MALLEE: A NEW SHORT ROTATION CROP FOR THE WESTERN AUSTRALIAN WHEATBELT

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Background

Agricultural development of the Western Australian wheatbelt region began in the late 1800s. Development was initially slow due to the very low fertility of the ancient, highly-weathered land surface of Western Australia. The discovery of cheap sources of phosphorus, trace element deficiency, and crop and pasture rotations including annual legumes, saw rapid acceleration in the rate of development. These advances came mainly after the second world war and the majority of the 18 million ha of agricultural land in the south-west corner of Western Australia has developed since then. Development required the clearing of the native vegetation that consisted of forests, woodlands and shrublands but virtually no grasslands. After clearing, large applications of phosphorus and trace elements were applied and introduced annual crops and pastures were sown. The agriculture became very productive and is a major part of the Western Australian economy. Current annual value of production is approximately A$4 billion.

However, the nearly total dependence on annual plants in the agriculture has caused a serious hydrological imbalance. The shallow-rooted annual plants are not able to consume all incoming rainfall. In the generally very flat agricultural landscape most of the unused rainfall infiltrates deep into the subsoil and accumulates as groundwater. Groundwaters fill to intersect the surface, mostly on the valley floors. This sets up a cycle of recharge-and-discharge of groundwater systems that was not active under the original native vegetation cover. The large storage of salts that was built up in subsoils under the native vegetation cover is mobilized and flushed from the landscape. The extensive discharge of saline water is a serious economic and environmental problem. Inadequate water use under the present agricultural system is the fundamental driving force of this salinity problem.

The problem occurs over virtually all the agricultural land of the South West of Western Australia. While land damage by salinity is a serious problem to the farmer, predicted to afflict more than 30% of the landscape within a few decades, downstream damage will be an increasingly serious problem for the community. The entire drainage network is being degraded leading to loss of water resources, riverine and valley floor biodiversity and amenity, and increased stream flow volume and erosion, instability in valley floor infrastructure due to saturated foundations and flood risk.

Salinity has provoked much discussion about the ecological sustainability of agriculture. However, perhaps the greater concern for the farmer, is that the present form of agriculture might not be politically-sustainable. The downstream impacts of salinity appear severe enough to provoke political demand for comprehensive remedial measures to be developed and applied. Hatton and Salama (1999) recently overviewed remedial treatments and came up with pessimistic projections of the scale and response times required for such treatments. However, the political pressure for fundamental solutions, or at least a serious attempt at remediation, is unlikely to be deflected by the difficulty of the task.

Salinity can be manipulated by the water management practices adopted by agriculture. There is scope to increase water use by plants and to drain or pump water to reduce the amount in groundwater systems. The options to improve water management practice can be grouped into five categories (Salinity Action Plan 1998):

- increase water use by the annual crops and pastures that dominate current agriculture;
- improve the health and vigour of remnant native vegetation;
- collect, reuse and dispose of surface water;
- drain or pump, reuse and dispose groundwater; and
- increase the range and proportion of perennial plant species used in agriculture.

The Salinity Action Plan (1998) recognised that of these, perennial plants offer the best prospect for significant increase in water use within agriculture.

Perennial plant options

Historically, annuals have dominated Western Australian agriculture and surprisingly little has been done to develop perennials. There were many good ecological and economic reasons why annuals came to achieve their dominance. However, the emerging recognition of the extent of the salinity threat appears to be enough to justify much larger commitment to the development and use of perennials.

Perennial plants come in many forms. Table 1 gives an overview of the range of types and some examples in current use. The major division used in this table is between grazing plants and non-grazing plants. This is a convenient separation because it indicates very different management and product options. Within the grazing category there are well known herbs and grasses and some newer woody fodder shrubs. Within the non-grazing category the separation is between trees (with conventional timber producing options) and shrubs with a wide range of, as yet little developed, product options. The listing of 'farm trees' and 'understorey' reflects the wide interest restoring some of the natural biodiversity during revegetation. Non-grazing shrubs are divided into sprouters and seeders indicating a major management difference - sprouters can regenerate from the stump but seeders must be replanted after harvest. Both may be harvested on cycles as short as 2 years and are therefore called short rotation tree crops. The Australian flora is especially rich in sprouting species such as mallee.

Table 1. *Overview of perennial plants types.*

Perennials				
Grazing		**Non-grazing**		
			Shrub	
Herbs/Grasses	**Shrub**	**Tree**	**Sprouters**	**Seeders**
Lucerne Phalaris	Tagasaste *Acacia saligna*	bluegum maritime pine	mallee melaleuca	Acacia understorey
Saltbush	farm trees	understorey		

The scale of planting of perennials necessary to control salinity is in the order of millions of hectares. The cost of establishment will be measured in billions of dollars. To occupy land on this scale, and to attract the necessary capital investment, perennials will generally have to be profitable as well as improve water use. Hence the major question is 'which perennials have the best commercial potential?'

Perennials that already have a commercial track record are an obvious choice. Table 1 shows an overview of the current commercial perennials and the limits of their range.

Table 2. *Current commercial perennial options.*

Perennial species	Plant form	Rainfall zone	Soil preference	Products	Development status
Bluegum	tree	>600 mm	deep fertile	pulpwood saw logs	new crop, demonstrated
Pinus radiata	tree	>600 mm	deep fertile	chipwood, saw logs	old established
Pinus pinaster	tree	>400 mm	light infertile	chipwood, saw logs	old, expanding to drier areas
Lucerne	herbaceous legume	>400 mm	deep freely drained, not	grazing, fodder	old established, expanding to drier areas
Tagasaste	woody legume shrub	400–600 mm	light infertile	grazing	new, well demonstrated
Mallee (many species)	woody shrub	< 600 mm	full range	eucalyptus oil, wood, bioenergy	commercially unproven

Perennial grazing plants feed into already established sheep and cattle industries and are therefore available for immediate use by farmers. However, the soils and rainfall preferences of existing options are too narrow and grazing industries have suffered a long-term cost/price squeeze. It would be desirable to use the development of perennials as an opportunity to diversify the economic options available to farmers (Bartle *et al.* 1996).

Table 2 lists three timber producing tree crops. These offer opportunity for entry into existing industries and provide economic diversification but they are only available where annual rainfall is 400 mm or greater. What is clear from Table 2 is that there are no existing tree crop options available for extensive use in the wheatbelt. The oil mallee project has been designed to fill this gap.

The challenge for new tree crops is the cost of development. Being 'new' there are few established practices and little relevant industry from which to take a lead. Hence the entire suite of establishment, management, harvest, processing, product and marketing options must be developed within a whole industry context. The costs and lead times are large. Hence the target tree crop must be very carefully selected.

The oil mallee development was initiated after a careful assessment process that systematically addressed the question 'why oil mallee?' The following discussion presents a brief review of the logic of this process.

Why develop oil mallee as a tree crop?

1. Market size

The extent of revegetation required to impact on salinity can be measured in millions of hectares. This inevitably means large volume markets to minimize the risk of oversupply. This does not exclude development of dozens of small industries based on tree crops producing specialist products like specialty timber, essences, flowers, fruits and nuts. However, it does indicate that we must also create some substantial new industries, able produce large volume commodities at world competitive prices, to provide the base-load for revegetation. The oil mallee development is a deliberate attempt to fill this role.

Eucalyptus oil has a small existing market of some 3000 tonnes worldwide used in a wide array of non-prescription pharmaceuticals and cleaners. This could be a useful market while scaling up but is trivial in relation to the production volumes needed to achieve a regional scale impact on salinity. Eucalyptus oil has good solvent properties and potential to become a major industrial solvent (Barton *et al.* 1997). The manufacture of a major industrial solvent, trichloroethane, was discontinued in 1996 under international convention because of its ozone depleting properties. Some 700 000 tonnes of this material were consumed annually. Solvent industries are busy developing replacement products while running down existing stocks of trichloroethane. Eucalyptus oil has the opportunity to enter this market. Table 3 shows planted areas required to supply the entire market, in relation to areas required to supply small proportions of the former trichloroethane market.

Table 3. *Quantity and area of eucalyptus oil production required for various world market shares.*

	Existing oil market	Former trichloroethane market		
World market share	100%	1%	5%	10%
Production required for that market share (tonnes)	3 000	7 000	35 000	70 000
Area required at a yield of 100 kg/ha/yr	30 000 ha	70 000 ha	350 000 ha	700 000 ha
Area required at a yield of 200 kg/ha/yr	15 000 ha	35 000 ha	175 000 ha	350 000 ha

Perhaps the most exciting aspect of the oil mallee development is the potential to turn the large volume of residues into products. Given the potential scale and low cost of such residues there are many options. This will be discussed in a later section.

2. Amenable to extensive production systems

West Australian wheatbelt farmers have highly mechanized, low labour input businesses. They are world leaders in applying new technology and generating economies of scale. They compete successfully in highly competitive world markets. These farmers will be keen to apply their comparative advantage in large-scale commodity production systems to new perennial crops. From this perspective it is unlikely that tree crops producing products like flowers, fruits and nuts will be at home in the wheatbelt.

Oil mallee can produce bulk commodity materials in extensive cropping systems. The plants are robust and easy to grow. They can be harvested and transported in mechanized systems similar to conventional annual crop systems.

3. Transport horizon or local processing to improve value

Annual crops have products with values in the range $200 to $400/tonne. A 300 km trip to a coastal port represents less than 15% of product value and is not a serious constraint on the viability of the crop. In contrast, many raw wood products have values in the order of $30 to $50/tonne and cannot be transported very far without some form of local processing to add value.

Eucalyptus oil as a feedstock for solvent products will have a value of about $2000/tonne and could be efficiently transported downstream from the extraction plant. However, raw leaf will have to be transported to the local extraction facility. The extraction cost of $20/tonne of leaf and an oil concentration of 3% indicates a raw leaf value of $40/tonne and therefore a limited transport radius. This simple analysis ignores residue value and the option of leaf and wood separation in the field but it accurately indicates that the industry will be centred on local processing facilities.

An alternative scenario under investigation by the Oil Mallee Company considers the viability of producing eucalyptus oil from 'in the paddock' extraction systems thus avoiding the need for transport of raw leaf into a central facility.

The smallest operational plants are likely to require 100 000 tonnes/year of feedstock (leaf and wood). To produce 100 000 tonnes/year at a yield of 10 tonnes/km/year of standard hedge will require 10 000 km of hedge. In alley planting configuration it will require 50 000 ha planted at 50 m spacing or 100 000 ha at 100 m spacing. Table 4 shows how transport radius will vary with the extent of adoption of oil mallee planting in these alley layouts to produce a volume of 100 000 tonnes/year. It also shows that a quite viable 50 km transport radius requires only a modest level of adoption to produce the volume required for a minimum plant size.

Table 4. *What planting area radius would produce 100 000 tonnes/year?*

Radius	Total area	% adoption to produce 100 000 tonnes: in 50 m alleys	% adoption to produce 100 000 tonnes: in 100 m alleys
20 km	126 000 ha	40	80
30 km	283 000 ha	18	36
40 km	503 000 ha	10	20
50 km	786 000 ha	6.4	13

4. Short rotation

The establishment cost and alternative annual revenue foregone on land occupied by tree crops imposes an economic constraint on the rate of adoption of tree crops by farmers. In other tree crop industries 'sharefarming' arrangements have been developed where an off-farm investor shares the growing costs and the harvest revenue with the landowner. Another way to facilitate adoption of tree crops is to select short rotation tree crops where harvest revenue starts early and comes regularly, thereby maintaining farm cash flow and helping the landowner to finance the investment.

On a whole industry level the investment required for short rotation tree crops will be less than long rotation crops and therefore a short rotation industry should be more readily developed.

Oil mallee is ready for harvest by age 5 and can then be cut on a 3-year-cycle. In the wetter western wheatbelt these times might be reduced to 4 years for the first harvest with a 2-year-cycle of harvests thereafter. Mallee is harvested to ground level and sprouts or coppices back from the subsurface 'mallee root' or ligno-tuber.

5. Residue use options

In oil mallee the eucalyptus oil fraction makes up less than 2% of whole-tree fresh weight. Not surprisingly, existing eucalyptus oil production industries are either a byproduct of forestry or at least use some of the residue as fuel to generate steam for extraction of the oil.

It is simply not credible to approach the development of a new eucalyptus oil industry without a strategy for residue utilization. At the scale of planting necessary to have some impact on wheatbelt salinity, production of residues could exceed 10 million tonnes/year. This material would be available in lot sizes between 0.2 and 0.5 million tonnes/year in many wheatbelt areas. A processing plant would need to be located in (or near) towns because the low value of the residue precludes transport to coastal centres.

Table 5 lists the range of product options for use of oil mallee residues. From the inception of the mallee project in 1992 CALM has carefully monitored developments in all these areas. All the product categories have the necessary market size to be relevant to the mallee industry, all are relatively undiscriminating on feedstock type and all seek large volume/ low cost reliable sources of supply.

Table 5.. *Potential products from mallee residue.*

Cataegory	Product
Reconstituted wood products	panel board (oriented strand board and fibre board)
Carbon products	charcoal, activated carbon
Energy	liquid fuels (ethanol, methanol) solid fuel for electricity
Chemicals	gasification (ammonia, methanol) fractionation (cellulose/lignin)

The greenhouse issue, and the Kyoto protocols that impose a ceiling on national carbon emissions, are likely to help renewable products and renewable energy to improve their economic competitiveness in the medium-term

The Oil Mallee Company has just completed a feasibility study to investigate the production of eucalyptus oil, activated carbon and electricity in a fully integrated plant. Plant integration is likely to achieve major economies, for example, waste heat can be utilized for steam extraction of the oil. It is anticipated that a plant size of 100 000 tonnes/year would deliver full economies of scale. If the feasibility investigation confirms viability several of these plants could be built across the wheatbelt.

The activated carbon option is attractive because it has a relatively small economic plant size. However, activated carbon markets are competitive. To achieve its ambitious objectives the oil mallee industry will have to diversify residue utilization industries. Larger economic plant size in other product areas, probably a factor of 3 or 4 times as large, should be more readily achieved based on the success in activated carbon production.

6. Compatibility with present agricultural practice

The oil mallee industry is being developed to be complementary to traditional agriculture, in particular to provide a high water use option to help reduce salinity. To be effective in achieving high water use it will be necessary to have mallees widely dispersed across the farm. It is anticipated that the most common form of dispersal will be in the form of belts. Belts will permit efficient harvest while also achieving the objective of dispersal. The focus on belts gives rise to the frequent reference to alley farming.

Two particular problems of compatibility emerge with belt or alley planting systems.

In belts there is a large degree of exposure of the adjacent annual crop or pasture to competition from the perennial mallee. Shading is not likely to be a problem given that the mallee will be kept at a height of less than 2 m by frequent harvest. However root competition will occur.

Ideally mallees would have only deep roots exploiting water surplus to that required by the annual plants. While this ideal will not be achieved there is potential to select mallee species that have the strongest deep rooting ability. There is also the quite simple management option of ripping adjacent to mallee belts every few years to trim lateral root development and reduce competition. On the other hand, if mallee is economically competitive, the farmer can be indifferent as to whether revenue comes from mallee or the annual plants. Observation of mallee to age 6 shows that root competition with cereal crops is minimal.

The second problem with any tree crop arranged in belts is palatability. Fencing long narrow belts in alley farming systems to protect trees from grazing would not be viable. The only alternative is to choose unpalatable species. The initial assessment of low palatability of oil mallee has been confirmed in practice over the past six years. Young seedlings need protection and are generally established in conjunction with a crop. A light stubble grazing can be taken in the first autumn after establishment. Thereafter only minimal extra input to grazing management is necessary. There is little experience with grazing management of a coppicing crop but small plot observation shows no cause for concern. Finally, some variation in palatability between species is observed. There are many prospective commercial species and the option to exclude the most palatable types can be taken.

7. The advantage of native species

A major period of development of new perennial woody plant crops is now emerging. If exotic species are used as the source of new commercial crops probably hundreds of species would need to be screened to locate several that may have commercial value. In such a process some of those tested may have potential to become weeds and may escape from cultivation to express their weed habit. For example, the desirable attributes of low palatability and rapid regeneration could be the makings of a successful weed. Weeds can cause economic loss through the need to impose controls or suffer the loss of use of land. Woody weeds also present a risk to the nature conservation value and biodiversity of the native bush.

Weed risk would be greatly reduced if new woody crop development first considers the potential value of native species. There is little risk of native species becoming weeds because they have evolved within the checks and balances of local ecology. The oil mallee project has embraced this principle.

There are also some strong commercial advantages in giving priority to native species.

Native species are adapted to the native environment and are unlikely to fail abruptly after some extreme climatic event or when they reach an advanced stage of growth. For example, blue mallee (*Eucalyptus polybractea*), the species that is harvested for oil in inland areas of NSW and Victoria, initially grows well but fails dramatically at age 3 or 4 years in the northern wheatbelt of WA. Also these perennial species must do an unusually difficult job i.e. develop deep root systems in what is clearly a harsh subsoil environment. It is therefore sensible to consider native species because they are well adapted to these conditions.

The WA flora is unusually diverse and rich in species containing high levels of extractive products such as gums, resins and oils. There has been some interest and commercial exploitation of these products but the potential remains largely untapped. Eucalyptus oil was harvested in the WA wheatbelt in small amounts several decades ago. Until the work by Brooker *et al.* (1988) and subsequent work by CALM (Bartle *et al.* 1999) the potential was largely undefined. There are now known to be more than 20 mallee species with commercial oil potential. Species could be selected to suit particular environmental niches, to provide particular oil constituents or to meet particular management needs such as low palatability.

Progress in mallee industry development

1. Background

The extraction of leaf oils from *Eucalyptus* species has its origins in the first colonies in NSW and Victoria. Through its long history eucalyptus oil production has been a small-scale subsistence industry punctuated by very brief booms. Eucalyptus oil has established a world market mainly as a non-prescription pharmaceutical and cleaning agent with a market volume of some 3000 tonnes. Australia was formerly the major producer but China now dominates world markets.

The first significant step to take eucalyptus oil beyond its traditional 'cottage industry' status was by Professor Allan Barton from Murdoch University. He saw cineole, the major constituent of eucalyptus oil, as having chemical properties that could be developed for large volume industrial products, especially solvents. During the 1980s he undertook investigation of many aspects of mallee production including its potential role in salinity control.

In the late 1980s the Department of Conservation and Land Management (CALM) commenced development of bluegum as a commercial landcare tree crop for the greater than 600 mm rainfall zone of the lower south west of WA. By the early 1990s it was clear than this development was commercially viable and new horizons could be explored in pursuit of further benefit from the techniques and experience gained from bluegum. With a secure allocation of development funds the 'oil mallee project' started, re-starting the work begun by Allan Barton. The objective was to develop a perennial crop for the wheatbelt and build up a resource base for the creation of a major new industry.

2. Progress

CALM sought interest from growers in six wheatbelt centres and pre-commercial planting commenced in 1994. In the first three years CALM helped finance seedling costs and provided leadership for the infant industry. Strong interest was generated. Growers formed an association to further their interests and took over management of the industry in 1996. In 1997, as the potential for commercial development of harvest and processing became clear, the Association sponsored the formation of the Oil Mallee Company (OMC) to facilitate the start of commercial operations.

The record of planting is given in Table 6. There are now 800 growers and a solid base of establishment and management knowledge has been gathered.

Table 6. *Mallee planting statistics 1994 – 2001.*

Planting year	Seedlings planted (millions)	Number of growers	Area planted (ha)
1994	1.10	80	412
1995	2.05	170	769
1996	2.80	250	1050
1997	1.05	100	394
1998	2.00	200	750
1999	2.85	273	1069
2000[1]	4.72	429	1770
TOTAL	**16.57**	**800[2]**	**6214**

1. Estimated
2. Many growers have planted over more than one year and this total is not the arithmetic total of the column

The industry recently commenced its first commercial feasibility investigation in partnership with the state-owned electricity utility Western Power. This project is evaluating a plant designed for integrated processing of mallee feedstocks to concurrently produce eucalyptus oil, activated carbon and electricity. The investigation looks promising and the partners have commenced assembling funds to construct a 20% scale pilot plant at an estimated cost of $5 million.

Mallees are eucalypts that have a characteristic multi-stemmed form (up to 12 m in height) with a large woody rootstock or ligno-tuber just below the ground surface. There are some 200 species that mostly occur in the arid and semi-arid regions of Australia. The ligno-tuber has many dormant buds that enable the plant to regenerate (or coppice) prolifically after the above ground parts are damaged or removed by natural events like fire or drought, or by harvest. As mature stands they appear very slow growing but as coppice they can grow rapidly. In agricultural land where extra water and nutrients are available, and when planted in belts designed to intercept subsurface water movement, they can be maintained in the productive coppice mode of growth indefinitely under a regular (every 2–4 years) harvest regime.

Harvest of mallee can commence at age 4 or 5 and be repeated on a cycle or rotation of 2 or 4 years. Each new crop coppices back from the subsurface lignotuber or mallee root.

Mallee biomass yields will be in the range 10 – 20 green tonnes/ha/year or 30 – 60 green tonnes/ha/harvest (for a three-year-harvest cycle). The oil is contained within the leaf fraction that constitutes 35% of biomass. Oil content will average 1% of whole green biomass or 2.9% of leaf biomass. With the availability of genetically improved seed the leaf oil content should increase to greater than 1.2% of whole above ground biomass or 3.4% of green leaf.

Major current areas of research investment include genetic improvement, harvest and handling system, processing and products.

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