Oil Mallee must look to multi-product industries

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Introduction

The Western Australian salinity action plan identified woody perennial crops as a key measure to reduce the impact of agricultural salinity (State salinity council, 2000). In Western Australia secondary salinity threatens to reduce agricultural yields on one third of the agricultural land (Ferdowsian et al., 1996), cause the extinction of 450 species (State salinity council, 2000), damage infrastructure such as towns and roads (Salama et al., 1994), and lead to further degradation of rivers through increased salinity and flooding (Bowman and Ruprecht 2000; Williamson et al., 1987). The problem of salinity is driving the search for woody perennial crops that can be integrated into and dispersed across the broad scale agricultural landscape of south western Australia.

Oil mallees, various species of eucalypt chosen for high leaf cineole concentration and coppicing habit, are being developed in Western Australia as a potential woody perennial crop in the lower rainfall agricultural regions (<550mm average annual rainfall) of southern Australia. Initial development concentrated on eucalyptus oil as the product but Bartle et al. (1996), showed that economic return from residues would probably be necessary to achieve commercial viability. More recently, multi-product industries have dominated the development of oil mallees.

A feasibility investigation conducted during 1999 (RIRDC, in press) showed that integrated mallee processing (IMP) (i.e. the concurrent production of eucalyptus oil, activated carbon and electricity from mallee feedstocks) could be commercially viable. Western Power Corporation have announced that they will finance the construction of a demonstration scale integrated mallee processing plant at Narrogin, Western Australia during 2001. This plant will produce 210 tonnes of eucalyptus oil, 7.5 GWh of electricity and 690 tonnes of activated carbon annually from 20,000 green tonnes of oil mallees. Upon the successful completion of testing it is envisaged that up to nine full scale IMP plants will be built in the low to medium rainfall agricultural region of south western Australia (Chegwidden et al., 2000). Each full scale plant will be five times the size of the pilot plant.

Nine IMP plants will produce 9,450 tonnes of eucalyptus oil, which is more than three times the current world trade (Abbott, 1989). The prospective market for the additional eucalyptus oil is as an industrial solvent. The industrial solvent market has lost its major product 1,1,1 trichloroethane, leaving a void of greater than 500,000 tonnes. Trichloroethane is the “gold standard” for solvent capabilities, but has been phased out due to its impact on the ozone layer (Montreal Protocol, 2001).

Cineole, the major component of eucalyptus oil has competitive solvent properties that are improved in blends with other natural compounds such as limonene (Barton & Knight, 1997). Natural solvents should enjoy a premium in future markets. As a complement to laboratory testing, eucalyptus oil has been subject to several years of trial use for industrial degreasing in some of Alcoa's workshops in Western Australia. Therefore, there is confidence that if eucalyptus oil can be produced at the right price it will able to penetrate this market. There are many competitor products in industrial solvent markets ranging from cheap hydrocarbons, such as kerosene, that are poor solvents for some grease compounds, to more expensive compounds such as limonene with a market value of US$1.50 per kg (Agtrans, 1998). It would be ideal for eucalyptus oil to be produced at less than AUS$2 per kilogram to facilitate rapid penetration of industrial solvent markets.

This paper will address two important questions that will help direct future research and development funding for oil mallees as a feedstock for industrial solvent production.

1) Using data from the IMP feasibility study (RIRDC, in press) it will be determined whether IMP plants could produce eucalyptus oil at a price suitable for the industrial solvent market.

2) By analysing hypothetical eucalyptus oil-only industries, it will be determined whether they can produce eucalyptus oil for the industrial solvent markets in competition with the multi-product IMPs.

Methodology

An economic simulation model was developed in Microsoft Excel 97 to represent the oil mallee industry, from the agricultural production phase through to the finished products. The model assesses industry viability based on internal rates of return (IRR). Internal rates of return were used in preference to net present values or benefit cost ratios because the IRR is a more practical criterion and is commonly used in industry.

Three industries were assessed in this analysis:

- an integrated mallee processing industry producing three products;
- a large scale oil-only processing plant (of equivalent size to an IMP) and
- a small scale oil-only industry relying on evaporative cell technology for in the paddock extraction.

Assessing the IMP

Data were obtained from the literature. IRRs were calculated for an IMP plant selling eucalyptus oil at AUS$3 per kilogram and AUS$2 per kilogram based on the key parameter values given in Table 1. Tax has been excluded from the analysis and it is assumed that all prices are constant in real terms.

Table 1: Key parameters for the IMP plant (RIRDC, in press; Collins, 1999)

Parameter name	Parameter value
Feed[1] consumed	100,000 t/y
Feed composition	40% wood, 25% bark and twig, 35% leaf.
Feed cost	$30/t
Capital cost	$28.4 million over two years
Annual operational expenditure	$7.9 million
Plant life	15 years
Activated carbon products	GAC 2,720 t/y @ $3000/t ex works CAWP 1,090 t/y @ $3000/t ex works PAC 294 t/y @ $1000/t ex works
Product licensing	3% of Activated carbon sales
Eucalyptus oil	1,050 t/y @ $2000/t ex works
Electricity for export	5 MWe “green” electricity at $60/MWh, 8000 h/y
Oil mallee establishment cost	$0.56 per mallee or $1494/ha
Land opportunity cost	$65/ha/year
Mallee maintenance cost	$10/ha/year
Mallee survival rate	95%
Mallee productivity per harvest	15kg/mallee
High productivity harvest regime	First harvest at 4 years, subsequently every 2 years
Medium productivity harvest regime	First harvest at 5 years, subsequently every 3 years

[1] Feed for the plant is the whole of the mallee above ground biomass chipped and is measured in green tonnes

Assessing hypothetical eucalyptus oil-only industries

This analysis is a scoping study for two hypothetical oil-only industries to determine whether further work is warranted on either option as a source of low cost eucalyptus oil for the industrial solvent market. Existing data on feedstock supply and from the IMP feasibility study were used to set hurdles that each option would have to clear before warranting further investigation.

For both options, harvest and transport were assumed to be the same as for supplying the IMP plant and all parameters were set at the levels reported in the IMP feasibility study (Table 2). Additionally, scenarios were run to consider the effects of increasing the oil percentage in the leaves, the selling price of oil, oil mallee growth rates and the percentage of leaf in the total above ground biomass (Table 3).

Table 2: Key agricultural parameters used in this study (RIRDC, in press)

Parameter	Parameter value
Harvest speed	5 km/h
Harvester cost	\$225/h
Harvest transfer cost	\$2/t
Transport cost	\$4.84/t

Table 3: Scenarios used to test the likely feasibility of hypothetical oil-only industries

Scenario	Scenario parameter values
1. Standard oil percentage, oil price, productivity, leaf percentage	3%, \$2/kg, 15 kg/mallee/harvest, 35%
2. High oil percentage in leaf	4%
3. High oil selling price	\$3/kg
4. High mallee growth rate	22.5 kg/mallee/harvest
5. High leaf percentage in above ground biomass	45%
6. High oil percentage and oil price	4%, \$3/kg
7. High oil percentage and productivity	4%, 22.5 kg/mallee/harvest
8. High oil percentage and leaf percentage	4%, 45%
9. High oil price and productivity	\$3/kg, 22.5 kg/mallee/harvest
10. High oil price and leaf percentage	\$3/kg, 45%
11. High productivity and leaf percentage	22.5 kg/mallee/harvest, 45%

Large scale oil extraction

The large scale processing option would be in direct competition for feedstock with IMP plants and so would only gain access to the feedstock if it could return a competitive IRR or if markets for other IMP products were saturated. To calculate IRRs, the large scale plant was given a building period of one year, a plant life of 15 years, a building costs ranging from $2,000,000 to $10,000,000 and operating costs ranging from $400,000 to $2,000,000 per annum. The ranges of building and operating costs are used to cover uncertainty of what the actual costs would be.

A key difference between this industry and the IMP is that only the leaf material is transported to the processing plant. To simplify the analysis it has been assumed that leaf-wood separation could occur on a modified harvester that operates at the same cost per tonne of total biomass as the harvester used for an IMP plant. Additionally it was assumed that the density and handling characteristics of leaf were similar to chipped biomass, so the transport costs per tonne were equivalent to that for the IMP feedstock.

For the standard parameter values and each scenario (Table 3) IRRs were calculated for the large scale oil-only option and compared with the IRR for an IMP plant.

Small scale evaporative cell oil extraction

Small scale in the paddock extraction within a passive ‘evaporative cell’ apparatus is under investigation. This concept would be most likely to be used in remote areas where transport costs for biomass would prohibit the farmer supplying feedstock for an IMP or for small scale boutique industries. This analysis examines the cost of in the field extraction to produce eucalyptus oil at a price competitive with an IMP plant. It is assumed that the whole above-ground biomass will be harvested and taken to a convenient point in the paddock for extraction at an equivalent cost to harvesting for the IMP plant. Therefore, off-farm transport cost for the biomass is zero. The transport cost of extracted oil to a central facility is included in the calculated extraction cost. Extraction cost is calculated as the difference between oil revenue, and the cost of production and harvest.

Evaporative cell oil extraction is a new technology currently being researched (RIRDC project AFT 98-28). The concept is to use solar energy to evaporate eucalyptus oil from mallee biomass contained within a lightweight portable enclosure or cell. The oil is recovered progressively over some days by overnight condensation or by stripping from the enclosure atmosphere using a small volume circulation system. Two key features of this technique are very low capital and running costs, and incomplete oil recovery. The aim of this RIRDC funded project is to extract oil at less than $15 per tonne of biomass.

The IRR for in the field extraction is a function of feed cost, plant cost, operating costs, transport cost for the extracted oil, oil recovery percentage and the selling price for oil. Of these variables, only the feed cost and selling price for oil are known and hence the IRR cannot be calculated. As a proxy for calculating an IRR the capital remaining for extraction is calculated as the dollar value of the oil produced minus the cost of feed, and is used to imply the likely viability of the industry.

This paper examines the effect of a range of oil recoveries from 60 to 100 percent on the capital remaining for extraction for a range of scenarios (Table 3).

Results

Simulation results will now be presented for the three industries.

Integrated mallee processing plant IRRs

The IRR for an IMP plant selling eucalyptus oil at $3 per kilogram over 15 years was 28.9 percent. When the price of eucalyptus oil was reduced to $2 per kilogram the IMP was lowered to 25.8 percent. Paying a factory gate price of $30 per kilogram for biomass is equivalent to the farmer earning an IRR of 8.9 percent on highly productive sites that allow first harvest at year four and subsequent coppice harvest on a two year cycle. Farmers would receive an IRR of 2.8 percent for less productive sites that require a five year period until first harvest and coppice harvests on a three year cycle.

Large scale oil extraction

Leaf delivered to a large scale processing plant for oil extraction cost $76.73 per tonne, or approximately 2.5 times the cost of whole biomass delivered to an IMP plant (Table 4). This increase in cost was due to the fact that leaf only constituted 35% of the total biomass and agricultural production and harvest costs were inversely proportional to this ratio.

Table 4: Costs of production for whole biomass and leaf only feedstock

Cost component	Whole biomass cost per tonne (RIRDC 2000)	Leaf only cost per tonne
Agricultural production	$16.09	$45.97
Harvest	$9.07	$25.91
Transport	$4.84	$4.84
Total	$30.00	$76.73

A feedstock cost of $76.73 per tonne of leaf is high enough to render unviable the production of oil in a large scale oil-only plant, because the revenue that can be raised per tonne of leaf is only $60. Therefore, no analysis of plant cost versus operating and maintenance costs was required.

Scenarios

There were no positive IRRs for hypothetical oil-only industries for the increased oil percentage in leaf, increased oil selling price, increased oil mallee productivity or increased leaf percentage scenarios. Positive IRRs were only realised in scenarios where more than one parameter was improved (Figure 1). The data contained in the graph for scenario 6 will now be analysed for illustrative purposes. Scenario 6 is the most likely of the scenarios analysed to succeed. For the range of plant costs analysed IRRs could be calculated for operating costs of $400,000, $800,000 and$1,200,000. Operating costs of $1,600,000 or above had no possible solution for IRRs for plant capital costs of $2,000,000 and above. Positive IRRs would result for plant costs of $2,000,000 and $4,000,000, and operating costs less than or equal to $1,200,000 or for plant costs of $6,000,000, $8,000,000 and $10,000,000, and operating costs less than or equal to $800,000. Only a plant costing $2,000,000 with an operating cost of $8,000,000 or less would return an IRR greater than an IMP returning 31.8% for this scenario.

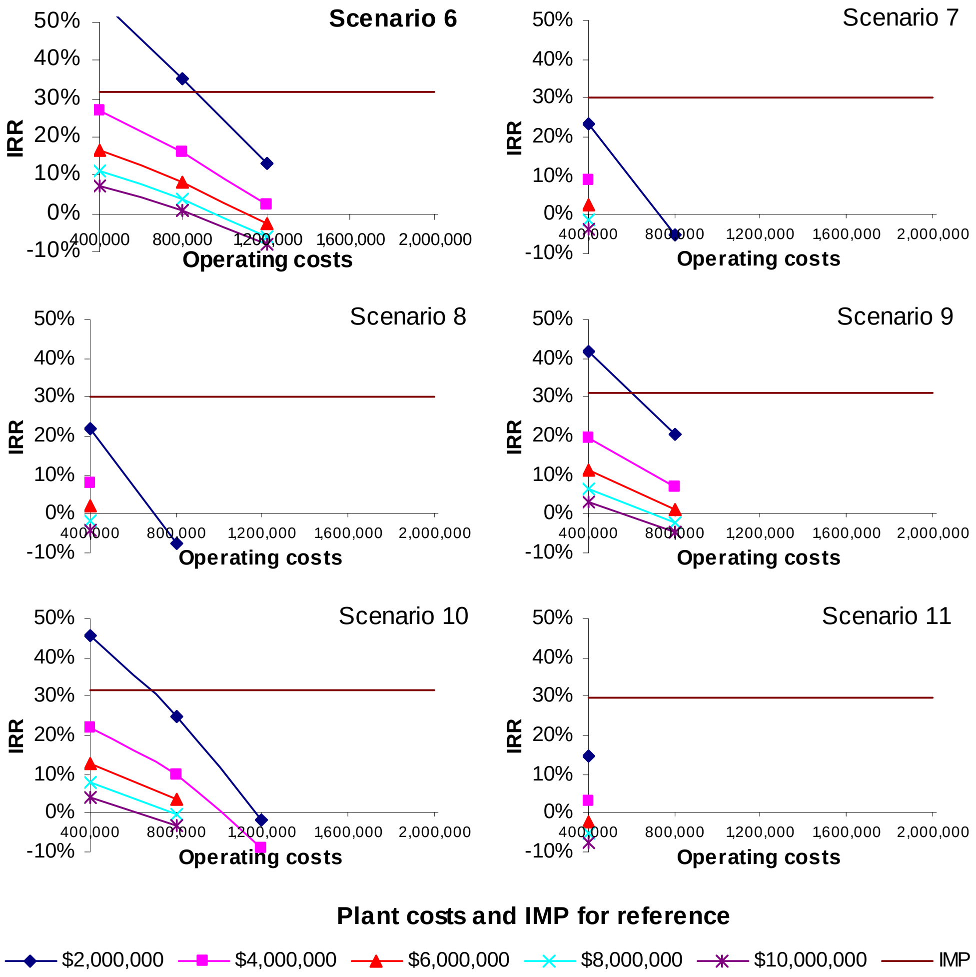

Figure 1: IRRs versus annual operating costs for six scenarios of large scale oil-only extraction, with plant costs ranging from $2,000,000 to $10,000,000 and IMP IRRs for reference

In scenarios 6, 9 and 10, high oil price combined with high oil percentage, productivity and leaf percentage respectively, a large scale oil extraction facility would return a higher IRR than an IMP plant if the capital cost was $2 million and the operating costs were at the lower end of the range examined. For all other scenarios plant cost and operating cost the IMP returned a higher IRR than a large scale oil-only plant.

Small scale evaporative cell oil extraction

Biomass could be delivered to a convenient location in the paddock for oil extraction at a cost of $25.16 per tonne, this is equivalent to the IMP feedstock total cost minus transportation costs (Table 4). The revenue from oil contained in the biomass regardless of recovery level is less than this cost (Table 5).

Table 5: Revenue from oil extracted per tonne of biomass at a range of oil recovery rates

Recovery	60%	70%	80%	90%	100%
Oil value per tonne of biomass	$12.60	$14.70	$16.80	$18.90	$21.00

All scenarios except the base case had some capital available for extraction at some recovery rates (Table 6). Funds available for oil extraction only exceeded $15 per tonne of biomass for scenarios 6 and 10 with 100 percent recovery.

Table 6: Funds available for in the field oil extraction

Scenario	60%	70%	80%	90%	100%
1	-$12.56	-$10.46	-$8.36	-$6.26	-$4.16
2	-$8.36	-$5.56	-$2.76	$0.04	$2.84
3	-$6.26	-$3.11	$0.04	$3.19	$6.34
4	-$4.84	-$2.74	-$0.64	$1.46	$3.56
5	-$8.96	-$6.26	-$3.56	-$0.86	$1.84
6	$0.04	$4.24	$8.44	$12.64	$16.84
7	-$0.64	$2.16	$4.96	$7.76	$10.56
8	-$3.56	$0.04	$3.64	$7.24	$10.84
9	$1.46	$4.61	$7.76	$10.91	$14.06
10	-$0.86	$3.19	$7.24	$11.29	$15.34
11	-$1.24	$1.46	$4.16	$6.86	$9.56

Discussion

Based on the results presented in this paper only the IMP will be able to produce oil at the price required to enter the industrial solvent market. These results will now be discussed for each industry.

Integrated mallee processing plant

The IRR of 28.9 percent calculated for the IMP in the study when oil was sold at $3 per kilogram exceeded the IRR of 18.8 percent reported in the feasibility study (RIRDC, in press). This was because this study simplified the calculation removing the inflation of purchase costs, and taxation of profits and plant depreciation.

Decreasing the sale price of oil to $2 per kilogram reduced the IRR by 3.1 percentage points to 25.8 percent. Whilst this lessens the attraction of the investment slightly it enables the oil to be aggressively priced in order to hasten market penetration. This could be an acceptable marketing strategy for later IMP plants after the higher value oil markets saturate.

The IRR for farmers supplying the IMP are positive for both average and high productivity oil mallees. Although these IRRs will not make the farmers wealthy they are a good start for an infant industry and they begin building an economically viable Landcare option.

Large scale oil extraction

The results presented in this paper for the base case support previous studies by Bartle (1996) and Cooper (2000). A large scale industry relying solely on eucalyptus oil for income is not likely to produce oil at a low enough price to enable entry into the industrial solvent markets. Even in the case of setting multiple parameters to optimistic levels, hypothetical oil extraction industries appeared unlikely to compete with the IRR of an integrated mallee processing plant (Figure 1).

Examination of costs (Table 4) demonstrates that the agricultural and harvest costs per tonne of leaf only are almost three times those for biomass. This is because leaves cannot be grown or harvested alone, so the cost of growing and harvesting stems must also be paid even if stems are not used. The value of the oil in the leaves is insufficient to pay for whole biomass to be grown and harvested. Therefore, industries such as the IMP need to be developed that allow multiple products to share the agricultural production and harvest costs. Any additional product using a complementary part of the mallee in which the feedstock is more valuable than the transportation costs would help share costs and hence decrease the oil production cost.

Small scale evaporative cell oil extraction

Despite low extraction costs and eliminating biomass transport costs, the evaporation cell concept will not be able to supply into the industrial solvent market. As with large scale oil extraction, the cost of growing and harvesting mallees exceeds the product value when oil is sold at $2 per kilogram. Revenue exceeds growing and harvest costs by approximately $15 only when recovery is 100 percent and optimistic values are used for two parameters, one of which is a high oil price. This suggests that evaporative cell extraction will be more suited to lower volume higher price boutique oil markets than the high volume, low price industrial solvent market.

Conclusions

Integrated mallee processing plants producing three products can produce oil at a low enough cost to enable an aggressive market development position to be taken. This is due to cost sharing of the growing and harvest costs by a high value product made from the quality wood chip, oil from the leaves and energy production from all the residues. At the same time the price paid to farmers is sufficient to drive mallee planting for land care in an effort to decrease the impact of salinity. Conversely, neither large scale oil production nor small scale paddock extraction are likely to be able to produce oil at low enough cost to be competitive in the bulk solvent market. Low cost paddock extraction is only likely to succeed for small scale high value markets. Based on this study there appears to be little scope for large scale eucalyptus oil extraction industries that produce oil as the only product.

In order to win access to the large industrial solvent markets and open the prospect for large scale revegetation, mallee feedstocks will have be used for multiple products. The projected nine IMP plants to be built in Western Australia will not saturate industrial solvent markets or the agricultural region's need for perennial crops. Therefore, more multiple product industries need to be developed to use the woody component of mallees, the oil from the leaves and the residues, and for other perennial crops.

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