by water use (Borg and Giles, 1988).

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 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. Pine agroforestry plantations have been shown to increase land productivity (Anderson and Moore, this volume). Also fast growing eucalypt plantations show considerable promise for pulpwood production (Bartle, this volume).
How to Plant?

On all sites, preparation for tree planting includes ripping and herbicide spraying for pasture (weed) control. In saline seep areas, research has shown that planting in a trough between two ridges (double ridge mounds) improves survival and growth (Ritson & Pettit, 1988). These authors have also demonstrated other beneficial treatments in saline seeps including site drainage, mulching and use of larger seedling containers, while fertilizing was not found to be of benefit in seep areas with many years of agricultural fertilizer application.

How Many?

In converting native forest to farmland, the water balance was altered in favour of increasing groundwater recharge because pastures and crops transpire less than trees. Because trees can transpire more than annual rainfall per unit area reforested (Greenwood et al., 1985), only a part of the farmland requires replanting. Schofield (in press) 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 mm/yr ranged from 51% of farmland at 1,200mm/yr rainfall to 32% of farmland at 750mm/yr rainfall.

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 (Figure 9). A regression of average rate of water table reduction against proportion of cleared area reforested is shown in Figure 10a. 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 mm/yr. Using this information and the regression in Figure 10a, it can be shown that reforestation of 24% of the cleared area is required to lower the water table at a rate of 200 mm/yr (i.e. 2 metres over 10 years) relative to the ground surface.

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 350 mm/yr. In this case the regression of Figure 10a indicates that about 57% of the cleared area would need to be reforested to lower the water table at 200 mm/yr relative to the ground surface.
A second regression which takes into account the crown cover of the reforestation is shown in Figure 10b. 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.

**Where to Plant?**

Planting location is an important aspect of any tree planting programme and will depend on objectives. In the control of groundwater tables, planting location is probably still the question causing most confusion, with some people advocating recharge control and others discharge control. Certainly trees planted out of salt/waterlogged areas will grow faster and transpire more water so long as it is available. On the other hand, there is evidence that groundwater will still rise to or remain at the surface of valley floors if there are no tree plantings in these areas. Whatever plan is adopted it should be designed to meet specified objectives.

**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 summarized 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 Schofield *et al.* (1989) and Bell *et al.* (in press).

**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 (Figure 11). A comparison of the water table through a valley section for 1979 and 1988 is shown in Figure 12. 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.
Figure 9. Location of study areas.
Figure 10. 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.
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 (Figure 9). These sites represent a range of species and planting densities. The Flynn’s and Stene’s sites have similar average rainfall (720 mm/yr) while Boundain has somewhat lower rainfall (500 mm/yr). The average water table changes under agroforestry compared to pasture are shown in Figure 11 (Stene’s) Figure 13 (Flynn’s) and Figure 14 (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.

Strip or Block Planting

The strategy of strategically planting strips or blocks which cover only a small percentage of farmland has been investigated at three sites: Flynn’s Landscape, Stene’s Strip and Bannister (Figure 9). In each case the tree planting has had little or no effect on the water tables. Thus in areas with annual rainfall greater than 700 mm, planting less than 15% of farmland is unlikely to have a significant impact on the water table.

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 in) of the water table beneath pasture over the same period (Figure 13).

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 (Figure 11).

Will the Trees get ‘Salted Out’?

Concern over the potential for salt concentration increases under valley floor plantations affecting the long term viability of plantations has been raised by Conacher (1982), Morris and Thomson (1983), and Williamson (1986). At all sites with rainfall greater than 700 mm/yr, groundwater salinities have decreased over the monitoring period (Schofield et al., 1989). At a lower rainfall site (500 mm/yr), however, groundwater salinities have increased, soil salt contents have increased in the depth range 0.75-2.25 in, decreased in the depth range 0-0.75 m and remained the same beneath 2.25 m. The combined effects of salt and waterlogging on trees appear to be greater than either one alone (van der Moezel et al., 1988).
Table 1: Characteristics of experimental reforestation sites

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<th>P. radiata</th>
<th>P. pinaster</th>
<th>E. globulus</th>
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* depth corresponds to the lowest groundwater level during the year.
Summary

Strategically placed strips or blocks of trees which cover c 15% of farmland have been unsuccessful in controlling saline water tables in areas with 700 mm/yr rainfall.

Wide-spaced plantations have lowered the water table by 1-1.5 in relative to pasture but in two of three sites the lowering has halted. At this stage it is uncertain whether the area and density of these plantings are adequate to eliminate groundwater discharge to streams in areas with > 700 mm/yr rainfall. There is evidence, however, that wide-spaced plantings will be effective in lower rainfall areas.

Lower slope/discharge zone plantings have lowered the water table by 2.4 in relative to pasture at the one site studied. The continuing downward trend in the water table at this site indicates that this valley planting strategy has considerable promise for the control of stream and land salinity.

Dense, extensive plantations have clearly been the most effective strategy for lowering the water table in areas with, 700 mm/yr rainfall. This strategy is clearly the best when rapid and large reductions in groundwater levels are required and/or where benefits from extensive commercial tree planting are required.
Figure 11. Groundwater level changes relative to the ground surface and pasture for various reforestation strategies at Stene’s Farm.

Figure 12. Comparison of the yearly minimum groundwater levels in 1979 and 1988 across Stene’s Valley Planting site.
Figure 13. Groundwater level changes relative to the ground surface and pasture for various reforestation strategies at Flynn's Farm.
Figure 14. 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.
Operational Reforestation and Integrated Catchment Management

The first major reforestation programme in Australia was initiated in the Wellington Dam (Collie R.) catchment in 1979 by the Water Authority. The objective was to control the inflow salinities to the reservoir which have been increasing steadily since the 1950s (Loh, 1988). 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. By the end of 1988, 5,700 hectares of farmland had been reforested, which is nearly 10% of the farmland in the eastern low rainfall part of the catchment (Figure 15).

In 1988 a second major reforestation programme was initiated by the Department of Conservation & Land Management (Bartle, this volume). While this programme has a commercial pulpwood production objective, the plantations are also being directed into salt affected areas (600 to 900 mm/yr rainfall) to control groundwater tables. At present the fast-growing species *E. globulus* is the predominant species planted for pulpwood. Because this species is salt-sensitive, it is generally being located on free-draining sites away from salt/waterlogged areas. Two thousand hectares of *E. globulus* were planted in 1988 and a further 5,000 ha is planned for 1989.

In recent years the concept of Integrated Catchment Management (1CM) 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, 1CM promotes the use of a range of options (of which reforestation is one) in developing farm management and catchment plans so as to control or reclaim salinized land and water whilst simultaneously maintaining land productivity. In 1987 1CM was adopted by the Western Australian government and in the context of salinity control, is currently being evaluated on the Denmark catchment. The first phase of this study involves extensive land capability surveying and farm planning.

Conclusions

Southern Western Australia has extensive and increasing problems associated with rising saline groundwater tables which are causing broadscale stream and land degradation.

Trees can exert control over groundwater tables both by reducing groundwater recharge and extracting groundwater.

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.
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 rainfall requires high density plantations covering at least 30% of cleared land. Smaller areas are required at lower rainfalls.

Planting location is an important aspect of any tree planting programme. If the objective is to prevent groundwater discharging salts to streams, then the reforestation strategy must include lower slope and discharge zone planting.

Choice of reforestation strategy depends on objectives and constraints. However in areas with >700 mm/yr rainfall, the strategy should emphasize a high tree cover of farmland. The most promising strategy is dense plantings on the discharge zone and lower to midslopes, covering at least 30% of farmland.

Operational reforestation for salinity control involving government purchase of farmland for tree planting now has a history of 10 years in the Wellington Dam catchment. With the growing appreciation of the wider benefits of tree planting and recognition of the need to maintain land productivity, integrated catchment management is a promising future approach for the south of the State.

At this time of substantial and increasing community support for tree planting, careful research and evaluation should be maintained to maximize benefits.
Figure 15. The Wellington Dam catchment, showing areas of cleared land and reforestation.
Acknowledgements

The author is grateful for comments on the paper by Mr R. George, Dr J. Marshall, Mr P. Ritson and Mr I. L. oh. Also thanks are given to Mr J. Ruprecht for assisting with Figures 1, 3, 4 and 5 and to Mr M. Ban for assisting with Figures 10, Li, 12 and 13.
References


3. Windbreaks and Shelterbelts on Farms

*Reasons for Planting Tree Windbreaks*

Three areas of value are found in agriculture:

**Reduction of windspeed (see Figure 1)**

Windspeed is reduced according to the height, spacing, orientation, density and form of the windbreak.

Benefits are:

- soil erosion control;
- reduction of windchill to livestock;
- reduced evaporation demand on plants within the sheltered area;
- reduced mechanical damage to sheltered plants;
- increased opportunity to spray and carry out other management practices.

1. **Increased water use**

Planting 'windbreaks' on or near problem areas can use extra water because the perennial trees and shrubs generally use more water than the annual vegetation of current farming systems, particularly near:

- swamps and sumps;
- saline areas;
- drainage lines;
- seeps;

2. **Tree and shrub products**

Extra value can be gained from your windbreak if it can generate secondary products such as:

- sawlogs;
- poles and posts;
- fuel wood;
- fodder;
- honey, oil, flowers.
The Case for Windbreaks

The relative profitability of establishing tree windbreaks will be determined by how well the windbreak addresses the reasons for which it was planted. An awareness of the losses from wind exposure and low water use, and the benefits of tree and shrub products in agriculture is needed to make a rational decision to plant. An example of losses in productivity due to severe weather is shown by the reduction in lamb marking percentages in the Esperance shire (Figure 2). Unfortunately, there are little data available to quantify the extent of the problem. Only in the lower South-west and parts of the South coast are timber products, by themselves, justification for planting windbreaks.

Figure 1. Wind speed in relation to a windbreak. Plan view (Oates and Clarke, 1987, p.17).
Productivity Gains

Example gains for a particular environment have been collected by P.R. Bird, of the Hamilton Pastoral Research Institute, Victoria (Figure 3).

Plant growth

10% increase from windbreaks spaced 25 tree heights apart.

20% increase from windbreaks spaced 12.5 tree heights apart.

Maintenance energy of stock

10% saving at 25 tree height spacing.

17.5% saving at 12.5 tree height spacing.

Lamb survival

Extra 5% weaned per year (conservative estimate).

Losses of shorn sheep

Reduction of 0.5% pen year on average. Individual properties in particular years will have much larger gains.

Potential animal production gains from windbreaks, or the losses from exposure, are not well documented in Australia. Most of the measurements relate to sheep and lamb deaths from exposure to cold, wet winds.
However, with the information available, it is safe to say that many areas would have nett increases in pasture growth, crop yields, sheep survival, and sheep productivity from the presence of planned windbreaks. (See Figure 3).

The higher the probability of loss, the greater the gain from windbreaks.

Esperance, with its highly erodible soils and strong winds, has the potential for large gains from wind protection. Farmers in the region have recorded nett profits from windbreaks within five years. This is especially so for cropping areas, that may suffer from multiple sandblasting during establishment.

For the NSCP project I am involved in, I have recorded a lupin yield increase, between five year old pines planted in parallel rows, of 27 per cent. When the area taken up by the windbreaks is allowed for, the nett yield increase is 19 per cent. This gain is not including the control of wind erosion before and after cropping, or the increased water use contribution by the windbreak. Clearly, it is difficult to quantify the multiple benefits of windbreak systems. The rest of this paper deals with the design factors involved in tree windbreak establishment.

Figure 3. Tree windbreak effects on pasture and crop yield. Qualitative diagram (Oates and Clarke, 1987, p.17).
Landscape Requirements

These are base factors to be considered when preparing a farm plan; an essential part of any tree planting programme.

For detail on tree planting for windbreaks, specialist advice may be needed. The following is a list of basic considerations for the tree planting plan.

- Roads, drainage lines, power lines.
- Valleys, ridge lines, hills.
- Native vegetation, previous plantings, neighbouring vegetation.
- Lakes, swamps.
- Degraded areas, rock outcrops.
- Visual impact on the farm and from outside the farm.

Climate
Records are the only reliable source of the required information. Distribution and probability of the following events helps design and justify the windbreak. Consider:

- Wind speed, direction and duration for periods of the year — which are the most harmful?
- Temperature. Seasonal variation and mm/max.
- Rainfall total and distribution.
Landform/Land Uses

Landforms and land uses will help to decide on the design of the windbreak, its species composition and its location.

- Soil types.
- Landform. Slope, orientation, others.
- Intended land uses e.g. cropping, grazing, lot feeding.

Design Factors - Considerations

When designing windbreaks and shelterbelts for particular sites, it is important to consider a range of factors which will influence the value and success of the planting.

- Landscape requirements.
- Climatic determinants.
- Landform and land use.
- Risk aversion.
- Cost/benefit.
- Species selection.
- Windbreak aerodynamics.
- Spacing and effective porosity.
- Personal preferences.

Risk Aversion

- Risk related to type of land use; e.g. multiple cropping versus grazing.
- Climatic factors. Incidence of strong, cold, wet winds, drought and so-on.
- Previous history of planting on the farm or experience of problems.
- Available technical information to avoid risk.
- Other means of avoiding risk.

Costs

- Seed or seedlings.
- Site preparation.
- Planting.
- Fencing.
- Establishment and early maintenance.
- Continuing management.
- Harvesting and replacement.
- Competition effects.
Benefits

- From reduction in windspeed allowing greater plant and animal productivity.
- From increased water use contribution by windbreak itself.
- From tree/shrub products.
- From environmental and amenity considerations.

Species Selection

Will be dependant upon the following variables:

- rainfall;
- soil type;
- land use;
- width of windbreak;
- desired porosity of the windbreak;
- height and form;
- tree products;
- amenity or visual effect.

Aerodynamic Design

- Height.
- Length.
- Porosity.
- Width.
- Orientation.
- Spacing.
- Gaps.
- End design.
- Place in the landscape. On slopes, in valleys and so on. For example see Figure 4.

Personal Preference

This is usually important in selecting the tree species.

Many people do not want exotic species, especially pines, if a native species is available to do the job.

Some trees will release pollen and may aggravate asthma. Other trees may be toxic to stock if eaten (serve them right!).
With some care, a mix of species to give variation in form, colour and tolerance to the problems encountered on the farm, can be selected. Some examples of windbreak types are shown in Figure 5.
Figure 5. Windbreak types.

Recommended Reading


4. Evolution of the Forestry Sharefarming Concept

Background

CALM developed the forestry sharefarming concept in response to difficulties which emerged in the early 1980s in maintaining the rate of establishment of Pinus radiata plantation. These difficulties were the escalating cost and growing local community concern with State purchase of farmland and abruptly in 1983, the State Government decision to discontinue the clearing of State Forest as a supplement to farmland purchase for pine planting. CALM had to develop a cost-effective and communally acceptable method to grow the entire pine crop on farmland.

The major economic impediments to making pine plantation forestry attractive to individual farmers were risk and uneven cash flow (Treloar, 1983). The method developed to overcome these impediments was called ‘sharefarming’. The essential characteristics of sharefarming are that the State (or the investor) underwrites the expected future revenue from the plantation established on the farmer’s land, and, after setting aside sufficient funds to recover its costs, pays the farmer the discounted surplus in the form of annual payments.

The first softwood sharefarming scheme was floated in the Manjimup district in 1985. It did not attract much interest.

It was decided to extend the scheme to the Albany region. Although not a traditional forestry area, scattered plots of pine provided evidence of satisfactory yield potential (Ellis, in prep). It was also found that the problem of drought death in unthinned mature stands was not as great in the benign south coast climate compared to the more severe west coast climate, and that reasonable yields could be expected down to 700 mm rainfall. This opened an area of about 0.5 million ha of farmland for potential planting. This area also has considerable land and water degradation problems. The scheme aroused great interest and opened for the first time the possibility that economically attractive tree planting could be used to rehabilitate degraded farmland, rivers and estuaries.

This development was of immediate interest to the community of research workers and managers involved in the treatment of salinity in water resource catchments and eutrophication in estuaries.

A programme of planting non-commercial eucalypts to control the salinity problem arising in farmland on the Wellington catchment had commenced in 1979. This operation required the subdivision and purchase of valley bottom land at considerable cost and with some disruption to farmers. The selection of species for planting was biased to slow-growing drought-resistant, deep-rooted species considered likely to require minimum management effort, be able to restore a desirable water balance with minimum canopy cover and therefore have a minimum impact on agriculture. Research aiming to refine species selection identified superior slow growing high water use species (Hookey et al. 1987). This work also showed that some fast growing species had good water use potential. Fast growing species had previously been discounted for...
use in rehabilitation on the assumption that their widely observed proneness to drought death on reaching full canopy indicated poor water use potential. This finding provoked an examination of their wood production over short rotations i.e. before the onset of drought stress. An initial evaluation indicated that *E. globulus* had potential to produce commercially attractive yields of wood suitable for pulp, even down to a rainfall of 600 mm.

This realization coincided with the emergence of the interest in softwood sharefarming in the Albany region. Since *P. radiata* has only limited local demand and poor export prospects, it was logical to consider applying the sharefarming method to the fast-growing eucalypts, especially *E. globulus*, which could sell into strong, large volume world markets for eucalypt pulp (Groome 1987). A preliminary assessment revealed that there was potential to develop a large pulpwod industry which could capture economies of scale and provide the opportunity to treat land and water degradation problems on a regional scale.

In 1987 the State commenced developing a pulpwood cropping industry based on the sharefarming method.

**Development of the Industry**

CALM has taken a leading role in the early development of a pulpwood cropping industry. Programmes of technical and commercial development have been initiated. They include:

Yield potential: Some 60 growth plots have been established in existing plantings which cover the full range of potential planting sites (G. Inions, pers. comm). Stem analysis has been used to determine production over time. The results have been used to provide yield estimates for input to economic models which specify annuities.

Demand/price projections: Detailed studies of world market prices and local production and export costs have been undertaken to provide estimates of costs and returns for input to economic models which specify annuities.

Area potentially available for planting: The total private property area potentially suitable for growing *E. globulus* in the lower south-west of Western Australia i.e. rainfall greater than 600 mm, has been determined to be approximately two million ha (Bartle and Shea, 1989). Planting as little as 5% of this area would be sufficient for a large scale industry.

The commercial vehicle: The Western Australian Government has announced plans to support the formation of a Tree Trust to operate the industry on a commercial basis.

Research and development: Basic practices for fast growing eucalypt planting on farmland are already available. However, there is considerable scope to refine practices. The selection of planting sites and prediction of yields can be upgraded by better understanding of site quality attributes and the scope for management input to improve yield. Substantial establishment costs can be entertained over short rotations since the return comes relatively early. There is considerable scope for genetic improvement of *E.*
*globulus* and for diversification into other productive species. A Commonwealth National Afforestation Programme grant of $1 million has given considerable impetus to research and demonstration.

Planting operation: In order to establish an operational capability CALM undertook large scale plantings in 1988 (2,000 ha) and 1989 (5,000 ha) under an interim sharefarming scheme. This early rapid introduction of large scale planting was seen as essential to open the opportunity to capture world pulp market share in the next decade. It provides a demonstration of confidence and commitment to the industry and develops operational experience upon which further rapid expansion could be based.

**The Concept of Integration**

Perhaps the most important achievement to date in the development of the pulpwood cropping industry has been the recognition of the potential for tree crops to be integrated with conventional farming practices. In this respect pulpwood cropping can be seen as another form of agroforestry, where the tree crop is complementary to, not competitive with regular farming activities.

Eucalypt pulpwood crops have some particular strengths as a component of agroforestry. Although they are probably best grown in dense stands they are amenable to being distributed in any pattern, from long narrow belts (down to 40 m wide) or up to whole farm sized blocks. With their short-rotation (8-12 years) and range of species adapted to any site, great flexibility in farm planning is possible. The likely scale, economic attractiveness and availability of sharefarming arrangements of the prospective industry means that the benefits of agroforestry might be readily accessible to farmers.

Other factors which will favour the development of integrated, agroforestry style pulpwood cropping systems are:

The direct economic return from pulpwood crops appears likely to be quite sound, but it will not exceed conventional agricultural returns by such a margin that mainstream farmers would be motivated to convert to pure tree plantations. However, the combination of direct and indirect returns from well designed agroforestry systems could be very attractive to most farmers. Considering only one indirect benefit of trees, that of shelter, Bird (1988), showed that farmers in southern Australia would be economically justified in having some 20% of their land under timberbelts and woodlots. In many potential pulpwood areas in the lower south-west, tree cover in the form of retained native vegetation is less than 10% and declining in extent and vigor (Schofield et al. 1989). This indicates scope for agroforestry style planting of pulpwood crops on at least 10% of farmland. This is sufficient across the two million ha of farmland with rainfall greater than 600 mm in the lower south-west, to provide a land base for a major pulpwood cropping industry.

The scope to acquire whole farms for tree plantations, either by purchase or by contract, is likely to be limited by supply of suitable properties. The limited supply may also be further constrained by the emergence of local community opposition to any extensive conversion of whole farms to forestry. Such opposition has frequently accompanied the
expansion of plantation forestry into farmland both in Australia and overseas. It was one of the factors which initially motivated the development of the sharefarming concept in Western Australia. A recent study in Victoria addressed the issue of community concern about the Victoria government plantation expansion programme (Centre for Farm Planning and Land Management, 1989). This study identified numerous concerns but those that may have particular relevance in Western Australia include:

Uncertainty about the wider social and environmental impact of plantations;

Lack of community participation in the planning and implementation of plantations where matters of general district interest are clearly involved;

Community decline through loss of population, services and facilities; and

Plantations being bad neighbours from the point of view of weeds, vermin, maintenance of fences, mutual aid networks especially for emergencies etc.

A major recommendation arising from this study was that the potential for an integrated, sharefarming style tree planting industry be developed.

Hence rural community pressure for tree cropping systems to be incorporated into the existing social fabric can be anticipated. This will favour sharefarming or contractual arrangements which retain farming families and which are complementary to conventional agriculture.

The benefits in terms of salinity and eutrophication control which could be gained from tree planting require only partial reforestation (Schofield et al. 1989). However, the trees must be widely distributed with virtually every farm needing to be involved. In the case of salinity this is because of the shallow, local-scale character of the groundwater systems and the large quantities of salt that are leached from any area (up to five tonnes per ha per year). In the Denmark River, for example, only 8,000 ha of farmland development out of the 50,000 ha of forest in the upper part of the catchment has been sufficient to compromise the water resources value of the river. The wide dispersal of tree-planted areas required to treat salinity can also be designed to be complementary to agriculture.

Overall these factors suggest that integrated, agroforestry style pulpwood cropping systems will dominate the industry. Such systems are likely to be more profitable and attractive to the participants, more communally acceptable, better able to attract large land area quickly, and most appropriate to gain the important off-farm community benefits in the amelioration of water quality problems. In the development of the pulpwood cropping industry prominence should be given to the following objectives.

The development of integrated agroforestry systems which optimize pulpwood yield, the on-farm indirect benefits, and the off-farm water quality benefits.

The development of sharefarming schemes appropriate to pulpwood agroforestry systems.

The quantification and demonstration of all aspects of performance of pulpwood agroforestry.
The promotion of agroforestry style pulpwood cropping systems.

The Denmark Catchment Project is an early example of a project which will develop some of these objectives. It is a joint Department of Agriculture, Water Authority and CALM project with Commonwealth NSCP support. The project aims to prepare an integrated catchment management plan which will maintain the profitability of agriculture and restore the water quality of the Denmark River. Agroforestry pulpwood cropping systems will be designed to be part of this plan. More recently two small-catchment scale projects in the Peel and Denmark areas have been initiated by the same three partners, with Commonwealth NAP support. The aim is to quantify and demonstrate pulpwood agroforestry. There is considerable scope to expand these types of studies to facilitate the rapid evolution of pulpwood agroforestry as a component of sustainable agriculture in the lower south-west of Western Australia.

References


5. Advances in Research on Tagasaste, Martindale Research Project, October 1988

Summary

The Martindale Research Project has as its objective the development of management strategies to improve the efficiency of sheep production in south Western Australia. The production of wool and surplus sheep for sale are the primary sources of income in a sheep enterprise. The efficiency of wool production and reproduction are controlled by many factors but in south Western Australia the lack of good feed in summer and autumn overrides all others.

Tagasaste, an evergreen leguminous small tree, producing edible leaf and stem that was apparently both palatable and nutritious for sheep and cattle appeared to have potential to provide an economic alternative feed in summer. An added bonus was that tagasaste would establish and appeared to grow vigorously on deep sands. Most farms in south Western Australia have significant areas of this problem soil type that is just economic to crop and only produces poor annual pastures.

When the research programme commenced in July 1985, the fact that tagasaste could be established from seed on deep sand and would persist over summer without rain was irrefutable and evidenced by the 60,000 trees standing 2 to 3 m high on 60 ha of sand on Martindale’s farm “Newdale”. Experiments have subsequently researched many aspects of establishment and have shown the annual production of edible leaf and stem from adult tagasaste to be 7,500 kg per ha of green material when harvested by hand or 3,400 sheep grazing days per ha when grazed directly by young sheep. In summer the edible fraction of tagasaste was measured as 40% dry matter, 15% crude protein and 70% digestible. Sheep grazing tagasaste did not consistently gain weight but did consistently maintain live weight and grow more wool than flockmates grazing traditional dry summer pastures.

Analysis with the aid of a “whole-farm” computer model suggests that it was economic to establish and graze plantations of tagasaste, grown on deep sand, to replace the grain traditionally fed to young sheep and pregnant/lactating ewes in autumn. Tagasaste in excess of this requirement should be used to graze young sheep throughout summer and autumn to increase their wool production.

The economics of establishing sufficient tagasaste to replace the grain hand fed in autumn was approached in a number of ways. All suggested that tagasaste was a economically robust use of deep sands. For example the internal rate of return is 23%.

Based on the experimental results obtained to date the increased productivity of deep sands under tagasaste suggested they should be revalued from less than $100 per ha to around $600 per ha.
Introduction

Animal production in south Western Australia is constrained by the low feeding value of the dry annual pasture over the summer. By autumn there is very little paddock feed left and typically sheep are hand fed grain and cattle are fed hay.

In July 1985 Martindale Pty Ltd contracted the University of Western Australia to research strategies of feeding sheep over summer that increase farm profit. The research programme is known as the Martindale Research Project (MRP) and is located within the Animal Science Group of the School of Agriculture.

The major part of the research and development is conducted on Martindale Pty Ltd’s properties at New Norcia, approximately 130 km north of Perth. The area receives around 550 mm of rain per year. Soils range from sandy loams and gravels, to deep white and yellow sands. The deep sands are generally greater than one metre of coarse sand over fertile yellow sand, gravel or clay. They are a problem soil, as crop and pasture production are only marginally profitable on these sands. At the home property, “Newdale”, about 10% of the arable area is deep sands.

In 1987 Martindale Pty Ltd purchased a 3,000 ha property, “Dunmar”, at Badgingarra. This property is 70% deep sand and has a similar rainfall to “Newdale”. “Dunmar” was purchased to test the general hypothesis that run down sandplain farms could be economically redeveloped by applying research results from “Newdale”.

Why Tagasaste?

A tree that would grow vigorously on deep sands, whose foliage was of high feeding value and directly grazable by sheep and cattle would have potential to provide an economic alternative to grain/hay hand fed in autumn and/or increase the wool production of sheep over summer.

Tagasaste (Chamaecytisus palmensis) or tree lucerne is a small evergreen leguminous tree native to the Canary Islands. Seed was first sent to Australia in 1879 and tagasaste has become naturalized on roadsides and the edges of native forests. Tagasaste is often grown around farm chicken runs.

Analysis of the edible leaf and stem of tagasaste in summer and autumn has shown crude protein levels around 15%. Digestibility values around 70% and dry matter around 40% of the wet weight.

At “Newdale” a plantation of 900 tagasaste trees per ha, sown from seed in rows 5 m apart on deep sand in 1983, has produced 3 tonnes of edible dry matter per ha or 3,400 sheep grazing days per ha, in experiments conducted in 1986 and 1987.

The plantation at “Newdale” is now 6 years old and it is anticipated that it will have a life-span of at least 15 years.
All these attributes suggest tagasaste is a good feed for sheep, particularly as it can be stored green on the tree, safe from damage caused by summer rain, until autumn, a time when pasture feed and stubble feed is scarce.

**Research into Tagasaste**

In discussing the research into tagasaste at “Newdale” it is important to first understand the system of animal production in the absence of tagasaste before describing the new systems incorporating tagasaste. Thus, research into tagasaste will be discussed under the following subheadings:

- Traditional pattern of feed supply and wool production.
- Traditional pasture production from deep sands.
- Research into establishment of tagasaste.
- Research into the management of tagasaste.
- Research into new farm systems using tagasaste.
- Is it profitable to grow tagasaste?

### 1. Traditional Pattern of Feed Supply and Wool Production

In south Western Australia the quantity and quality (protein content and digestibility) of pasture on offer to grazing animals is closely related to the pattern of rainfall. The rate of growth and rate of wool growth of sheep are in turn determined by the quantity and quality of the feed on offer.

There is no clear best time to lamb and shear. At “Newdale” ewes lamb over two months beginning in mid April. Ewes are shorn and lambs are weaned in August. Weaners are shorn in October.

**Mid October to March (summer drought. 136 days)**

Summer drought begins abruptly in mid October with no regular rainfall until mid April.

The protein content and the digestibility of pasture drops markedly within days of wilting. Thereafter, the feeding value of dry pasture is primarily dependent on the frequency and intensity of summer rainfall. With rain the cell structure in the dry pasture rapidly breaks down leading to leaching of nutrients and a lower digestibility.

Within a few weeks of the pasture wilting the rate of wool growth falls to less than half the level during the green pasture phase (approximately 7 g of greasy wool per day). This minimum rate of wool growth is reasonably resilient to further deterioration in the quality of the pasture but towards the end of summer even a short period of feed shortage can cause a weak point in the staple.
By late summer the quantity and quality of dry pasture has normally deteriorated to the point where sheep lose liveweight and body condition and hand feeding of ewes and weaners is required.

March, April and May (autumn feed gap. 92 Days)

Opening rains in April destroy remaining dry feed.

Cattle are normally fed hay and grain is fed to ewes and weaners. At this time of year wool production is low, for a weaner about 7 g of greasy wool per day, the grain feeding is only intended to keep the sheep alive and prevent a break in the wool.

The cost of feeding ewes and weaners is dependent on the season. On average it costs $3.60 per head (250 g of grain per head per day for about 90 days with grain costing $160 per tonne - 1988 costing).

With about 16,000 ewes and weaners requiring feeding at “Newdale” the autumn feed bill for sheep is about $58,000.

June and July (winter, 61 days)

In most years pasture quantity is short, but feed quantity is compensated for by the high quality of feed.

In some years hand feeding is still required thoughout June.

Due to the high quality of the pasture the rate of wool growth rises to about 17 g per weaner per day.

August to mid October (spring flush, 76 days)

With longer days and higher temperatures, pasture production rapidly outstrips demand so that at “Newdale” there was 3 tonnes of dry matter on offer in October 1987.

The rate of wool growth is maximum by the end of spring.

2. Traditional Production from Deep Sands

“Some districts have large areas of sandplain and others belts of ironstone; useless country unfit almost for anything……..These belts of country intersecting every district in the Swan River colony will scarcely ever pay to clear and cultivate and might almost be described as worthless except for the purpose of grazing”. 1887-90 Commission on Agriculture.

About 10% of “Newdale” is deep sands. However, Martindale”s new property at Bagingarra, “Dunmar”, has about 70% deep sands.

Deep sands are still considered problem soils, as the commissioner pointed out in 1887. Stocking on these soils has to be carefully managed to avoid sand blowing. Fertilizer applied to deep sands quickly leaches Out of the root range of plants. Crop production
on deep sands at “Newdale” is just profitable and pasture production is only a fifth of the production from better soils.

The sands are best grazed in late autumn, soon after the break of the season when they show an advantage for early production of the new seasons pasture, and again lightly in spring/early summer. Grazing at these times nets between nothing and at best $15 per ha.

Although it is hard to apportion land values to different soils on a property, the market price for deep sand is recognized to be under $100 per ha.

3. Research into Establishing Tagasaste

The 1st year

The original tagasaste plantation at New Norcia was established from seed by Australian Revegetation Corporation (Kimberley seeds) in 1983. The all inclusive contract rate was about $150 per ha. Five years and a number of experiments later the general principles used in the sowing method are still similar.

The method detailed in the following sections was used to sow 1,000 ha of tagasaste at “Dunmar” in May and June 1988. At “Dunmar” the sowing system has established a mean of 8,000 trees per ha, 5 to 20 cm tall, in October 1988. Evidence from “Newdale” suggests that about 70% of these trees will survive their first summer. What follows is a rundown of this method and associated costs.

Origin and method of collection of seed: Most of the seed used at “Dunznar” was collected from adult tagasaste trees at “Newdale”. Branches that were heavily podded were cut and stacked in a shed in late November. When the branches had completely dried in late January we crushed the pods by driving over the stack with a tractor. The seed was separated from the rubbish by manually feeding material into an old clover harvester. Three hundred and eighty kilograms of seed was collected from about 900 trees.

Seed was also purchased from John Cook (harvested mechanically from trees at Dandaragan, Western Australia), Barry Trimmer (washed from soil from under 10 to 15 year old trees at Orange in New South Wales) and DSIR in New Zealand (collected by hand from roadside trees). The purchased seed cost $40 per kg, and is likely to cost about $60 per kg in 1989.

Scarification: Tagasaste has a high proportion of hard seed. The coat of hard seed must be broken to allow water to enter the seed and hence germinate the seed. Experimental work showed that the seed was easily damaged by vigorous mechanical scarification. Mechanical damage is similar to that caused by excessive handling of lupins. Seed vigorously scarified germinated normally, but within a week cotyledons fell off and seedlings died. Three passes through a spinning disc scarifier (supplied to CALM by Kimberly seeds), at a moderate setting, achieved 60% germination within a month of sowing with only a few seedlings losing their cotyledons. Doing the scarifying ourselves cost about $1.45 per kg.
Germination, over a range heat treatments (30 seconds up to 2 minutes in boiling water) to break down the seed coat, was poor and very variable and therefore was not used in the MRP programme.

**Inoculation:** Tagasaste, being a legume, fixes nitrogen in nodules formed on its root system. Specific soil bacteria (rhizobium) initiate and are incorporated into the root nodules. A commercially available inoculant (Nitrogen 100, Root nodule Pty Ltd., Woy Woy, NSW) was used at “Dunmar”. The cost of this is $2.50 per packet and a packet treats approximately 50 kg of seed.

Tagasaste seed is very oily and no adhesive is required if the inoculant is mixed dry with the seed. Tagasaste is nodulated by the same soil rhizobium as native acacia species. Hence, it is probably not necessary to inoculate the seed. The MRP has on-going trial work to evaluate the benefits of inoculating seed and the efficiency of native or commercial rhizobium to fix nitrogen.

**Seeding rate:** Two seeding rates were used at “Dunmar”, a low rate of 350 g per ha, and a higher rate of 600 g per ha. Six seeds were dropped each metre, or just under six seeds each half metre for the low and high rate respectively.

The seed costs were:

<table>
<thead>
<tr>
<th>OPERATION</th>
<th>COST ($ PER KG)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purchase</td>
<td>40.00</td>
</tr>
<tr>
<td>Scarification</td>
<td>1.45</td>
</tr>
<tr>
<td>Inoculation</td>
<td>0.05</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>41.50</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SEEDING RATE</th>
<th>COST ($ PER HA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>At 350 g per ha</td>
<td>14.53</td>
</tr>
<tr>
<td>At 600 g per ha</td>
<td>24.90</td>
</tr>
</tbody>
</table>

The extra cost of the higher seeding rate was calculated to be recouped by increased grazing in the second year. The evidence for this conclusion is discussed later in the section on grazing in the second year.

**Where to sow tagasaste:** Tagasaste grows well on deep sands. The alternatives of cropping or annual pastures are only just economic on these problem sands. At “Newdale” where tagasaste has been sown on heavier soils the production appears to be lower than that from deep sands, further heavy soils are more profitable under pastures and crops. Thus, in the MRP programme tagasaste has only been sown on deep sands.
These sands are readily identified from a well colour balanced aerial photograph, taken in full sunlight, in August. The delineation between the better soils that support vigorous stands of subterranean clover and the sparse capeweed and grass on the deep sands is graphic.

Given the advantage of growing tagasaste on deep sands it is important to identify and plan the tagasaste planting thoroughly. At “Dunmar” we used aerial photos, soil surveys and vegetation surveys to determine where best to plant tagasaste. We have attributed a cost of $6 per ha to the planning phase of establishing tagasaste.

**Plantation:** “Dunmar” was sown in single rows, 5 metres apart this results in 2 km of row per ha. The aim was to establish a tagasaste bush or group of bushes each metre, giving a total of 2,000 trees per ha.

There is no evidence for this particular density. However, it is well established that production per ha from trees tends to plateau at relatively low tree densities. The plateau level of production is maintained over a wide range of tree densities and it seems likely that at 2000 trees per ha tagasaste will utilize all the available rain and stored soil moisture. Hence, in the absence of a water table, within reach of the roots of the tagasaste, no increase in adult production is expected in our environment by increasing the tree density above 2,000 trees per ha.

A hydrological study in co-operation with the Department of Agriculture has been started at “Newdale”. This study should provide information on the water use of tagasaste and therefore an indication of the maximum productivity that may be possible from tagasaste.

**Seeding:** Seeding was a two pass operation. The contract price for the two passes was $58 per ha. In addition, MRP supplied the tractor and some labour. It is estimated the total cost to the MRP was $71 per ha.

**Deep ripping:** The first pass ripped the ground to about half a metre. The rip-line was immediately consolidated by the passage of the wheel supporting the weight of the ripper plus fertilizer bin. Trials at “Newdale” failed to demonstrate any benefit of deep ripping upon germination, early seedling growth or survival of seedlings over their first summer. However, these studies were incomplete when sowing started at “Dunmar”. It was believed that deep ripping would break through the hard pan developed in sandy soils at a depth of around 25 cm. This opens up a path below the seed-bed down which the tagasaste roots and rain water can more easily penetrate. Theoretically this would increase ~survival of seedlings over the first summer.

**Placement of fertilizer:** Experiments at “Newdale” showed a clear penalty for placing fertilizer too close under the seed-bed of tagasaste. The number of trees per ha 12 months after sowing was decreased when fertilizer was placed 5 to 10 cm below the seed compared with application on the surface or 10 to 25 cm below the seed.

**Amount of fertilizer:** Experiments at “Newdale” showed that fertilizer applied in the year of sowing stimulated about a 30% increase in the yield of edible dry matter by 15 month-old tagasaste bushes.
At “Dunmar”, 25 kg of super-copper-zinc-molybdenum per km of row (50 kg/ha) was placed in the rip-line 25 cm below the seed-bed during the deep ripping. The on farm price of this fertilizer is $9.00 per ha. In future it is recommended that plain super at 25 kg per km of row be applied at seeding.

**Preparing the seed-bed**

The seed-bed was prepared by:

Scalping to depth of 7 cm and a width of one metre was achieved using a fixed blade mounted on the front of the planter. Without having experimental evidence for scalping it was felt that the theoretical benefits were sufficiently strong to scalp. These theoretical benefits are to remove weed competition, non wetting soils and insect larvae; and to form a water harvesting area.

Two rows of cereal rye were sown in the edge of the scalp on each side of the tagasaste. It was hoped that the cereal rye would provide early wind protection to the emerging tagasaste. The cereal rye grew slowly initially, but by October it was probably tall and dense enough to provide some protection from wind over summer. The rye was planted at 4 kg per ha, the seed costing $1.60 per ha.

A tine, 25 cm deep, followed the scalping blade to further break up the seed-bed below the seed. This was followed by another press wheel and a loop of light chain to loosen some sand on the surface of the seed-bed. The press wheel insures any air pockets from the ripping are removed. At “Newdale” an experiment showed a 300% increase in trees per ha at 12 months when a tractor was driven down the seed-bed after sowing (3000 verses 1000 trees per ha 12 months after sowing). The increase in the number of trees appeared to be made up of an increase in both germination and survival.

Seed was dropped in groups of six seeds by a precision seeder at one cm below the surface. Depending on the seeding rate these clumps where at metre or half metre intervals.

This seed was pressed into the ground using a second press wheel. This press wheel pressed the moist sand around the seed and ensured that there was no seeding trough into which caterpillars could fall and be trapped close to the emerging seedlings.

A wetting agent was sprayed directly over the seed bed. It was considered that the small cost was worth the knowledge that the seed bed was being wetted with each rain. Further, if the surrounding soil was non-wetting water would be concentrated over the seed bed. Aqua-soil cost $1.80 per ha.

**Cost of seeding at “Dunmar”**

<table>
<thead>
<tr>
<th>OPERATION</th>
<th>COST ($ PER HA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contract, rip, scalp, press, spray wetting agent</td>
<td>58.00</td>
</tr>
<tr>
<td>Support for contractor</td>
<td>13.00</td>
</tr>
</tbody>
</table>
Fertilizer 9.00
Cereal rye 1.60
Wetting agent 1.80
SUB-TOTAL 83.40

Insect control: Experience had shown that insect control in the year of establishment was very important. The insect control program at “Dunmar” started a few days ahead of the seeding program. Lorsban at 350 mL per ha was misted onto the site to be seeded. It was felt that it was important to control the initial insect population while there was pasture for the chemical to bind onto. As the seedlings were emerging, (2 weeks after the first rain following seeding or 3 weeks after sowing in damp soil) insects were again controlled using Lorsban for cut-worm and Rogor for the red legged earth mite. Rates where 350 mL of Lorsban and 85 mL of Rogor per ha. On reflection the second Lorsban application could have been economically replaced by Sumicidin at 200 mL/ha.

Monitoring of emerging seedlings for insect attack is very important. At “Dunmar” a monitoring site (5 m of row within which the number and position of seedlings is recorded) was established in each 20 ha of tagasaste. Each site is visited every four days from emergence until seedlings are one year old. Insect out-breaks happen very quickly, one 5 m site without any evidence of insects on one visit lost five seedlings by the next visit. After spraying, up to 20 dead cut worm were counted per square metre of seed-bed.

Monitoring has resulted in one extra application of Sumicidin when cutworm activity was identified, this probably made the difference between a good stand and a failure. It is budgeted to spray cut-worms once more before summer and then control rutherglen bugs/grass-hoppers once during the summer.
Summary of the cost of insect control at “Dunmar”

<table>
<thead>
<tr>
<th>TIMING</th>
<th>TREATMENT</th>
<th>COST ($ PER ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-treatment</td>
<td>350 mL/ha Lorsban</td>
<td>5.00</td>
</tr>
<tr>
<td>Emergence</td>
<td>350 mL/ha Lorsban</td>
<td>5.00</td>
</tr>
<tr>
<td>Winter</td>
<td>85 mL/ha Rogor</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>200 mL/ha Sumicidin</td>
<td>2.00</td>
</tr>
<tr>
<td>Spring</td>
<td>200 mL/ha Sumicidin</td>
<td>2.00</td>
</tr>
<tr>
<td>Summer</td>
<td>500 mL/ha Maldison</td>
<td>3.00</td>
</tr>
<tr>
<td>Application</td>
<td>6 @ $1.00/ha</td>
<td>6.00</td>
</tr>
<tr>
<td>Monitoring</td>
<td>$200/week for 50 weeks</td>
<td>8.33</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>32.33</td>
</tr>
</tbody>
</table>

**Fencing:** The tagasaste area needs to be fenced off from adjacent pasture paddocks. Planning of the fencing at “Dunmar” cost about $6 per ha. At “Dunmar” an estimated 35 km of fencing costing $800 per km was required to fence off the tagasaste in the first year. Over the 1,000 ha planted the fence cost is on average $28.00 per ha of tagasaste. A further cost of sub-divisional fencing of $5.00 per ha will be required prior to the first grazing.

The cost of fencing at “Dunmar” may not be necessary on some farms and/or may only involve fencing out a corner of a paddock.

**Fire:** Without grazing during the growing season the inter-row is a fire risk. At “Dunmar” the outside inter-rows will probably be cultivated as fire breaks. No cost has been estimated for the risk of loss from a fire or the cost of fire breaks.
Total establishment costs in first year

<table>
<thead>
<tr>
<th>OPERATION</th>
<th>COST ($ PER HA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seeding</td>
<td>83.40</td>
</tr>
<tr>
<td>Seed</td>
<td>24.90</td>
</tr>
<tr>
<td>Planning</td>
<td>6.00</td>
</tr>
<tr>
<td>Insect control</td>
<td>32.33</td>
</tr>
<tr>
<td>Fencing</td>
<td>28.00</td>
</tr>
<tr>
<td><strong>GRAND TOTAL</strong></td>
<td><strong>174.63</strong></td>
</tr>
</tbody>
</table>

4. Research into the Management of Tagasaste

The 2nd year

**Grazing:** Standard practice has been to graze new plantations of tagasaste for the first time in August/September of the year following sowing, when the seedlings were about a metre high and 15 months old. This grazing is thought to trim the trees and promote a multi-branched, compact form more suited to grazing in the future. In addition, the grazing made use of spring production from the inter-row pasture in the 2nd year and at the same time controlled the weeds and reduced the fire risk in the second summer.

In the experimental programme at “Newdale” the penalties and benefits from grazing new plantations of tagasaste from as early as 6 months of age (October in year one) are being measured.

Trees were at risk at any age if they were less than 25 cm high (less than 50% survival). However, at 11 months (grazing in May over the break of the season) less than 5% of the trees were less than 25 cm high and survival from heavy grazing (700 sheep grazing days/ha) was greater than 95%. The effects of early grazing on future production will not be known for some years.

The new plantation of tagasaste at “Dunmar” will be grazed for the first time at 15 to 18 months of age. The strategy will most likely consist of a light grazing in December, mainly to remove some of the inter-row fire hazard. This will be followed by a heavy grazing and cutting of the bushes in late summer and early autumn. About 1,500 sheep grazing days per ha is expected from summer and autumn grazing in the second year. About two thirds of the grazing (990 sheep grazing days) will be at a time when hand feeding of sheep is usually required. If the period of hand feeding is 90 days, tagasaste would replace the grain feeding of 11 sheep. Using the value of $3.60 per head for grain feeding calculated in the first section of these notes, the gross return from tagasaste in the second year is ($3.60 * 11) $39.60 per ha.
Fertilizer. At “Newdale” 900 adult tagasaste trees per ha produced 7.5 tonnes of edible green matter per ha per year. This yield has not responded to added fertilizer. Comparing the results of leaf analysis from “Newdale” and other sites shows trees from “Newdale” had far higher concentrations of all of the major nutrients. This result and the lack of a production response to added fertilizer at “Newdale” is probably the result of past fertilizer applications. At “Durimar” this might not be the case, leaf analyses will be used early in the second year to determine the rate of to be applied. If result of this leaf analysis is low, about 100 kg of plain super will be banded beside the trees early in the winter of the second year. Cost, 100 kg ha at $130/tonne is $13.00 per ha.

**Cutting:** Cutting is used to encourage a low multi-stemmed plant, vigorous regrowth and to bring feed into the reach of grazing sheep. At “Newdale’ trees have routinely been cut to about half a metre in their second year. It has been noted that bushes left uncut are slower to recover following grazing and develop little feed in the grazing zone.

The cutter is a modified sickle bar hay mower mounted on the three point linkage of a tractor. Modifications were made by Harvestaire Pty Ltd and cost about $800.00. Even with these modifications cutting is slow. This year at “Newdale” trimming was completed at 1.5 ha an hour. This cost $25.00 per ha if the cost of repairs was included.

**Fencing:** It will be necessary to subdivide the tagasaste into small paddocks prior to grazing in the second year. Twenty ha has been chosen as the optimum paddock size at “Dunmar” and it is planned to graze paddocks for about three weeks each. A cost of $5.00 per ha is budgeted for sub-divisional fencing in the second year.

**Water:** To avoid stock damaging trees around troughs and to supply water to the large number of sheep that are anticipated to be grazing tagasaste at any one time during summer, a number of troughs per paddock and an efficient delivery method is required. At “Dunmar” water supply to the total property is costing $46.00 per ha. This value is used as watering costs for the tagasaste.

On farms with a reliable delivery system the cost of watering tagasaste paddocks would be less. Further, a farmer may adopt a strategy of not having water in the tagasaste paddocks, moving stock into adjacent pasture paddocks to water.

**Adult tagasaste**

**Fertilizer:** As previously mentioned, at “Newdale” there has been no response to added fertilizer, however this may not be the case at “Dunmar” which has a poor fertilizer history. Even though the tagasaste did not respond to added fertilizer, sheep graze both the tagasaste and the pasture grown in the inter-row. As the pasture in the inter-row does show an economic response to superphosphate, this analysis assumes that 100 kg of plain super costing $13.00 per ha is applied.

This summer an experiment in progress at “Newdale” will determine the importance of the inter-row to the total feeding value for sheep of plantations of tagasaste and hence at what rate the inter-row should be fertilized.
Cutting: Cutting during grazing brings leaf and edible stem above one metre into the reach of sheep and stimulates vigorous regrowth. Experience at “Newdale” has shown that sheep and cattle will not stip the bark from uncut or freshly cut trees. Leaves remain on the cut branches after wilting and sheep choose to eat a mixture of fresh and wilted tagasaste. While no measurements have been carried out yet it is assumed that rain will spoil dry tagasaste just the same as it does any other dry feed.

Grazing and cutting are budgeted to be annual events. An experiment at “Newdale” showed that the number of sheep grazing days/ha was 40% lower when tagasaste was grazed twice in a year compared with once only in autumn.

Cutting during grazing, once per year, is necessary to utilize all the available feed. Cutting is budgeted to cost $25.00 per ha per year using a sickle bar mower.

5. Research into New Farm Systems Using Tagasaste

Two strategies are considered for the use of adult tagasaste. Firstly, for a farm with up to 10% of the farm in tagasaste, the tagasaste is used to replace grain feeding in autumn. The second strategy concerns a farm with more than 10% of the farm growing tagasaste. This strategy uses tagasaste to replace grain feeding, then uses the extra feed to grow extra wool over the summer. The annual application of fertilizer and cutting of trees back to 50 cm high, described in the preceding section, is common to both strategies.

A farm with less than 10% tagasaste

At “Newdale”, 4 ha of five year old tagasaste trees, at a tree density of 900 trees to the ha, and allowed to grow ungrazed for 12 months, maintained 340 weaners weighing 30 kg for 40 days in April/May 1988. This is a yield of 3400 sheep grazing days per ha. If the normal period of grain feeding is 90 days then 38 sheep could be fed on each ha of tagasaste in place of grain. Using a value of $3.60 for grain feeding, tagasaste is worth $136.80 per ha as a replacement for grain feeding.

At “Newdale” the 16,000 sheep that are normally supplemented with grain could be fed on 420 ha of tagasaste. This would save Martindale Pty Ltd $58,000 a year in grain feeding.

It would be nice if the world really was quite as simple as the above analysis indicates. The duration of the period when it is necessary to hand feed sheep is not always 90 days or even predictable. In some years hand feeding would last only 30 days, in other years it could extend to 130 days. With grain feeding, adequate grain to cover the worst case is usually stored on farm. Once grain feeding finishes surplus grain is sold. The cost of keeping surplus grain is low, consisting of foregone interest on the grain, plus storage costs, these are often offset by an increase in the sale price of grain in autumn.

If all the tagasaste available is not used over a particular summer/autumn the excess tagasaste can not be marketed at the moment and so is wasted. Alternatively sheep may be grazed on tagasaste after the break of the season to spell pastures in the early stages of pasture growth. This pasture sparing should increase total winter and spring
production of pasture. However, holding stock on tagasaste to allow pastures to grow would theoretically result in a reduction in annual wool growth because the rate of wool growth is lower on tagasaste than on pasture.

Given the current state of knowledge the most economic management system would probably plan to graze tagasaste for 70 days with sufficient grain on hand for a further 70 days, if the tagasaste runs out. When the magnitude of the difference in wool growth between tagasaste and green pasture is confirmed, and the theoretical benefit from deferred grazing of pastures is measured a better strategy may be evolved.

**A farm with greater than 10% tagasaste**

A farm with more than 10% tagasaste could graze sheep on tagasaste over the entire summer.

Experiments to date have used weaners or adult wethers, rotated through one ha plots of tagasaste or set stocked in larger areas of tagasaste. In general tagasaste has been regarded as available ad libitum. In all experiments sheep grazing tagasaste have grown wool at a faster rate than flockmates grazing dry pasture or hand fed a supplement of lupin grain on dry pasture. If it is assumed that the economic optimum stocking rate for wool production is less than that for survival feeding of weaners it seems reasonable to hypothesize that a system of controlled grazing, paddocks of tagasaste grazed for say 3 weeks once per year, should yield 2500 sheep grazing days per ha. If it is further assumed that the period of dry feed is 210 days then 12 months growth of tagasaste should carry 12 sheep per ha over summer.

The established relationship between clean fleece weight and mean fibre diameter, for a great range of feeds, is that for every extra kg of clean wool grown the mean diameter of the wool fibres should increase by 1.8 microns. Experiments at “Newdale” in 1986/87 showed weaners grazed on tagasaste throughout the summer produced an extra 700 g of clean wool but the mean fibre diameter increased by only 0.7 microns. A repeat of the weaner experiment in 1987/88 yielded a lower increase in wool production, 400 g clean, but there was no difference between the mean fibre diameter of the wool from the weaners grazing tagasaste compared with that of flockmates grazing dry pasture.

The 1987/88 sheep had a bad infestation of worms, this could be responsible for the lower production. However, at the moment there is no explanation for the breakdown in the relationship between clean fleece weight and mean fibre diameter in the wool grown by sheep grazing tagasaste.

In both experiments at “Newdale” the value of extra wool produced from weaners grazing tagasaste was $4.80 per head. Using 12 sheep per ha the increase in value of wool from tagasaste is $57.60 per ha.

The 12 sheep per ha on tagasaste for a total of 210 days will not require grain feeding for 90 days and pasture or stubble feed for the whole period. The saving in grain feeding is $3.60 per head times 12 head, equals a further $43.20 per ha.
The value placed on the pasture saved by grazing tagasaste for the first 120 days of summer is estimated from an agistment fee of $0.02 per head per day. The value placed on this pasture is $28.80 (12 sheep * 120 days * 0.02).

When the saving in grain feeding ($43.20) and pasture saving ($28.80) is added to the extra wool returns ($57.60) the total gross return per ha from tagasaste used for wool production is $129.60. This value is less than the $136.80 achieved when tagasaste is used to replace grain feeding alone.

The value for summer plus autumn grazing of tagasaste for wool production is sensitive to both the number of grazing days per ha of tagasaste and changes in wool quality/quantity. If the grazing days from tagasaste grazed over the entire summer and autumn (210 days) was the same as that achieved experimentally from weaners grazed on tagasaste in autumn only and the advantages in wool production from grazing tagasaste for 210 days over summer remained the same, then grazing tagasaste for wool production would be more profitable than grazing tagasaste to replace grain feeding.

6. **Is it Economic to Grow Tagasaste?**

In the previous sections the cost of establishing tagasaste, timing of grazing and returns from grazing tagasaste were discussed. This section attempts to integrate these aspects so that a comment on the economics of growing tagasaste can be made. The assessment is made for a farm that has less than 10% tagasaste. Hence, the returns are those for a farm replacing grain feeding with grazing of tagasaste. A number of different approaches are used:

- A bank balance approach;
- An annuity over fifteen years;
- Increase in land values;
- Minimum production to achieve 10%, 15% and 20% return on investment.

1. **Bank balance**: This method calculates a hypothetical bank balance for one ha of land. Only one interest rate is reported for this hypothetical bank balance, the rate is 8% per annum calculated on a monthly balance. This rate is realistic as it takes into account the currently higher nominal rate, the likely increase in grain values over time and further it does not change the story if different rates are used.

Figure 1 shows the monthly balance in the hypothetical account over a fifteen year period. At the end of the first year the balance is a negative $197 per ha. This is composed of $13 interest and $184 direct costs and lost production.
Figure 1. The monthly bank balance for one ha of tagasaste at a real interest rate of 8% over 15 years.

The balance shown continues to fall in the second year. Major costs in the second year are fertilizer ($13.00), lost production ($10.00), water ($46.00) and cutting ($25.00). These costs are partly offset by grazing ($39.60). The balance at the end of the second year has fallen $250.00.

The balance continues to fall until a peak debt of $315 is recorded in the 3rd year, just prior to the first significant income from grazing tagasaste. It is not until production from the sixth year is credited that the balance becomes positive. Once the balance becomes positive it steadily grows to finish at $1600 at the end of the fifteenth year.

It is quite possible that the tagasaste will continue to produce beyond 15 years and if it does need replanting the fencing and water cost will not be required again.

The bank balance is a lot healthier if the costs of fencing and water supply are reduced to $10 and $5 per ha respectively. These values would be appropriate for a farm that has a good existing fence and water infrastructure. The peak debt is still in the third year, but it is reduced from $315 to $247. The balance becomes positive a year earlier at five years and the balance at the end of fifteen years rises from $1,600 to $1,800.

A farmer may have surplus labour or establish only a small area of tagasaste each year, hence place no value on labour. The bank balance without labour is $116 per hectare at the end of the first year. The peak debt is still in the third year, but the peak debt is a low $183 per ha. With the lower debt load the bank balance becomes positive in the third year. The bank balance at the end of 15 years rises from $1,600 to $2,324 when labour costs are ignored.
At “Dunmar” increasing the production by 50% in the second year with the higher seeding rate improves the balance. The return in the second year increases from $39 to $59 per ha. This clearly covers the $12 spent on extra seed. The peak debt in the third year decreases from $315 to $294 per ha.

In summary the bank balance approach demonstrates the need for a farmer to have the finance available to sustain a high debt until at least the sixth year. Further the bank balance approach highlights the financial need to cover the peak debt of $315 per ha in the third year. No doubt farmers will be able to reduce their real outlay to establish tagasaste by contributing their own labour.

2. **The annuity approach:** An annuity is a constant annual payment over the life of an investment. It takes into account the cost and returns and their timing. An annuity is calculated at an interest rate, in this case a range of rates are given.

In this case an annuity is a hypothetical value that a farmer expects to receive each year, including the establishment years, from tagasaste. He receives this return from an investor who puts up the capital to establish the tagasaste on the farmers deep sand in return for a fee when the farmer grazes the plantation.

Table 1 shows the annuity at a range of interest rates. At 8% the annuity is $58 per ha. This annuity of $58 per ha is directly comparable with the $10 per ha return expected from conventional agriculture on deep sands. Hence, tagasaste has increased the profitability of these sands by 400%.

**Table 1. Annuity at a range of interest rates for tagasaste on deep infertile sands, using costs and projected returns from “Dunmar”**

<table>
<thead>
<tr>
<th>Interest (%)</th>
<th>Annuity ($/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>$74.00</td>
</tr>
<tr>
<td>5</td>
<td>$67.00</td>
</tr>
<tr>
<td>7</td>
<td>$61.00</td>
</tr>
<tr>
<td>8</td>
<td>$58.00</td>
</tr>
<tr>
<td>9</td>
<td>$54.00</td>
</tr>
<tr>
<td>11</td>
<td>$48.00</td>
</tr>
<tr>
<td>13</td>
<td>$42.00</td>
</tr>
<tr>
<td>15</td>
<td>$35.00</td>
</tr>
</tbody>
</table>

3. **Increase in land values approach:** As seen in the annuity approach tagasaste increases the profitability of deep sands. Land values reflect capitalization of the stream of income. The time period is arbitrarily set at 50 years, a period which is long enough for the end value to not influence the result. Returns from traditional pastures on the deep sands are assumed to be $10 per ha. Hence, the present value of costs and returns over fifty years is taken to reflect the increase in land value attributable to tagasaste.

Table 2 shows the increase in present values at a range of interest rates. At an interest rate of 8%, the increase in present value resulting from tagasaste is $578 per ha. At this interest rate land values would rise from under $100 per ha to somewhere between $578 and $678 per ha due to the greater profit resulting from tagasaste production.
Table 2. Increase in present value (land values) at a range of interest rates

<table>
<thead>
<tr>
<th>Interest (%)</th>
<th>Increase in present value ($/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>1,617.00</td>
</tr>
<tr>
<td>5</td>
<td>1,035.00</td>
</tr>
<tr>
<td>7</td>
<td>696.00</td>
</tr>
<tr>
<td>8</td>
<td>578.00</td>
</tr>
<tr>
<td>9</td>
<td>483.00</td>
</tr>
<tr>
<td>11</td>
<td>341.00</td>
</tr>
<tr>
<td>13</td>
<td>240.00</td>
</tr>
<tr>
<td>15</td>
<td>166.00</td>
</tr>
</tbody>
</table>

4. **Minimum return:** In the analysis so far, the result of grazing trials at “Newdale” have been used to calculate the adult production from tagasaste. This approach asks what the adult production would need to be to achieve a range of target returns on investment. The target returns are 10%, 15% and 20%.

Table 3 shows the number of sheep grazing days and change from the production measured at “Newdale” to achieve the target returns on investment. All target returns on investment are achieved at lower production levels than the 3400 sheepdays per ha achieved at “Newdale”.

To achieve a 20% return on investment the production from adult tagasaste needs to support 3060 sheep grazing days, a fall of 360 sheep grazing days on the values recorded for “Newdale”. If an investor was happy with a target return on investment of 10% the adult production could fall to 2170 sheep grazing days, a fall of 1230 sheep grazing days, or a one third reduction in productivity.

The return on investment over fifteen years calculated from production at “Newdale” and cost for “Dunmar” was 23%. If the life-span of tagasaste is extend to thirty years, the return on investment increases by only 1.5%.
Table 3. Return on investment and target returns on investment

<table>
<thead>
<tr>
<th>RETURN ON INVESTMENT</th>
<th>SHEEP GRAZING DAYS</th>
<th>CHANGE IN SHEEP GRAZING DAYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Newdale” 23%</td>
<td>3,400</td>
<td>0</td>
</tr>
<tr>
<td>Target 20%</td>
<td>3,060</td>
<td>340</td>
</tr>
<tr>
<td>15%</td>
<td>2,550</td>
<td>890</td>
</tr>
<tr>
<td>10%</td>
<td>2,170</td>
<td>1,230</td>
</tr>
</tbody>
</table>
6. Vegetation Farm Planning

With the enormous surge of interest in revegetation, it is appropriate to dwell on the why, where and how questions regarding revegetation. We may not get another chance at it! Farm planning has a central role to play in helping to address the answers to these questions. It gives us a framework within which we can focus upon what the important problems are on our farms, and how we can deal with them using a revegetation programme.

Revegetation can be aimed at providing solutions for, one or more problems. Many land degradation problems can be tackled using revegetation, as well as problems of agricultural production, conservation and aesthetics. More often than not, a revegetation programme will address more than one problem, and if well designed, will result in multiple benefits. Addressing multiple problems and providing multiple benefits should be an integral part of the revegetation aspect of a farm plan.

Procedure

A simple procedure is suggested for the farm planning exercise.

- Identify the problems to be addressed.
- List the options.
- Consider the implications of each.
- Select the best option.
- Integrate the best option into a whole farm plan.

Some Examples

The following are examples of the sorts of problems that revegetation may address. For each problem there are some suggested revegetation options and the possible implications of any revegetation strategy.

1. Dryland salinity

Revegetation or drainage are the two basic options to lower saline water tables. Combinations of these may be optimal depending on circumstances. The revegetation options range from adopting perennial pasture species to plantation forestry. In between these extreme options lie increased cropping rotations, fodder shrubs, strategic tree planting and wide spaced tree planting. If dealing only with the groundwater discharge area (salt affected land), halophytic shrubs such as Atriplex species are an option (saltland agronomy). Let us now consider some of the implications of these options.

The water use of perennial pasture species such as lucerne have been shown to be higher than annual species, but they require more managerial skills and rotational
grazing is essential. There will undoubtedly be areas on the farm that lucerne is not adapted to. The provision by lucerne of some green pick during summer should allow better maintenance of stock over summer/autumn.

Crops also use more water than pastures (providing they grow well). An increased cropping rotation obviously must fit in with other aspects of the farm operation and be applied on a suitable soil type.

If these “soft” options are the only ones adopted, it will probably be necessary to change the land use on a large proportion of the catchment in order to influence the water table. The effects of changing to crops or perennial pastures on water tables has not yet been documented. Also, if there are large areas of waterlogged non-saline land, it would be worth considering a shallow drainage system to remove this water before it percolates beyond the perched layer and into the deep groundwater system. Then there are obvious implications for drainage, e.g. water disposal, design capability, vehicle access.

Fodder shrubs are perennial and generally deeper rooted than annual species. Little is known about their water use or effect on water tables, but the theoretical basis for their proposed higher water use is sound. Tagasaste is receiving widespread attention currently and appears to be well suited to deep sands.

Oldham and Mattinson (this volume) have covered this subject in some detail, and it is obvious from their analysis that the potential for tagasaste to improve a farm with deep sands is enormous. Planting patterns, management and cutting need to be considered when planting.

Strategic tree planting can be effective in lowering water tables, but as Schofield (this volume) has pointed out, the area to be reforested and its positioning will be critical to its success. Multiple benefits such as shelter, fodder, conservation, wildlife corridors, timber or other products should be considered when deciding on a strategic tree planting programme. Salt-tolerant clones of *Eucalyptus camaldulensis* are about to be tested for their ability to lower saline water tables and produce timber for pulping in the high rainfalls area of the south-west.

Wide spaced plantations have been shown to lower water tables and provide other multiple benefits (G. Anderson and R. Moore, this volume). The requirement for labour, stock carrying capacity, patterns of expenditure and returns, proximity to a mill, and site location must be carefully considered. A farmnote dealing with wide spread pine agroforestry is being prepared.

Dense, extensive plantation forests are most effective in lowering water tables and may provide shelter and other benefits. It should be remembered that greater than 15% of the cleared area needs to be reforested to have a significant impact on the water table in the greater than 700 mm rainfall zone (N. Schofield, this volume). Silvicultural advice will be necessary and insurance and fire protection for this high value crop should be considered.
Revegetating saline discharge areas with saltbushes is particularly effective in the lower rainfall areas. The provision of extra fodder during the summer/autumn drought, and the reduction of soil erosion from bare saline sites are big advantages. The effect of saltbush on water tables is still uncertain, but grazing production from a previously waste area is a worthy goal alone. The provision of fresh water for stock drinking is necessary. Trees can also be used on saline areas in wide spaced and dense configurations and have lowered water tables. Salt tolerant species, landforming and drainage techniques for establishment need to be considered.

2. **Wind erosion**

Windbreaks have been in use for many years in the USA for control of wind erosion. They have not been adopted on a broad scale in Australia. Yet we know from the disastrous drought years at Jerramungup and other parts of the South Coast and S.W. Wheatbelt, that even low (3 m) belts of remnant mallee or scrub were very valuable in breaking up the erosion process. Windbreaks are seen very much in the same light as contour banks are for water erosion control. They are an important infra-structure or backstop which is there if all else fails; that is in dry years when crops and pastures produce inadequate groundcover to protect the soil surface. Stubble mulching, trash-farming, grazing control, etc., are all held up as important practices to prevent wind erosion, but in certain adverse situations they can fail.

Western Australian farmers are now beginning to plant windbreaks, usually 2-3 rows wide and I think they will become a much more common feature in our landscape. A number of farmers are now planting three row windbreaks along the levelled out banks of seepage interceptor drains. Apart from curbing wind erosion, in a small way they also add to the other upland plantings in reducing recharge to the deep groundwater. In some areas of the south coast, windbreaks have some value as a timber resource. Species, alignment and configurations need to be carefully considered if reducing wind speeds are your main objective.

3. **Water erosion**

It has been recognized for many years that clearing of main waterways and creek banks has lead to gully erosion. The presence of trees or mallees not only prevents damage by stock and vehicle tracks or cultivating machinery but also stabilizes the soil by means of extensive root systems. Planting of trees along the sides of eroded gullies or just upslope of gully heads can be effective in controlling this type of water erosion. Again, the shelter and water use provided by the trees are beneficial.

4. **Dam pollution**

Pollution of dams with organic matter during summer thunderstorms is a frequent problem in the East Darling Range “sheep belt” from Boddington to Kojonup. Various silt traps, inlet pipes and “tea strainer” fence systems have been used in recent years. A newer approach is to fence out a block of land immediately upslope of the dam mouth. Prolific growth of pasture in this enclosure acts as an effective filter, removing solids
which flow through with run off water. These areas can be used as tree plantations as long as the density is low enough to allow good grass growth.

5. Dam evaporation

Reducing wind speed over the water surface of dams is one possible way of lowering evaporation losses. Some farmers plant tree blocks or belts on the side from which hot summer winds prevail.

6. Stock shelter

Few farmers deny the need to provide shelter belts or blocks for the comfort and hopefully increased production of their livestock. There is some debate regarding the best location of shelter areas (trees at the leeward end of the paddock may be used more by stock than at the windward end) and whether stock need to be able to get into the trees or merely shelter on the lee side of it. Trees for shelter may be able to provide fodder, timber or other products and encourage wildlife.

7. Aesthetics

Trees look nice. They can be used to beautify the landscape in much the same way as a landscape gardener can beautify a suburban backyard. Before planting for aesthetic reasons the implications of the plantings should be considered. The trees are likely to be there for longer than the planter will be around.

8. Conservation

Conservation of native flora and fauna are an important and worthwhile reason for revegetation of a decimated natural vegetation resource. Bush corridors can be incorporated into a farm plan, but consideration is only now being given to the implications of the size and shape of these for the plants and animals that use them as well as the effects on adjacent agriculture. Alignment of bush corridors with remnant vegetation and neighbour’s bush corridors should be considered.

9. Remnant vegetation protection

Protecting existing remnants is easier than establishing new areas. It is generally accepted that fencing to protect from stock will allow some rehabilitation of degraded remnants. The best means of managing these remnants after fencing is less clear. The benefits of a remnant vegetation block include increased water use, shelter, income from flowers, honey, etc. and in the event of a disaster, a drought reserve.
10. **Infertile soils**

Poor quality soils, such as deep sands, are planted to tagasaste or pines in order to protect the area from wind erosion and increase production from the area. These sandy areas should be fenced out and managed differently to the rest of the farm.

11. **Trees for drainage**

Finally, observations that rows of trees on waterlogged valley flats can de-water and drain these areas to the benefit of crop and pasture growth should be considered.

Back in the early 1980s, when thinking about places on farms to plant trees we (the Department of Agriculture) took the approach of identifying all non-arable areas on the farm and then planting the trees there. On many farms this gave the farmer scope for many years of tree planting on rocky ridges, along creeks and waterways, around the edge of saltland and deep sand areas and along laneways and contour fences. More recently, however the use of trees in an agroforestry type concept on “good” land as well as non-arable has come to the fore.

On these good quality soils it may be possible to improve productivity by incorporating trees in the landscape. Geoff Anderson and Richard Moore have provided a good example of this with their data on wide spaced trees. When you think about it, good soils that grow good pastures and crops will also be well suited to growing trees. The myth of mutual exclusion between trees and agriculture is dying. The integration of trees and agriculture is becoming increasingly relevant. Farm planning allows this integration to take place most efficiently by giving due consideration to the problems, the solutions, and the implications of the solutions on a whole farm scale.