



An Australian Government Initiative



Profitability of Agroforestry in the Medium to Low Rainfall Cropping Zone

**A report for the RIRDC/Land & Water
Australia/FWPRDC/MDBC
Joint Venture Agroforestry Program**

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Foreword

Increasing research effort is being directed towards the identification and adoption of perennial plants suited to the medium and low rainfall cropping zones of Australia. Before new land use systems such as woody crops can be integrated with traditional agricultural enterprises, it is important to evaluate their profitability.

This publication reports a series of case studies comparing the relative profitability of different agricultural systems incorporating woody crops with conventional agriculture in the dryland cropping zones of Western Australia (WA) and New South Wales (NSW). It uses current agricultural land practices to provide economic hurdles that prospective woody crops will need to clear to become a viable component of low-medium rainfall agriculture. The results of these analyses will help focus R&D effort in designing profitable agroforestry systems, and provide investment information required by growers, investors and government.

The WA case studies were maritime pine (*Pinus pinaster*), oil mallees (*Eucalyptus loxophleba* subsp. *lissophloia*, *E. kochii* subsp. *plenissima* and *E. polybractea*), tagasaste (*Chamaecytisus proliferus*) and a conceptual woody phase crop. The NSW case studies were blue mallee (*E. polybractea*), jojoba (*Simmondsia chinensis*), and river red gum (*E. camaldulensis*). The systems analysed were alley farming, phase farming and plantation layouts. Results of partial budgeting and discounted cash flow techniques used in comparative analyses of alternative land use scenarios are reported. For each scenario the cash flow graphs, net present value, annual equivalent returns, break-even time, payback period and peak debt are reported. Estimates of temporal and spatial interactions between woody crops, and herbaceous crops and pastures are included to provide estimates of the indirect economic value of trees. Finally, a series of ‘what-if?’ sensitivity analyses highlight the biological, physical and market variables with the greatest impact on the viability of each agroforestry system.

The regions analysed have 325–450mm rainfall. The project found that oil mallee has the greatest potential for further development in the WA cropping zone, and jojoba and blue mallee were the most promising commercial prospects for the NSW cropping zone. The most attractive projects offset the costs of establishment e.g. share-farming, or integrate the trees with conventional agriculture and regularly harvest for biomass or use grazing by livestock e.g. alley farming. To assist development of these options, alternative debt financing and capital development funding schemes should be investigated, and joint venture financing arrangements where there are large up-front establishment costs. Additional data on commercial yields of trees, and industry level and farm-level business analyses are needed for the most promising agroforestry systems.

This project was funded by the Joint Venture Agroforestry Program (JVAP), which is supported by three R&D Corporations — Rural Industries Research and Development Corporation (RIRDC), Land & Water Australia, and Forest and Wood Products Research and Development Corporation (FWPRDC), together with the Murray-Darling Basin Commission (MDBC). The R&D Corporations are funded principally by the Australian Government. State and Australian Governments contribute funds to the MDBC.

This report, a new addition to RIRDC’s diverse range of over 1500 research publications, forms part of our Agroforestry and Farm Forestry R&D program, which aims to integrate sustainable and productive agroforestry within Australian farming systems.

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Peter O’Brien

Managing Director

Rural Industries Research and Development Corporation

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Contents

Foreword	iii
Acknowledgments	iv
List of figures	vii
List of tables	viii
Abbreviations	xi
Executive Summary	xii
Introduction	1
Methodology	3
Modelling of agroforestry	3
Investment analysis	4
Indicators of profitability and cash flow viability	6
Uncertainties and sensitivity analysis.....	7
The analytical spreadsheet tool - <i>Imagine</i>	8
Data collection.....	9
Overview of farming systems	11
General assumptions for WA and NSW	11
The northern agricultural region of WA.....	12
The central west region of NSW	16
WA case study 1 – maritime pine	18
Background	18
Scenarios	18
Assumptions	19
Cash flow and profitability	20
Sensitivity analysis.....	22
Conclusions	23
WA case study 2 – oil mallee	24
Background	24
Scenarios	24
Assumptions	24
Cash flow and profitability	26
Sensitivity analysis.....	27
Conclusions	29
WA case study 3 – tagasaste	30
Background	30
Scenarios	30
Assumptions	31
Cash flow and profitability	32
Sensitivity analysis.....	34

WA case study 4 – woody phase	37
Background	37
Scenarios	37
Assumptions	38
Cash flow and profitability	39
Sensitivity analysis	40
Conclusions	42
NSW case study 1 – blue mallee	43
Background	43
Scenarios	43
Assumptions	43
Cash flow and profitability	44
Sensitivity analysis	46
Conclusions	47
NSW case study 2 – jojoba	48
Background	48
Scenarios	48
Assumptions	49
Cash flow and profitability	49
Sensitivity analysis	51
Conclusions	52
NSW case study 3 – <i>Eucalyptus camaldulensis</i>	53
Background	53
Scenarios	53
Assumptions	53
Cash flow and profitability	54
Sensitivity analysis	56
Conclusions	56
Conclusions	57
Recommendations	59
References	60

List of figures

Figure 1. The net benefit of tree belts is a combination of the value of the tree product plus the positive and negative interactions of tree belts and the crops and pastures in the inter-rows.	4
Figure 2. The cash flow of two scenarios of <i>Pinus pinaster</i> compared with sheep grazing pastures in conventional agriculture.....	21
Figure 3. The cash flow of the oil mallee project compared to long sequence of wheat-lupin rotation.	27
Figure 4. The cash flow of the tagasaste project compared to long sequence of pasture for cattle grazing in conventional agriculture.....	34
Figure 5. The cash flow of an agroforestry project with the woody phase crop compared with a conventional agricultural land use sequence of whet and pasture.	40
Figure 6. The cash flow of alley farming with blue mallees compared to a typical agricultural land use in NSW.....	45
Figure 7. The cash flow of the jojoba plantation compared with conventional agriculture	50
Figure 8. The cash flow of the <i>E. camaldulensis</i> plantation compared with conventional agriculture.....	55

List of tables

Table 1.	List of abbreviations used in this report	xi
Table 2.	Summary of financial analysis of the Western Australian case studies.....	xiv
Table 3.	Summary of financial analyses of the News South Wales case studies.....	xiv
Table 4.	Parameters related to the interactions between woody crops, annual herbaceous crops and annual pastures in NSW and WA.	12
Table 5.	Cattle and sheep production parameters for NSW and WA.	12
Table 6.	Livestock feed supply and demand during the summer/autumn feed gap in WA.....	13
Table 7.	Assumptions of the sheep production system in WA.	14
Table 8.	Value and utilization of crop residues for livestock nutrition in WA.	15
Table 9.	Assumptions of the cattle production system in WA.....	15
Table 10.	Assumptions of the grain production systems in WA.....	15
Table 11.	Assumptions of the sheep production system in NSW.	17
Table 12.	Parameters related to the contribution of cereal crop stubbles to sheep production in NSW.	17
Table 13.	Assumptions of the grain production system in NSW.....	17
Table 14.	Establishment and maintenance costs of a plantation of maritime pine trees.	19
Table 15.	Price of different products harvested from the plantation of maritime pine.	19
Table 16.	Yield of products of maritime pine at different harvests.	19
Table 17.	Profitability and cash flows of timber production with maritime pine compared with agriculture.	20
Table 18:	Sensitivity of profitability and cash flows of forestry with maritime pine to variations in some key assumptions.....	22
Table 19.	Establishment and production costs of oil mallee trees	25
Table 20.	Price of the product of oil mallee trees and associated harvest costs of the product.	25
Table 21.	Yield of biomass from oil mallee trees and height of trees before and after harvest.....	25
Table 22.	Assumptions for competition and shelter between mallees and adjacent herbaceous plants.....	25
Table 23.	Profitability and cash flows of oil mallee in an alley farming system compared with agriculture.	26
Table 24.	Sensitivity of profitability and cash flows of alley farming with oil mallees to variations in some key assumptions.....	28
Table 25.	Ranking of parameter sensitivity assuming ranges of sensitivities tested are equally likely to occur for each parameter tested.	29
Table 26.	Establishment and production costs, harvest schedules, and expected tagasaste production for cattle production in an alley farming system.	31

Table 27. Establishment and production costs, harvest schedules and expected tagasaste production for cattle production in a plantation system.....	32
Table 28. Profitability and cash flows of cattle production with or without tagasaste in both alley and plantation layouts.	32
Table 29. Sensitivity of profitability and cash flows of cattle production with tagasaste to variations in assumptions regarding cattle price and stocking rates.	35
Table 30. Sensitivity of profitability and cash flows of cattle production with tagasaste to variations in assumptions concerning the spatial interactions in the alley farming system.....	36
Table 31. Establishment and maintenance costs of a plantation of a woody phase crop.....	38
Table 32. Biomass and harvest costs from a woody phase crop.....	38
Table 33. Yield of biomass from a woody phase crop.....	38
Table 34. Temporal interactions between a woody phase crop and subsequent agricultural activities.....	39
Table 35. Profitability and cash flows of acacia phase farming compared with a conventional agricultural rotation.	39
Table 36. Sensitivity of profitability and cash flows of a farming system incorporating a woody phase crop to variations in some key assumptions.....	41
Table 37. Ranking of parameter sensitivity assuming ranges of sensitivities tested are equally likely to occur for each parameter tested.	41
Table 38. Establishment and production costs of blue mallee trees, all costs based on area planted to mallees.....	44
Table 39. Price of the product of blue mallee trees and associated harvest costs.	44
Table 40. Yield of biomass from blue mallee trees and height of trees before and after harvest.....	44
Table 41. Profitability and cash flows of blue mallees in an alley farming system compared with agriculture.	44
Table 42. Sensitivity of profitability and cash flows of alley farming with blue mallees to variations in some key assumptions.....	46
Table 43. Ranking of parameter sensitivity assuming ranges of sensitivities tested are equally likely to occur for each parameter tested.	47
Table 44. Establishment and production costs of a jojoba plantation.....	49
Table 45. Price of jojoba oil and associated harvest costs.	49
Table 46. Yield of oil from a jojoba plantation at different harvests.	49
Table 47. Profitability and cash flows of a jojoba plantation compared with conventional agriculture.	50
Table 48. Sensitivity of profitability and cash flows of a plantation of jojoba shrubs to variations in some key assumptions.....	52
Table 49. Ranking of parameter sensitivity assuming ranges of sensitivities tested are equally likely to occur for each parameter tested.	52
Table 50. Establishment and production costs of an <i>E. camaldulensis</i> plantation.....	54
Table 51. Price of wood and timber harvested from an <i>E. camaldulensis</i> plantation.....	54

Table 52. Yield of wood and timber from a plantation of <i>E. camaldulensis</i> at different harvests.	54
Table 53. Profitability and cash flows of a plantation of <i>E. camaldulensis</i> compared with agriculture.	55
Table 54. Sensitivity of profitability and cash flows of a plantation of <i>E. camaldulensis</i> to variations in some key assumptions.....	56

Abbreviations

Table 1. List of abbreviations used in this report.

ABARE	Australian Bureau of Agricultural and Resource Economics
AER	Annual Equivalent Return
CALM	Department of Conservation and Land Management, Western Australia
CRC	Cooperative Research Centre
DAWA	Department of Agriculture, Western Australia
DCF	Discounted Cash Flow
FPC	Forest Products Commission, Western Australia
ha	hectare
IRR	Internal Rate of Return
JVAP	Joint Venture Agroforestry Program
kg	kilogram
MJ	Mega Joules
mm	millimetres
N/A	Not Applicable
NPV	Net Present Value
NSW	New South Wales
NSWAG	New South Wales Department of Agriculture
R&D	Research and Development
RIRDC	Rural Industries Research and Development Corporation
t	tonne
WA	Western Australia

Executive Summary

What the report is about

This publication reports a series of case studies comparing the relative profitability of different agricultural systems incorporating woody crops with conventional agriculture in the dryland cropping zones of Western Australia (WA) and New South Wales (NSW). It uses, as comparators, current agricultural land practices as economic benchmarks. Farming systems incorporating prospective woody crops are compared to these benchmarks to ascertain their commercial viability in the low-medium rainfall agricultural environments. The economic methodology and the spreadsheet developed to evaluate these farming systems have broad application to the evaluation of alternative land uses.

Background, and who the report is for

One of the fundamental determinants of adoption of any new land use system is profitability. However, perceptions of profitability for prospective land use systems need to be supported by sound data and appropriate analytical methods. This study was carried out to identify the key drivers of profitability for woody perennial crops to better focus R&D effort and generate the information required by growers, investors and governments to make sound investment decisions.

Methods

In Stage 1 of the project, a database of biophysical and economic data was developed for the seven farming systems. The dataset for WA included oil mallees (*Eucalyptus loxophleba* subsp. *lissophloia* and *E. polybractea*), tagasaste (*Chamaecytisus proliferus*), maritime pine (*Pinus pinaster*) and a conceptual woody phase crop. The NSW dataset included blue mallee (*E. polybractea*), jojoba (*Simmondsia chinensis*), and river red gum (*E. camaldulensis*). Datasets for both states included information for crops and pastures used in current agricultural systems.

In Stage 2, comparative analyses of alternative scenarios were conducted using partial budgeting and discounted cash flow techniques. A spreadsheet application, *Imagine*, provided the analytical framework and computational environment for analysing the case studies. Net Present Value, Annual Equivalent Return, Peak Debt, Break-Even Period and Payback Period of each agroforestry scenario were calculated (see definitions below) (Table 2).

- Net Present Value (NPV) is the lump sum value of the project expressed as the sum of discounted annual net returns. A 7% discount rate was applied across all case studies.
- Annual Equivalent Return (AER) is an indicator of the profitability of a project on an annual basis. This indicator allows profitability of long duration woody crops to be compared with shorter agricultural rotations.
- Break-even period is the length of time before the cumulative cash flow of the agricultural system incorporating woody crops equals or exceeds that of conventional agriculture.
- Peak debt is the highest discounted cumulative cash deficit during the investment project.
- Payback period is the length of time required for the discounted cumulative cash deficits of an agricultural system incorporating woody crops to become surpluses.

Results:

WA case studies

Maritime pine for timber production as a share-farming operation with the WA Forest Products Commission (FPC) produced an AER of \$52/ha with no debt and zero payback period. Under this arrangement, FPC pays the landowner to gain access to their land and finances the cost of establishing the plantation. Revenues from timber sales were shared 80:20 between FPC and the landowner. In comparison, maritime pine plantations established and managed by the landowner had

an *AER* of \$14/ha. Additionally, the establishment costs combined with a wait of 15 years until first income make farmer managed pines unattractive from a cash flow perspective. The poor quality pastures that can be supported on this soil type have an *AER* of \$31/ha.

Oil mallee in an alley farming configuration on deep sandy soils in the medium rainfall zone of the Upper Great Southern agricultural region of WA with a wheat-lupin rotation in the alleys had an *AER* of \$125/ha, peak debt of \$290/ha and a payback period of three years compared with conventional agriculture which had an *AER* of \$121/ha. The farming system including oil mallees did not break-even with conventional agriculture until year 20.

Tagasaste for cattle production in alley farming or plantations proved more profitable than cattle production from conventional annual pastures. Tagasaste in alley farming generated an *AER* of \$37/ha per annum while cattle production in a tagasaste plantation generated an *AER* of \$44/ha. The cost of establishment meant the landowner waits 16 and 6 years respectively for plantations and alley farmed tagasaste to break-even with conventional cattle production. The experience that tagasaste can provide a valuable feed source from the 2nd year after planting is a key factor in its profitability. The poor quality pastures that can be supported on this soil type have an *AER* of \$31/ha.

Conceptual woody phase crops farmed in rotation with wheat and pasture on the sand over clay duplex soils of the medium rainfall zone of the Upper Great Southern region of WA had an *AER* of \$140/ha compared to \$176/ha for conventional agriculture with two years of wheat followed by two years of annual pasture. Under phase farming the paddock is planted to a woody phase crop for four years. At the end of that period, the trees are removed and the entire tree biomass is sold off-farm. The paddock is returned to the agricultural rotation for a period of sixteen years before another four-year woody phase crop. Phase farming has a peak debt of \$371/ha occurring in year four and a payback period of four years. Under these assumptions, the farming system incorporating a woody phase crop does not break even with the conventional agriculture.

NSW case studies

Blue mallee in alley farming on red brown earths in the central west zone of NSW had an *AER* of \$186/ha, a peak debt of \$104 in the first year and a payback period of one year. The farming system incorporating blue mallees broke-even with the conventional cereal pasture rotation in year six. The conventional rotation was a seven-year rotation of barley, wheat and pasture and had an *AER* of \$103/ha.

Jojoba is the most profitable case study reported here. A jojoba plantation generates an *AER* of \$1256/ha per annum, twelve times more profitable than conventional agriculture, which had an *AER* of \$103/ha. However, to achieve this reward the landowner must be able to endure a peak debt of \$6400/ha in year six and has to wait 11 years for a positive cash flow.

River red gum (*E. camaldulensis*) grown in plantations for timber production was not viable under the assumptions used, making a loss of \$181/ha. The high establishment costs resulted in a peak debt of \$2716/ha in the 35th year after planting and it did not break-even with conventional agriculture. The main reasons for negative net returns are the high establishment costs and the long wait before timber of only modest yield and market value could be harvested. Timber harvest was assumed to take place in the 20th and the 35th year after planting. Timber products include firewood, posts, and several grades of sawlogs. In projects such as this where revenues occur towards the end of the life of the project, discounting erodes the value of the harvest making it difficult to overcome the establishment costs at the beginning of the project. This is a common problem with slow growing timber crops.

Table 2. Summary of financial analysis of the Western Australian case studies.

Agroforestry systems	Enterprise and products	NPV (\$/ha)	Analysis Period (years)	AER (\$/ha)	AER Agricultural Comparator (\$/ha)	Peak debt (\$/ha)	Break-even period (years)	Payback period (years)
1a Maritime pine Farmer established Plantation	Timber	176	33	14	31 ^{PS}	984 year 15	Not reached	32
1b Maritime pine FPC established Plantation	Timber	668	33	52	31 ^{PS}	Nil	Immediate	Immediate
2 Oil Mallee Alley farming	Biomass, sheep and grains	1334	20	125	121 ^{WLWL}	289 year 1	20	3
3a Tagasaste Alley farming	Cattle	466	33	37	31 ^{PC}	28 year 1	6	1
3b Tagasaste Plantation	Cattle	555	33	44	31 ^{PC}	360 year 2	16	8
4 Phase farming	Biomass, sheep and wheat	1485	20	140	176 ^{WWPP}	371 year 4	Not reached	4

^{PS} continuous pasture grazed by sheep; ^{PC} continuous pasture grazed by cattle; ^{WLWL} continuous cropping rotation of two years of wheat followed by one year of lupins; ^{WWPP} rotation of two years of wheat followed by two years of pasture. After the grain is harvested, sheep graze the crop residues and stubbles in summer and autumn. The pasture phase is for winter and spring grazing of sheep for production of wool and meat.

Table 3. Summary of financial analyses of the News South Wales case studies.

Agroforestry systems	Enterprise and products	NPV (\$/ha)	AER (\$/ha)	AER Agricultural Comparator (\$/ha)	Peak debt (\$/ha)	Break-even Period (year)	Payback period (year)
5 Blue mallee Alley farming	Oil, wheat & barley, and sheep	2,018	186	103 ^{CP}	140 year 1	6	2
6 Jojoba Plantation	Oil	13,683	1,256	103 ^{CP}	6,400 year 6	12	12
7 <i>E. camaldulensis</i> Plantation	Timber	-2,353	-181	103 ^{CP}	2716 year 35	Not reached	Not reached

^{CP} seven-year rotation of barley and wheat grain crops and a pasture phase. After the grain is harvested, sheep graze the crop residues and stubbles in summer and autumn. The pasture phase is for winter and spring grazing of sheep for production of wool and meat.

General observations

- Jojoba (*Simmondsia chinensis*) in NSW stood out as clearly more profitable than conventional agriculture. Under the assumptions used in this analysis jojoba had an AER \$1,153/ha higher than conventional agriculture. The other woody crop systems studied were within $\pm$ \$100/ha of conventional land use with the exception of *E. camaldulensis* for sawlogs in NSW which delivered an AER \$284/ha less than a cereal pasture rotation. Blue mallee has the lowest peak debt and shortest break even period of all the NSW agroforestry system investigated. It has higher profitability than the conventional agricultural land use which translates to \$83 per ha more profit per annum.

- The least viable woody crop systems are those requiring complete replacement of crops and pastures by a woody crop with high up-front costs and a long harvest cycle.
- Where integrated systems such as alley farming are economically competitive with traditional agriculture, interactions between trees and crops can make a significant difference to the relative profitability.
- The analytical framework developed here has potential to be applied more generally in evaluating alternative land uses, given its ability to handle spatial and temporal interactions with existing land use and its in-built sensitivity analysis.

Recommendations

1. Oil mallee has the greatest potential for further development in the WA cropping zone. Additionally, both maritime pine share-farming and tagasaste are economically attractive alternatives for infertile sandy soils in areas with a mean annual rainfall exceeding 450mm.
2. Jojoba and blue mallee were the most promising commercial prospects for the NSW cropping zone. Further research to determine potential yield, market size and demand elasticity for the oils from these woody crops is required.
3. The development of alternative debt financing and capital development funding schemes should be investigated for agroforestry systems generating products for on-farm use, where they represent the most profitable perennial land use options for a particular land management unit or region. Perennial fodder species, like tagasaste, require further whole-farm economic analysis. They provide valuable feed during the feed gap in autumn and early winter and can affect the carrying capacity of the entire farm.
4. Joint venture financing arrangements should be investigated where there are large up-front establishment costs. Such arrangements, making annuity payments to growers, provide incentives for adoption through early cash flow. These payments could be extended to include environmental services when institutional arrangements and markets have been established for credits associated with carbon sequestration or salinity.
5. For the promising agroforestry systems reported here future business analyses, at both industry level and farm-level, should account for the perspectives of different stakeholders. These include the landowner, the investors or equity partners providing the financial capital for whole or part of the project, the buyers, processors and manufacturers of the tree products. For a more complete analysis, the analytical framework should be further developed to incorporate modules on debt financing, capital budgeting, taxation subsidies and groundwater impact.
6. Additional empirical data needs to be collected to firm up estimates of commercial yields of trees evaluated in this project. Estimates of various parameter values varied widely among agronomists, forest researchers, hydrologists and tree crop advocates. There was a diversity of expert opinion about the production of trees and their likely responses to edaphic and climatic conditions and to silvicultural management. This indicates a problem for the industry as it is unlikely that landowners, any potential investors or equity partners would seriously consider tree cropping investment projects without sound and credible production and cost estimates.

Introduction

The medium to low rainfall zone occupies some 47 million hectares across southern Australia. This zone is dominated by cropping and mixed livestock production. State and Federal institutions are increasingly directing larger R&D efforts into the identification and adoption of suitable perennial plants for this area. The CRC for Plant-Based Management of Dryland Salinity, the FloraSearch cosponsored by RIRDC and the aforementioned CRC, and the NSW Farm Forestry Advisory Unit are examples of R&D teams with aims to develop woody perennial crops suitable for large-scale adoption in this zone.

In a report to JVAP, Buffier and The Allen Consulting Group (2002) stated that “Low returns form a significant barrier to agroforestry investment in areas where it is likely to deliver environmental benefits, especially in low to medium rainfall areas.” They believed to overcome the low returns tree based industries need to be developed in medium and low rainfall areas. Second, they argued for payments for off-farm environmental services as some environmental benefits flow off-farm. This is an area subject to ‘market failure’. Many of the environmental gains are unpriced public goods or externalities. This report focuses on the first issue of identifying which of the prospective agroforestry options proposed for the low to medium rainfall cropping zones of WA and NSW are profitable when compared with conventional agricultural practices.

One of the fundamental determinants of adoption of innovations is farmers’ perception of profitability of innovations. It is well established that landholders base their decision mainly on the actual profitability and cash flow consequences of an innovation (Abadi Ghadim and Pannell 1999, Trapnell 2001). Jgap and Ong (1997) warned against widely advocating so called ‘best-bet’ technologies to farmers without first carrying out an analysis of the conditions and scenarios under which agroforestry would be economically viable. Their warning was based on experiences in Africa where promotion of ‘best-bets’ in the absence of farming systems analysis has proved very costly and often led to a loss of credibility with farmers and research donors. Determining these boundary conditions for agroforestry in southern Australia requires an integrated farming system analysis inclusive of interactions between different phases of land use. Economic analyses that identify key drivers of profitability of alternative agroforestry systems can help focus R&D effort in generating the information required by growers, investors and governments to make sound investment decisions.

This publication reports on a series of case studies comparing profitability of seven agroforestry systems with conventional agricultural land uses in the cropping zones of WA and NSW. It maps out the economic boundary conditions under which several promising agroforestry systems may be viable.

The first section of the report contains the methodology and analytical framework used to evaluate the alternative scenarios. It describes the partial budgeting and discounted cash flow techniques used to conduct comparative analyses of alternative uses of a block or paddock. This section also includes a description of the spreadsheet application, *Imagine*, developed to carry out the analyses. This section ends with a table of general assumptions in the analysis of all the case studies. The second section gives an overview of the farming systems of WA and NSW. It includes a description of climate, soils, land use sequences and rotations as well as crop yields and pasture carrying capacities. Tables of assumptions about the costs, yields and prices of commodities of conventional agricultural systems complete this section.

The sections that follow are dedicated to each of the case studies. The four WA case studies were oil mallees (*Eucalyptus loxophleba* subsp. *lissophloia* and *E. polybractea*), tagasaste (*Chamaecytisus proliiferus*), maritime pine (*Pinus pinaster*) and a conceptual woody phase crop. The three NSW case studies were blue mallee (*E. polybractea*), jojoba (*Simmondsia chinensis*), and river red gum (*E. camaldulensis*). For each case study, a series of tables describe the assumptions used to

evaluate different scenarios. Tables of results list the *NPV* and *AER*, break-even time, payback periods and peak debt of each scenario.

Imagine, the analytical spreadsheet tool used in the study, and the user manual accompanies this report. Additional copies are available on request from the authors.

Methodology

Modelling of agroforestry

In agroforestry projects, trees and shrubs are incorporated into farming systems for direct net benefits derived from tree products as well as the indirect net benefits resulting from their interaction with agricultural activities. Direct benefits may include the profit derived from production and sale of timber or biomass while indirect benefits may include shade, shelter and increased water use of the farming system. The term net benefit refers to the benefit that remains after establishment and maintenance costs as well as the positive and the negative interactions have been accounted for.

Plantation is the most common layout for trees in farming systems. A plantation is a planted forest of either native or exotic species with small plantations known as blocks or woodlots. Woodlots may also be grown in rotation with agriculture in 'phase farming' systems (Stirzaker *et al.* 2002). A typical phase farming rotation would be several years of grain crops or pastures between the phases of woody perennials. The idea is that soil moisture stored deeper in the profile during the agricultural phase would be depleted by the woody crop sponsoring enhanced growth. A major attraction of this system is the role woody perennials may play in managing the hydrological balance of the land.

Alley farming is a form of agroforestry where trees are arranged in belts with conventional agriculture in the 'alleys' between the tree belts. Tree belts are usually planted in straight rows or along contours, with either pasture or grain crops between the belts. Alley layouts are suited to agroforestry systems where trees such as oil mallees are regularly machine harvested or forage shrubs like tagasaste are grazed by livestock. Wide-spaced alley farming systems with alleys of 60 to 90 metres minimise the inconvenience to broadacre grain cropping requiring large boom sprays and seeding gear.

The choice of analytical framework that is used when considering the economic or commercial merits of changing from a conventional agriculture to a more complex one that integrates tree crops into the paddock is determined by the following question. Does a farming system that incorporates trees generate more profit than the conventional use of that land? It is important to know what a farmer earns from the existing land use to compare it with the proposed agroforestry project (Dayanandra *et al.* 2002). In the low to medium rainfall farming systems of Australia conventional agricultural land uses are typically grain and livestock production from a variety of crop and pasture enterprises.

The economic analysis used to evaluate these case studies incorporates a partial budgeting method. With this method the costs and returns, including those associated with the interactions between enterprises, were compared for each project or scenario (Makeham and Malcolm 1993). The opportunity cost of land was accounted for by comparing the cash flows of new tree crops to those of conventional agricultural land use.

In the comparative analysis, key assumptions were held constant while two scenarios or alternative land uses were compared. The constants are items such as project life, discount rate, farmer's terms of trade, block size and soil type. The partial budgeting technique asks the question, 'how much better off would a farmer be replacing his conventional agricultural practice with an agroforestry project?'

Tax is an important issue when an investor is considering the prospects of changing land management strategies (Trapnell 2001). However, consideration of taxation effects were beyond the scope of this study as the myriad of options and methods available for managing taxation make it difficult to arrive at a consensus on how to account for tax. Future studies may investigate taxation further.

In diversified and complex farming systems with a mixture of woody perennials as well as annual crops and pastures, the temporal and spatial interactions may be an important economic factors. It is important to account for competition for light, water and nutrients between enterprises. Combinations of trees and agricultural crops and pastures will only be profitable if the value of tree products and any benefits from shelter exceed the value of displaced crops and decline in crop yield through competition (Figure 1).

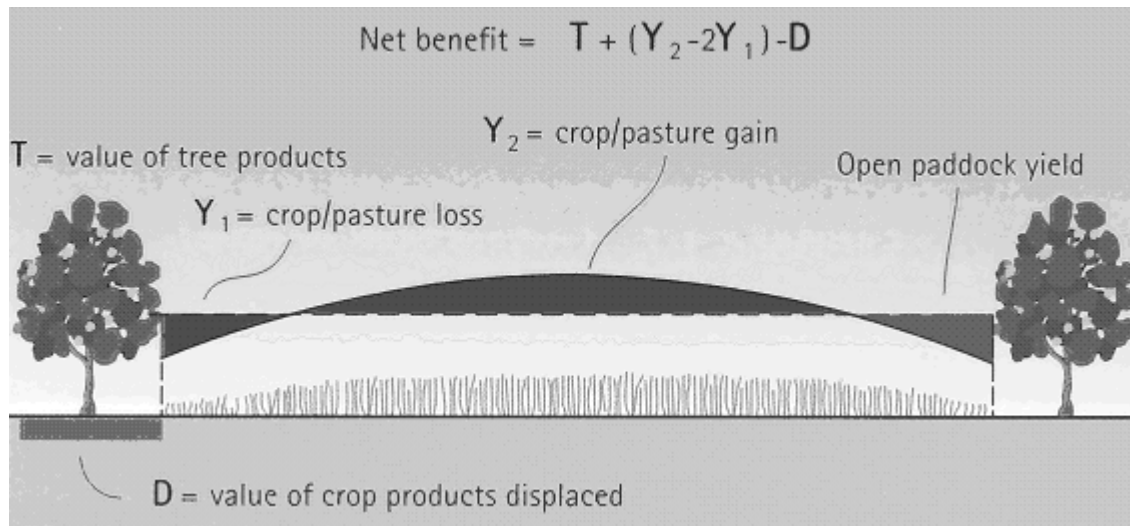


Figure 1. The net benefit of tree belts is a combination of the value of the tree product plus the positive and negative interactions of tree belts and the crops and pastures in the inter-rows. Image adapted from Lefroy and Scott (1994).

Cash flow estimates of growing woody perennials as a business enterprise will vary depending on a variety of factors. The largest impact on eventual cash flows is the yield of the main products from woody crop stands. The yield of woody perennials can be expressed as the volume of harvestable timber or other products, such as oil, produced at the specified harvest time. Numerous other bio-economic factors such as harvest-age and product price, as well as the interaction effects of one enterprise on another may affect eventual cash flows.

The largest common cash outflows associated with woody perennial crop operations are the establishment costs. These include land and site preparation such as clearing, fencing and ripping; purchase of planting stock, planting and watering. Other common cash outflows include weed control, fertilisers, pruning and thinning, and commercial harvesting. The major cash inflows come from the sale of one or more products from the trees including wood products such as sawlogs, and oil distilled from tree biomass.

Investment analysis

Most investment strategies involving tree-planting projects require expenditure 'up-front' with no returns for many years after the initial investment. To assess profitability of such a venture from a farmer's perspective, cash flows need to be assessed over the life of the project.

When analysing the financial consequences of an alternative project, investors require several important indicators of its financial viability before deciding between the innovation and the conventional practices. The first is whether the innovation is more profitable than the existing

alternative in the long run. The second is the question of cash flow. What is the pattern of cash flow associated with the new investment when compared with current conventional investments? This section describes procedures for calculating the key financial indicators of the viability of agroforestry investments.

Discounted cash flow technique

To answer the question whether an agroforestry project is more profitable in the long run than the existing alternative, it is necessary to conduct a Discounted Cash Flow analysis (*DCF*). Discounting of future costs and returns converts all numbers to a present day value. *DCF* is used to factor in different time preferences for money invested today for return on that investment in the future. This allows different cash flow streams to be compared on the same present day basis. Such an allowance is important for investment projects where the main costs or cash outflows occur in the initial years while the revenues or cash inflows are lagged and spread over many years. *DCF* analysis calculates the *NPV* of projects, a lump sum value incorporating the stream of discounted annual net returns.

There are two approaches to calculating *NPV*. One method is to forecast expected net profit from the project and adjust it for non-cash flow items such as depreciation. The second method, the one used here, is to estimate or forecast net cash flows directly. The cash inflows for agricultural and agroforestry projects are derived from yield and price estimates for all products at the scheduled harvest times. Cash outflows include expenditure on the so-called variable costs of establishment and maintenance of the crops, harvest processing, and transport of the crop products (Peirson *et al.* 2002).

The use of discounting and comparative analysis of cash flows provides a sound framework for the economic analysis of agroforestry projects because it accounts for the opportunity cost of key resources, such as land and credit. For example, the land planted to trees cannot be used for other enterprises until the trees are harvested and the land is cleared. If conventional agricultural enterprises such as crops and sheep grazing were producing a positive net income then the opportunity to continue earning that income is lost.

Discount rate

In *DCF* analysis the choice of discount rate is important and should reflect the interest earnings possible from the next best investment. Discount rate is the rate of interest at which the streams of cash inflows and outflows associated with a project are to be discounted. For commercial projects, the discount rate is commonly based on the cost of capital to the firm. The convention is to use a real interest rate – roughly equivalent to current commercial rates less the inflation rate (Peirson *et al.* 2002, Herbert 2000). The discount rate used in this study is 7%.

Project life

To compare different land management scenarios and strategies, it is important to choose the same project life for each project. This avoids a serious conceptual problem arising from mutually exclusive projects with unequal life spans. Agricultural rotations of four to six years duration, when viewed as investment projects, are not comparable to woody perennial projects on an *NPV* basis because the farm business would be in a different financial position at the end of the project if either one was selected (Peirson *et al.* 2002).

For example, a conventional agricultural project has a relatively short rotation of wheat and lupin crops, let's say three years. An agroforestry project, such as a maritime pine plantation, has a life span of thirty years or more. The question arises, what will be the farm's position at the end of the short term agricultural project? This project may have a lower *NPV* but it would give the farm the opportunity to re-invest the released resources from years 4 to 30 whereas the acceptance of the long

term agroforestry project excludes this possibility. Therefore, comparing the two projects solely by their *NPVs* is not a fair comparison (Dayanandra *et al.* 2002, Peirson *et al.* 2002).

Two techniques to handle this issue have been developed by extending the basic *NPV* model. They are the Replacement Chain method and the Annual Equivalent Return (*AER*) method. A discussion of these two methods is beyond the scope of this report but is well explained in Peirson *et al.* (2002) and Dayanandra *et al.* (2002).

In this report the project lengths for the current agricultural rotations have been set the same as those of alternate woody crop option by repeating the agricultural rotation the required number of times. Additionally, *AERs* have been calculated for all agricultural systems.

Indicators of profitability and cash flow viability

Net present value

NPV provides an indication of profitability of investment projects, allowing analysts to rank projects (Peirson *et al.* 2002, Trapnell 2001). *NPV* is the difference between the present value of cash inflows and the present value of cash outflows, all discounted at an appropriate interest rate, i.e. *NPV* is a project's net contribution to the wealth of a farm. An investment creating a positive *NPV* is normally considered acceptable. However, when two or more projects are compared, the one offering the highest positive *NPV* is preferred by the investor. The higher the interest rate used in calculating the *NPV*, the greater the discounting of future cash flows, causing the *NPV* of the project to be lower. *NPV* is the preferred selection criterion for mutually exclusive alternatives (Gittinger, 1982). In this project, *NPV* is used to compare profitability of alternative land uses, ranging from conventional agricultural rotations to novel agroforestry systems.

Annual equivalent return

AER can be thought of as an annuity spreading the net present value evenly across the project life. Discounting is taken into account when calculating the *AER*. For example, a project with a *NPV* of \$1,000, at a discount rate of 10% and a project life of 10 years will have an *AER* of \$163, not \$100 as would be expected if neglecting discounting.

AER is a useful method for comparing profitability of alternative land use systems ranging from short rotations in conventional agriculture to long-term land use such as tree crops.

Peak debt payback and break-even

As well as *NPV* and *AER*, several other financial indicators are reported for each case study including peak debt, payback period and the break-even period (Trapnell 2001).

- Peak debt is the highest cumulative discounted cash deficit (expressed in 2003 dollars) that occurs during the life of the investment project.
- Payback period is the time required for cumulative discounted cash flow of the agroforestry project to become surpluses.
- Break-even period is the time required before the cumulative cash flow of the agroforestry project equals that of the agricultural land use.

Reporting these key cash flow indicators is necessary because, a land owner or investor may reject new investment projects such as agroforestry, with higher profitability than conventional agricultural practices, on the basis of unsustainably high peak debt or long break-even periods. Often there are projects whose payback period is longer than a farmer (investor) can bear. Farmers, like most investors, prefer land management practices that are profitable and have short payback periods.

Uncertainties and sensitivity analysis

The viability of a project, indicated by the various financial summary indicators such as *NPV* or *AER*, is usually based on the ‘best estimates’ or ‘expected values’ of the input parameters of the model used. The *NPV*, based on such estimates, is often referred to as the base-case *NPV*. Any changes or errors in the assumptions about these input parameters results in changes to the cash flow pattern and financial viability of the project. The calculation of base-case *NPV* relies on ‘forecasts’ of cash flows. It was noted by Peirson *et al.* (2002) that in practice these forecasts will almost certainly be incorrect.

Such inaccuracies occur in agroforestry projects because integrating trees into farming systems is a complex innovation. Often there is little precedence or data for the key economic drivers of the project. The reasons may be:

- lack of information on the yield of trees under different management systems
- existing markets for products such as *Eucalyptus* oil are small compared to those of agricultural commodities such as wheat. Therefore, the price for *Eucalyptus* oil is likely to have greater price variability especially if the projects analysed here are looking to be large scale.
- establishment and maintenance costs vary a great deal between producers due to availability of supplies, skilled labour and contractors
- inadequate data on the spatial and temporal interactions between trees, and crop and livestock production systems.

In the presence of such uncertainty it is important the results of financial analyses of agroforestry projects are tested for the effect of changing the key input variables of economic importance. Sensitivity analysis, or ‘what-if’ analysis, involves testing the effect of changes or errors in the estimated variables on the *NPV* and the cash flow pattern (Pannell 1997, Peirson *et al.* 2002). This is achieved by running the financial model with alternative estimates of some key variables.

For the agroforestry projects reported here the question is, what if yields of timber or biomass are not as high as those in the original set of assumptions? How does that affect the *NPV*? Does the agroforestry project ever reach the same profitability as conventional agricultural enterprises? Does it delay the payback period and, if so, by how much?

Peirson *et al.* (2002) state that knowledge of the sensitivity of the results of the financial analysis to changes or errors in the key economic drivers place the investor in a better position to decide if the project is too risky to accept. In addition, being aware of the particular variables the project is sensitive to, researchers and project managers can strive to obtain estimates that are more accurate. The sensitivity analysis can focus and prioritise the R&D effort reducing ‘forecasting’ errors of economically significant parameters.

For the sake of consistency and brevity, the sensitivity analyses in this report focus on a few variables likely to be of economic importance. The sensitivity analyses use pessimistic, optimistic and expected expert-estimates for each key variable, limited to:

- yield of products from the woody perennial crop
- price obtained for products of the woody perennial crop
- costs associated with establishment and maintenance of the woody perennial crop
- harvest and transport costs for the woody perennial crop
- spatial interaction between the woody perennial and neighbouring agricultural crops and pastures
- salvage value at the end of the analysis or cleanup cost after ultimate harvest for the woody perennial
- for the woody phase crop case study, temporal interaction effect of trees on subsequent crops and pastures.

In conducting sensitivity analyses, all other variables were held at the base or original level while the variable involved in the sensitivity analysis was raised to an optimistic value or lowered to a pessimistic value. In relation to yield of product(s) harvested from woody perennial crops, an example question is ‘what-if the yield or price of product(s) was either 50% higher or 50% lower than the original value?’

In relation to the shelter benefit associated with trees and shrubs planted in belts in alley farming systems the questions are, what if

- a) yield of agricultural crops within 20 tree heights of tree belts improved by as much as 5% instead of the original assumption of a 2% gain?
- b) tree belts conferred no yield benefits to the agricultural crops?

In relation to the competition penalty associated with trees the questions are, what if

- c) competition for moisture and light within two tree heights of trees was so high zero yield was obtained from agricultural crops instead of the original assumption of a 50% yield reduction of agricultural crops?
- d) trees did not compete with agricultural crops and thus conferred no yield penalties on neighbouring agricultural crops?

This temporal interaction effect is the effect of the tree phase on yield of subsequent crops, or livestock carrying capacity of subsequent pastures. The duration of the temporal interaction effect may be as long as five years. The temporal interaction effect is modelled through a variable increasing or decreasing the productivity of a subsequent enterprise by a user-specified percentage value. The range of interaction effects assumed in this study is from a 30% boost to a 30% decline in the following crop.

The analytical spreadsheet tool - *Imagine*

Imagine is an economic and financial analysis tool providing the modelling environment, based on the partial budgeting technique. It is a Visual Basic Application in a Microsoft Excel spreadsheet developed with joint funding from NHT project 973849.

In *Imagine*, alternative land use strategies can be specified for a block of land of any size. It is possible to allocate land to any sequence of cropping or livestock enterprises. The structure of the database and its computational framework is designed to not limit its application to any particular agro-climatic or edaphic situation. *Imagine* can be used for analysing agricultural farm forestry or agroforestry land use systems.

In *Imagine* the project life, or evaluation period for the specified land use strategy, can be varied up to 50 years. Enterprises range from annual crops and pastures (e.g. wheat) to perennial species (e.g. oil mallees or maritime pine).

Alternative land uses can be arranged in alley or block plantation layouts. That is, the user can specify the temporal and spatial management sequence for the block.

Alternative management strategies can be saved for future reference and for comparison through scenario analyses. *Imagine* reports financial consequences of selected management strategies as tables and charts. The user is able to evaluate existing, emerging and prospective agroforestry systems against conventional farming systems over a wide range of yields, costs, prices, investment strategies and on-site benefits.

Some distinguishing features of *Imagine* include:

- flexible design to facilitate analysis of different agricultural or agroforestry projects in any edaphic or agro-climatic zone
- integration of perennial plants such as trees, shrubs and pastures in short or long rotations with agriculture
- allowance for various spatial configurations of tree crops such as narrow belts in alley farming systems or block plantings
- allowance for various temporal sequences of tree crops with other annual and perennial crops
- options for multiple tree harvests as in the case of coppicing tree types such as oil mallees
- ability to handle woody perennials with products other than timber such as biomass, oil, fibre, fruit, forage
- facility to specify temporal and spatial interactions between woody perennials and agricultural crops and pastures
- facilities for sensitivity analysis including break-even analysis to help identify economically important parameters
- features allowing the user to save and retrieve input and output data, facilitating export and import of input data to updated versions of *Imagine*
- features allowing the user to save and retrieve spatial and temporal layouts for the scenarios being evaluated
- export of all calculations as a Microsoft Excel file.

Data collection

There is only limited set of empirical data and cultivation history that are available from early adopters and researchers of woody perennial crops. In some cases, such as oil mallee in Western Australia and conceptual woody phase crops, no industries are yet in place. In addition, the costs and prices used were based on those that could be expected once large-scale industries have been established.

For each case study, data sources and key researchers were consulted to provide estimates of costs of establishing and maintaining trees, timing of harvests, and yields and prices of tree products. The use of expert estimates in long term forestry, agroforestry and other commercial investments projects is common among business analysts and strategic planners (see reviews Dayanandra *et al.* (2002), Abadi Ghadim (2000), Encel *et al.* (1975) and Clemen and Reilly (2001)). The data collection procedure used here is similar to that used to populate models such as MIDAS, a whole-farm bio-economic model used for strategic planning and analysis of future scenarios in farming systems (Kingwell and Pannell 1987, Pannell and Bathgate 1991).

Given the uncertainty associated with many of the above-mentioned production parameters, sensitivity analyses were used to test the robustness of the findings and the economic importance of key variables. Among the factors included were the economic value of shelter benefits, and crop and pasture losses associated with competition from trees.

The following information was collected for woody perennial crops and annual herbaceous crops:

- site characteristics (climate, soil type)
- silvicultural system or crop establishment techniques (eg. planting density, weed control, pruning)
- harvest age, harvest schedule, harvest and transport costs
- price of product(s) from the enterprise
- yield of different products of enterprise at each scheduled harvest

- interactions between enterprises – these interactions may be positive or negative and may occur over both space and time. Interactions may affect yield of products or costs of production. An example of a negative interaction between two enterprises may be yield lost due to competition between a woody species and an annual crop like wheat when they are planted alongside each other. A positive interaction may be non-wood benefits such as shelter benefits of trees conferred on nearby crops and pasture.
- costs for land preparation, planting and establishment, maintenance and harvesting
- revenues or costs through share-farming with an organisation such as the FPC in WA
- discount rate.

For agricultural crop and livestock enterprises, data published by regional economists of the State Departments of Agriculture in WA (DAWA 2002) and NSW (Patton and Mullen 2001) were used.

Overview of farming systems

The case studies reported here are in the low to medium rainfall agricultural regions of Australia. The WA case studies are located in the northern agricultural and upper great southern regions of the state. The NSW case studies pertain to the central west farming systems of the state's cropping zone.

General assumptions for WA and NSW

Table 4 lists the assumptions common to the seven case studies and relate to interactions between woody crops, annual herbaceous crops and annual pastures, and livestock production parameters.

- Competition width is the amount of land adjacent to herbaceous crops or pasture that is subject to competition from trees. This width is expressed in tree heights. It is used to calculate the penalty that reduces yield of crops or livestock carrying capacity of pastures due to competition for water, light and nutrients. Competition width increases linearly with the age of trees between planting and harvest(s). At harvest, tree height is reset to a user-specified value.
- Competition factor defines the proportion of crop yield and stocking rate lost due to competition within the competition width.
- Shelter width is the width of herbaceous crops or pasture adjacent to trees that is subject to shelter from the trees, expressed in tree heights. In the shelter zone there is an increase in crop yields or pasture carrying capacity due to reduced wind speed, stock protection and reduced soil erosion. The width of shelter increases over time as trees are assumed to grow linearly. At harvest tree height is assumed to reset to a user specified level.
- Shelter factor defines the proportion of yield and stocking rate gained due to shelter benefits conferred on crops and pastures by trees within the width specified for shelter.
- Yield penalty is the yield decline due to continually cropping the same crop on the same land.

Table 5 shows the parameters for cattle and sheep production. For the livestock purchase price it is assumed livestock spend 12 months on-farm. However, all that time is not attributed to the block for which the financial analysis is carried out. Consequently, costs and returns specified for the livestock (pasture) are in proportion to the assumed time the paddock is used for livestock production. In the sheep enterprise, it is assumed wether hoggets are purchased for fattening and sold as 2-year old shipping wethers. Cattle are assumed to be yearling beef cattle when purchased and sold as steers. Prices and costs are farm gate prices net of levies and all other charges. Wool price is the greasy weight on farm. Death rate is an adjustment factor for reduction in livestock numbers due to death (disease or accident).

Table 4. Parameters related to the interactions between woody crops, annual herbaceous crops and annual pastures in NSW and WA.

Variable	Value	Units
Competition width	2	tree heights
Competition factor	20	%
Shelter width	20	tree heights
Shelter factor	2	%
Yield penalty for a cereal crop immediately following a cereal crop of the same species	4	%
Yield penalty for a cereal crop immediately following a cereal crop of a different species	1	%
Maximum yield penalty for a cereal crop following another crop – sets an upper limit	10	%
Yield penalty for a lupin crop immediately following another lupin crop	30	%
Yield penalty for a lupin crop immediately following another pulse crop - different species	5	%
Maximum yield penalty for a lupin crop after a lupin or pulse crop – sets an upper limit	30	%

Main sources of data: Ted Lefroy at CSIRO, Amir Abadi at DAWA, the MIDAS model inputs and outputs supplied by Felicity Flugge at the CRC for Plant-Based Management of Dryland Salinity.

Table 5. Cattle and sheep production parameters for NSW and WA.

Variable	Sheep	Cattle	Units
Purchase price of livestock	40	450	\$/head
Sale price of the livestock	35	650	\$/head
Wool cut	5.50	N/A	kg/ha
Wool price	5	N/A	\$/kg
Annual average death rate	2	2	%
Average monthly energy requirements in the period of feed gap of late summer and autumn	200	2000	MJ/head
Shearing cost	3	N/A	\$/head
Crutching and mulsing cost	2	N/A	\$/head
Health supplies cost	3	5.00	\$/head
Requisites cost	2	1.00	\$/head
Repair and maintenance cost of sheds, yards, machinery, miscellaneous	2	6.00	\$/head
Average energy requirements of livestock in winter and spring	300	3000	MJ/head

Main sources of data: The Gross Margins Guide (DAWA 2002), the MIDAS model inputs and outputs, Amir Abadi and Allan Herbert at DAWA, Felicity Flugge at the CRC for Plant-Based Management of Dryland Salinity.

The northern agricultural region of WA

Towns in this region are Geraldton, Eneabba, Badgingarra, Moora, Dalwallinu, Wongan Hills, Morawa and Mullewa. Most farms are a mix of crop and livestock enterprises. Average annual rainfall is from 325 mm in the east to 450 mm in the west. Most rain falls from May to October, usually followed by a summer drought from December to March.

The average farm size is approximately 4000 ha, of which most is cleared and arable. Typically, 30-70% of the farmland is cropped each year depending on soil types and commodity prices (eg. wheat). Farm operations are highly mechanised and owner-operated, with not more than two other permanent labourers.

The six predominant soil classes, as commonly identified by farmers, are infertile acid wodgil sands, more fertile sandplain soils, gravelly sands, shallow duplex sand over clay soils, red loams and heavy clays (Perry and Hillman 1991).

Wheat yields in the region average from 1.4 to 1.8 t/ha. Enterprise selection and management according to soil type is a key part of the farming system. Crops are sown between May and July and harvested from November to January. Crops include cereals (mainly wheat) and lupins. Livestock production enterprises comprise mainly sheep or cattle, grazing open paddocks. The sheep enterprise is generally a self-replacing merino flock focusing mainly on wool production. Lambing is in late autumn or early winter and shearing is in spring and autumn. Sheep are run on annual pastures during winter and on a combination of crop residues, dry annual pastures and lupin grain in summer and autumn. Cattle enterprises are usually concerned with fattening steer for beef production and tend to be restricted to the medium rainfall zone.

The typical management of infertile wodge sands is continuous pasture grazed by cattle or sheep. Pastures contain volunteer annual grasses and herbs, with some annual legumes. On the slightly more fertile soils, from sandplain to clay, crops and pastures are generally grown in rotation. The cereal crop phase ranges from one to three years. Some farmers may also include broad-leaved break crops such as canola or lupins in their rotations.

Table 6 describes assumptions related to the autumn/summer livestock feed schedule. The assumption relating to the proportion of crop stubble or dry pasture available to livestock is to account for a grazing management strategy that conserves soil quality by preventing wind and water erosion and soil compaction. The cost of supplementary feed (lupin grain) includes storage and handling costs.

Table 6. Livestock feed supply and demand during the summer/autumn feed gap in WA.

Variable	Value	Unit
Proportion of energy demand of livestock met by paddock feed in the feed gap period	30	%
Energy concentration of supplementary feed	12	MJ/kg
Price of supplementary feed	190	\$/tonne
Energy concentration of paddock feed in winter and spring including pasture and tagasaste	11	MJ/kg
Energy concentration of paddock feed in summer and autumn. Includes stubbles and pasture	9	MJ/kg
Proportion of green pasture or tagasaste made accessible to livestock	100	%
Proportion of crop stubbles or dry pasture made accessible to livestock	50	%
Sources of data: The Gross Margins Guide (DAWA 2002) and the MIDAS model inputs and outputs from Felicity Flugge at the CRC for Plant-Based Management of Dryland Salinity.		

Tables 7 to 9 describe key production parameters of the livestock production systems. Calculations are based on assumptions in Tables 4 and 5. Adjustment is made for the time livestock utilise the specified feed source. The calculated values reflect expenditure and revenues for the specified period. The cost of supplementary feeding is based on the assumption of scarcity of paddock feed during March to May, a time commonly referred to as ‘the feed gap’ when paddock feed is sparse and nutritional quality is low. In Table 9, the cost of pasture production typically includes fertiliser only.

Grain prices are the expected average price over the period 2002-2012 (Table 10). Grain yields are the expected average yield including yield benefits or penalties conferred by previous phases of rotation such as lupins or pasture. Legume crops provide opportunity for economical grass weed control as well as providing a break phase from root disease cycle in wheat crops as well as adding biological nitrogen. Typically, the cost of production includes the costs associated with pest control, weed control, fertiliser, seed inoculums, insurance, machinery, labour, finance and testing.

Table 7. Assumptions of the sheep production system in WA.

Pasture Assumptions	Value	Units
Continuous pasture on the deep infertile sands of the 450 mm annual rainfall zone		
Period of livestock grazing or browsing attributed to this feed source	8	month
Revenue from livestock attributable to this feed source	40.83	\$/head
Period of supplementary feeding required during late summer and autumn	1	month
Amount of supplementary feed required	11.67	kg/head
Cost of supplementary feeding	1.48	\$/head
Replacement cost of livestock	26.67	\$/head
Cost of husbandry, repair and maintenance	7	\$/head
Cost of pasture production	10	\$/ha
Edible dry matter available to livestock under grazing in the specified period	400	kg/ha/month
Energy concentration of paddock feed on offer	11	MJ/kg
Stocking rate or livestock yield of the specified feed source	7.33	heads/ha
First pasture after two years of cereal crops on the duplex soils of the 350 mm annual rainfall zone		
Period of livestock grazing or browsing attributed to this feed source	6	month
Revenue from livestock attributable to this feed source	30.63	\$/head
Period of supplementary feeding required during late summer and autumn	1.5	month
Amount of supplementary feed required	17.5	kg/head
Cost of supplementary feeding	1.66	\$/head
Replacement cost of livestock	20	\$/head
Cost of husbandry, repair and maintenance	5.25	\$/head
Cost of pasture production	15	\$/ha
Edible dry matter available to livestock under grazing in the specified period	300	kg/ha/month
Energy concentration of paddock feed on offer	11	MJ/kg
Stocking rate or livestock yield of the specified feed source	5.50	heads/ha
Second pasture after two years of cereal crops on the duplex soils of the 350 mm annual rainfall zone		
Period of livestock grazing or browsing attributed to this feed source	7	month
Revenue from livestock attributable to this feed source	35.73	\$/head
Period of supplementary feeding required during late summer and autumn	1.5	month
Amount of supplementary feed required	17.5	kg/head
Cost of supplementary feeding	1.94	\$/head
Replacement cost of livestock	23.33	\$/head
Cost of husbandry, repair and maintenance	6.13	\$/head
Cost of pasture production	10	\$/ha
Edible dry matter available to livestock under grazing in the specified period	350	kg/ha/month
Energy concentration of paddock feed on offer	11	MJ/kg
Stocking rate or livestock yield of the specified feed source	6.42	heads/ha
Sources of data: The MIDAS model inputs and outputs from Felicity Flugge at the CRC for Plant-Based Management of Dryland Salinity, The Gross Margins Guide (DAWA 2002).		

Table 8. Value and utilization of crop residues for livestock nutrition in WA.

Variable	Value	Units
Period of livestock grazing or browsing on this feed source	1	month
Revenue from livestock attributable to this feed source	5.10	\$/head
Period of supplementary feeding required during late summer and autumn	1	month
Amount of supplementary feed required	11.67	kg/head
Cost of supplementary feeding	0.18	\$/head
Replacement cost of livestock	3.33	\$/head
Cost of husbandry, repair and maintenance	0.88	\$/head
Edible dry matter available to livestock under grazing in the specified period	750	kg/ha/month
Stocking rate or livestock yield of the specified feed source	16.88	head/ha
Sources of data: The Gross Margins Guide (DAWA 2002) and the MIDAS model inputs and outputs from Felicity Flugge at the CRC for Plant-Based Management of Dryland Salinity.		

Table 9. Assumptions of the cattle production system in WA.

Pasture Assumptions	Value	Units
Period of livestock grazing or browsing attributed to this feed source	6	month
Revenue from livestock attributable to this feed source	318.5	\$/head
Period of supplementary feeding required during late summer and autumn	1	month
Amount of supplementary feed required	11.67	kg/head
Cost of supplementary feeding	11.08	\$/head
Replacement cost of livestock	225	\$/head
Cost of husbandry, repair and maintenance	6	\$/head
Cost of pasture production	10	\$/ha
Edible dry matter available to livestock under grazing in the specified period	300	kg/ha/month
Energy concentration of paddock feed on offer	9	MJ/kg
Stocking rate or livestock yield of the specified feed source	0.54	heads/ha
Sources of data: MIDAS model inputs and outputs from Felicity Flugge at the CRC for Plant-Based Management of Dryland Salinity.		

Table 10. Assumptions of the grain production systems in WA.

Variable	1 st Wheat after lupins or pasture ASW 10%	2 nd Wheat after lupins or pasture ASW 10%	Lupin	Units
Medium Rainfall (450 mm annual rainfall)				
Grain price	160	160	170	\$/t
Grain yield	1.6	1.2	1.2	t/ha
Cost of production	156.70	156.70	174.50	\$/ha
Low Rainfall (350 mm annual rainfall)				
Grain price	160	160	170	\$/t
Grain yield	1.4	1.1	1.0	t/ha
Cost of production	134.20	134.20	146.60	\$/ha
Source of data: The Gross Margins Guide (DAWA 2002) and the MIDAS model inputs and outputs from Felicity Flugge at the CRC for Plant-Based Management of Dryland Salinity.				

The central west region of NSW

Dean Patton at NSWAG, Trangie provided the following information on farming systems of the central west region of NSW.

Two of the main towns in this region are Parkes and Dubbo. Most farms have a mix of crop and livestock enterprises. Crops consist of cereals such as wheat and barley, and broad-leaved crops such as canola and faba beans. Livestock consists of sheep or cattle production. Average annual rainfall is around 450 mm with most rain falling non-seasonally. High temperatures in summer cause high soil water evaporation making the effective summer rainfall low.

The average farm size is approximately 1500 ha most of which is cleared and arable. From a land management point of view only two soils dominate this region. The most prominent soil class, occupying 90% of the farming area, is the red and brown earths with a pH of 5.0. The other minor soil class, occupying 10% of a typical farm in the region, is the cracking grey clay.

Typically, around 35% of the farmland is cropped each year. Crops are sown around April and harvested in November. Farm operations are mechanised and owner-operated, with not more than two other permanent labourers. Sheep and cattle graze open paddocks. Sheep enterprises, which are the predominant grazing enterprise, are usually self-replacing merino flocks mainly for wool production. Shearing is in August. A livestock feed gap exists during the colder months of May and June when paddock feed is inadequate for the nutritional requirements of pregnant livestock. At that time of the year paddock feed is usually supplemented with grain and hay.

Up to 50 crop and pasture rotations have been identified in this region. Rotations often consist of three to five years of pasture followed by two to four years of cropping. In this study, it is assumed that a conventional agricultural land use in this region consists of a seven-year rotation of barley and wheat and a pasture phase. After the grain is harvested, sheep graze the crop residues and stubbles in summer and autumn. The pasture phase is for winter and spring grazing of sheep for wool and meat production. The various phases of the rotation are as follows:

1 st year:	A short fallow barley crop under-sown with lucerne.
2 nd , 3 rd and 4 th years:	A lucerne pasture containing volunteer grass and naturalised medics and weeds.
5 th year:	A pasture phase – in the first half of this phase pasture is available as livestock feed, and in the second half the paddock is in fallow to allow weed control and moisture conservation for wheat in the subsequent year. The paddock is sprayed or mechanically tilled for grass control in preparation for cropping.
6 th year:	A long fallow wheat crop.
7 th year:	A short fallow wheat crop.

Tables 11-13 describe the key production parameters of the livestock production systems.

Table 11 shows the assumptions for the sheep production system. The cost of supplementary feeding is based on the assumption of a shortage of paddock feed during May to June ('the feed gap') (Table 12). Calculations in Table 11 and 12 are based on assumptions in Tables 4 and 5. Adjustment is made for the time livestock utilise the specified feed source. The calculated values thus reflect expenditure and revenues for the specified period.

Grain prices are the expected average price over the period 2002-2012 including yield benefits or penalties conferred by previous phases of rotation such as lupins (Table 12). Pastures provide the opportunity for economical grass weed control, a break phase from root disease and addition of biological nitrogen. Typically cost of production includes costs associated with pest control, weed control, fertiliser, seed inoculums, insurance, machinery, labour, finance and testing.

Table 11. Assumptions of the sheep production system in NSW.

Variables	Pasture immediately before a wheat crop	1 st and 2 nd pasture after cereal crops	Units
Period of livestock grazing or browsing attributed to this feed source	6	8	month
Revenue from livestock attributable to this feed source	30.63	40.83	\$/head
Period of supplementary feeding required during late summer and autumn	1	1	month
Amount of supplementary feed required	11.67	11.67	kg/head
Cost of supplementary feeding	1.11	1.40	\$/head
Replacement cost of livestock	20	26.67	\$/head
Cost of husbandry, repair and maintenance	5.25	7	\$/head
Cost of pasture production	10	0	\$/ha
Edible dry matter available to livestock under grazing in the specified period	500	400	kg/ha/month
Stocking rate or livestock yield of the specified feed source	9.17	7.33	heads/ha
Main sources of data: Farm Budgets and Costs (NSWAG 2003), Dean Patton NSW Agriculture (pers. comm.) and the MIDAS model inputs and outputs from Felicity Flugge at the CRC for Plant-Based Management of Dryland Salinity.			

Table 12. Parameters related to the contribution of cereal crop stubbles to sheep production in NSW.

Variable	Long Fallow Wheat	Short Fallow Wheat	Short Fallow Barley	Units
Period of livestock grazing or browsing on this feed source	2	2	2	month
Revenue from livestock attributable to this feed source	10.21	10.21	10.21	\$/head
Period of supplementary feeding required during late summer and autumn	1	1	1	month
Amount of supplementary feed required	11.67	11.67	11.67	kg/head
Cost of supplementary feeding	0.37	0.37	0.37	\$/head
Replacement cost of livestock	6.67	6.67	6.67	\$/head
Cost of husbandry, repair and maintenance	1.75	1.75	1.75	\$/head
Edible dry matter available to livestock under grazing in the specified period	2400	1600	1800	kg/ha/month
Stocking rate or livestock yield of the specified feed source	54	36	40.50	heads/ha
Main sources of data: Farm Budgets and Costs (NSWAG 2003), Dean Patton NSW Agriculture (pers. comm.) and the MIDAS model inputs and outputs from Felicity Flugge at the CRC for Plant-Based Management of Dryland Salinity.				

Table 13. Assumptions of the grain production system in NSW.

Variable	Long Fallow Wheat	Short Fallow Wheat	Short Fallow Barley	Units
Grain price	180	160	130	\$/t
Grade of grain harvested	Prime hard	Australian hard	Feed	
Grain yield	2.4	1.6	1.8	t/ha
Cost of production	169.60	175.72	145.84	\$/ha
Main sources of data: Farm Budgets and Costs (NSWAG 2003) and Dean Patton NSW Agriculture (pers. comm. 2002).				

WA case study 1 – maritime pine

Background

Maritime pine (*Pinus pinaster*) is a medium-sized tree growing to about 30 m high on suitable sites in Australia. It is suited to infertile, well-drained soils including deep sands, deep gravels and sandy loams in WA. Maritime pine has the potential to grow in the wheatbelt of WA where mean annual rainfall is greater than 450mm.

A maritime pine industry is well established in WA on the coastal plains north of Perth. It is a preferred tree crop in this region because (i) the low fertility of deep sands make it unprofitable for annual crops, (ii) pastures are not very profitable because of their low carrying capacity, and (iii) there is an existing medium density fibreboard industry and sawmill based on the timber (DAWA 2000).

Maritime pine timber has extra strength and density compared with other softwoods including *P. radiata*. The timber is straight-grained, resinous and rather coarse in texture. There is a major forest industry based on maritime pine in France, Spain and Portugal. Maritime pine has been extensively planted in these areas for land rehabilitation and wood production. Demand is expected to increase for all maritime pine products (DAWA 2000).

Scenarios

Region: Medium rainfall northern agricultural region (>450 mm zone)

Soil Type: Deep infertile sands

Project Life: 33 years

Scenario 1: The conventional agricultural enterprise is sheep grazing a continuous pasture of annual grasses, brassicas and legumes in winter spring and early summer. This scenario is repeated for 33 years (the lifespan of the maritime pine project).

Scenario 2: This forestry enterprise is a block planted crop of maritime pine occupying the entire paddock. Pines are share-farmed with FPC, which establishes, manages and harvests the trees, and markets the wood products. The landowner (farmer) supplies the land and receives 20% of the stumpage for all products harvested from the land. At planting, FPC offers the landowner incentive payments for access to the land and for fencing.

Scenario 3: This forestry enterprise is also block planted maritime pine occupying the entire paddock. However, in this scenario it is assumed the landowner establishes and manages the trees using his/her own resources and engages contractors for some work such as harvesting and haulage. The land owner also arranges the sale of wood products. It is assumed the landowner achieves the same yields and prices as those achieved by FPC.

Main Sources: Owen Donovan, FPC, WA and Richard Moore, CALM, WA.

Assumptions

This section provides a list of key assumptions specific to the maritime pine project. Table 14 describes incentives and costs associated with establishing the plantation. Table 15 shows assumptions relating to the price of different products of maritime pine. The quoted prices are farm gate prices net of stumpage, haulage and harvesting costs. Table 16 describes the yield of products of maritime pine at different harvests. The cost of cleanup after ultimate harvest of maritime pine is dependent on the level of cleanup required for the following activity. For scenarios 2 and 3, no allowance was made for cleanup cost because the FPC offered contract extensions for further rotation of maritime pine; in this case the cleanup cost is minimal.

Table 14. Establishment and maintenance costs of a plantation of maritime pine trees.

Cost and incentive items	Owner established	FPC established	Units
Financial incentives paid to the land owner by FPC in order to gain access to land			
Signing Fee – an incentive from FPC split between years one and two	N/A	500	\$/ha
Fencing allowance – an incentive from FPC split between years one and two	N/A	25	\$/ha
Expenditure incurred by land owner in establishing and maintaining the tree crop			
Fencing costs	75	0	\$/ha
Land preparation – a one-off operation prior to planting	40	0	\$/ha
Pest management and control – a one-off operation prior to planting	20	0	\$/ha
Seedlings and planting – a one-off operation in the 1 st year	540	0	\$/ha
Pest management and control – annual operation from year one onwards	10	0	\$/ha
Maintenance and monitoring – annual operation from year two onwards	5	5	\$/ha
Weed management and control – 2 applications in years one and two	20	0	\$/ha
Pruning – a one-off operation in year seven	360	0	\$/ha
Fertiliser – 3 applications in years 13, 21 and 27	255	0	\$/ha

Table 15. Price of different products harvested from the plantation of maritime pine.

Products	Value	Unit
Industrial wood for chipping	12	\$/m ³
Posts and rounds	25	\$/m ³
Small sawlogs	20	\$/ m ³
Sawlogs	32	\$/ m ³

Table 16. Yield of products of maritime pine at different harvests.

Products and harvest schedule	1 st harvest	2 nd harvest	3 rd harvest	4 th harvest	Unit
Harvest schedule	15	20	26	32	Year
Yields when the tree crop is established by the land owner					
Industrial wood For chipping	47	25	22	33	m ³ /ha
Posts and rounds	11	10	0	0	m ³ /ha
Small sawlogs	0	22	12	13	m ³ /ha
Sawlogs	0	6	23	81	m ³ /ha
Land owner's share of yields when the tree crop is established by FPC					
Industrial wood for chipping	9.4	5	4.4	6.6	m ³ /ha
Posts and rounds	2.2	2	0	0	m ³ /ha
Small sawlogs	0	4.4	2.4	2.6	m ³ /ha
Sawlogs	0	1.2	4.6	16.2	m ³ /ha

Cash flow and profitability

This section describes results of the financial analysis of both maritime pine projects. The FPC share-farming option (Scenario 2) is the most profitable for the landowner with an *AER* of \$52/ha per annum and an *NPV* of \$668/ha (Table 17). It is \$19/ha more profitable than the conventional agricultural option of continuous pasture (Scenario 1). The maritime pine plantation established by the landowner has the lowest annual equivalent return of \$14/ha.

The FPC *Pinus pinaster* share-farming project with its initial incentive payments is an attractive deal for landowners. In contrast, there is little incentive for farmers to manage their own *Pinus pinaster* plantations. Based on this analysis share farming offers improved cash flow and net present value compared to a farmer managed plantation (Figure 2).

Table 17. Profitability and cash flows of timber production with maritime pine compared with agriculture.

Scenario	Product & System	<i>NPV</i> (\$/ha)	<i>AER</i> (\$/ha)	Peak debt (\$/ha)	Break-even period (years)	Payback period (years)
Scenario 1 Annual pasture	Sheep Winter spring grazing	399	31	10 year 1	N/A	1
Scenario 2 Plantation established by FPC in share-farming	Timber	668	52	0	Immediate	Immediate
Scenario 3 Plantation established by the landowner	Timber	176	14	984 year 15	Not Reached	32

The FPC project generates a net return of \$52/ha per annum. Unlike many other tree plantations established for timber production, the landowner does wait more than a decade for a positive cash flow. From the first year, incentive payments make the cash flow of this option better than conventional pasture. In contrast, a farmer managed plantation has much higher up front costs than pasture and requires high debt to be carried for over thirty years.

This analysis has assumed that a farmer managed plantation will get equivalent yields and prices to FPC managed plantations. However, farmers may obtain lower yields without the benefit of FPCs management experience and the prices obtained by individual growers without FPCs market presence may be lower.

A final advantage of the share farming scheme is that the FPC carries most of the risk of the project. Farmers receive an up front payment of \$500, which constitutes 75% of the *NPV* of the project. Conversely, 100% of the *NPV* of both pasture and farmer managed *Pinus pinaster* are dependent upon product yields.

The consequences of establishing a plantation of maritime pine trees on cash flow for the landowner are as follows:

- **Peak debt.** The maritime pine plantation project (Scenario 3) has a cumulative cash deficit of \$984/ha for the landowner in the 15th year after tree establishment. This is due to establishment and maintenance costs accumulating in the absence of any revenue. In Scenario 2, where FPC establishes and harvests the trees, the project has a nil peak debt since the landowner initially receives an upfront incentive payment of \$500/ha from FPC. There are few costs associated with the current volunteer pasture system but the fertiliser requirements in the first year of analysis cause a peak debt of \$10.

- **Payback period.** In Scenario 2, incentive payments from FPC result in an immediate payback period for the landowner (Figure 2). These payments, and the absence of any establishment costs for the landowner, create an immediate stream of positive cash flows making it the most desirable option from a financial point of view. In contrast, Scenario 3 does not reach a payback period until ultimate harvest. The three commercial thinnings do not provide sufficient revenue to overcome the establishment debt.
- **Break-even period.** Scenario 2 breaks even with conventional agriculture (Scenario 1) immediately due to the upfront payment. Furthermore the cashflow of scenario 2 is always better than that of scenario 1 after the upfront payment has been received. The cash flows of Scenario 3 never break-even with agriculture (Figure 2).

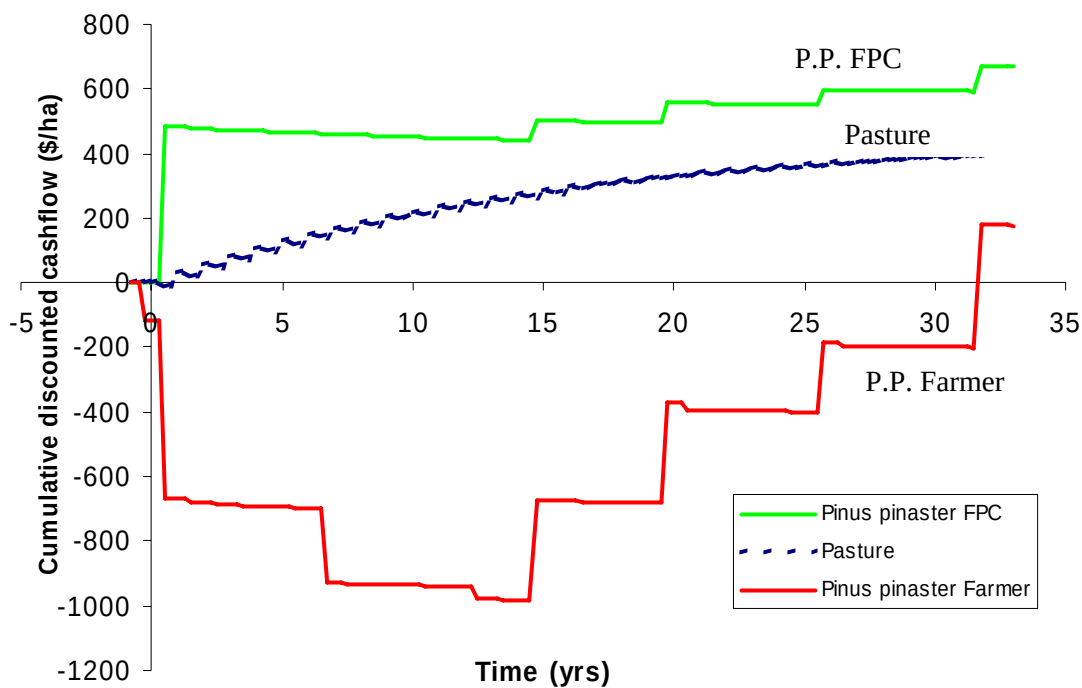


Figure 2. The cash flow of two scenarios of *Pinus pinaster* compared with sheep grazing pastures in conventional agriculture.

Sensitivity analysis

This section describes the sensitivity of results to key assumptions of the maritime pine production system (Table 18). Both Scenarios 2 and 3 were tested for sensitivity of results to variations in assumptions about yield and price of products harvested from the pine plantation. Changes in assumptions about yield and price had the same effect because the price provided is a stumpage. For Scenario 3 sensitivity to assumptions about establishment costs incurred by the landowner were also tested. Yields / prices were varied by 50% of the base case. However, because establishment costs are better understood they were varied by 25%.

Table 18: Sensitivity of profitability and cash flows of forestry with maritime pine to variations in some key assumptions

Variable	Change in assumptions	NPV (\$/ha)	AER (\$/ha)	Peak debt (\$/ha)	Break-even period (years)	Payback period (years)
FPC Established Share-farming Plantation – Scenario 2						
Timber yield or timber price	Original +50%	790	62	Nil	Immediate	Immediate
	Original -50%	545	43	Nil	Immediate	Immediate
Landowner Established Plantation – Scenario 3						
Timber yield or timber price	Original +50%	784	61	984 year 15	32	26
	Original -50%	-432	-34	984 year 15	Not reached	Not reached
Establishment costs	Original +25%	-11	-1	1162 year 15	Not reached	Not reached
	Original -25%	363	28	805 year 15	Not reached	26

Varying either the yield or price of maritime pine products by plus or minus 50% did not have a large affect on the overall economics of the FPC share farming scheme from the farmers viewpoint (Table 18). This is because the FPC takes 80% of the revenue from the products and the farmer gets most of their income from the upfront payment. A 50% change in either yield or price translates to a change in equivalent annual return of approximately \$10 to the farmer. However, changes of these proportions would have a much higher impact on the FPC.

The farmer managed maritime pine plantation was much more sensitive to changes in price or yield than the share farmer plantations. An increase in either yield or price of 50% increased the NPV of farmer managed maritime pine to \$784, which is equivalent to \$61 per annum. This is 85% higher than the volunteer pasture and \$47 per hectare per annum higher than the base case for farmer managed maritime pine. However, even at this optimistic level the pine plantation would still take 26 years to reach a positive cash flow and until the ultimate harvest in year 32 before the cumulative cash flow was better than that of volunteer pasture. If either the yield or price drops by 50% the farmer managed maritime pine will never have a positive cumulative cash flow. In this case the equivalent annual return would be \$-34.

Variations in establishment cost are important for farmer managed maritime pine plantations. However, within the limits tested it is unlikely that farmers would plant and manage maritime pine themselves. Even at the most optimistic establishment cost tested maritime pine was still unable to break-even with volunteer pasture and took 26 years to achieve a positive cumulative cash flow.

Conclusions

Based on this analysis the FPC share farming maritime pine scheme is an attractive alternative to volunteer pasture. The share farming scheme has a higher NPV and hence a higher equivalent annual return than pasture. Additionally, the large upfront payment makes share farming very attractive from a cash flow perspective and shelters the farmer from most of the risk.

In contrast there is little incentive for farmers to manage their own maritime pine plantation. The NPV and AER are lower than for volunteer pasture and the cash flow is poor with the farmer carrying a large debt for several years. Additionally, the farmer carries all of the risk of failing to achieve the yields and prices used in this analysis. Either yield or price would have to reach a level 50% higher than that used in the base case for this study before farmer managed maritime pine reached a similar NPV to share farmed maritime pine. Even then the cash flow for share farming would be preferred.

Therefore, if farmers were interested in growing maritime pine they would be well advised to share-farm with FPC. Although share-farming has better cash flow and higher NPV than pasture, the key advantage of volunteer pasture is the flexibility it offers the farmers in being able to choose the use of the land on an annual basis. Once share farmed pines are planted the land is tied up for over 30 years with little revenue expected after the upfront payment and hence will have a low resale value.

WA case study 2 – oil mallee

Background

Mallee is the common name for the ‘multi-stemmed’ *Eucalyptus* trees. They characteristically have many stems arising from a swollen woody structure just below the soil surface, known as the lignotuber or ‘mallee root’. The ‘mallee root’ is, in fact, an underground stem structure believed to be an adaptation to fire. Harvesting removes the above ground stems leaving the starch rich lignotuber intact. The mallee sprouts back from buds on the surface of the lignotuber. This process, referred to as ‘coppicing’, makes mallee trees suitable for regular biomass harvests (Bartle 2001, The Oil Mallee Company 2003).

Bartle and Brennan (2002) identified several key species of oil mallees for cultivation in the WA wheatbelt, including *Eucalyptus kochii* subsp. *plenissima*, *E. horistes*, *E. loxophleba* subsp. *lissophloia*, *E. gratiae* and *E. polybractea*. CSIRO has developed technology for the simultaneous production of activated carbon and electricity from woody biomass. Enecon has investigated the application of this technology to oil mallees, with *Eucalyptus* oil being a third product (Enecon 2001).

Bartle (1999ab) suggested that for oil mallees to be integrated into wheatbelt farming systems and to achieve high water use, the trees will need to be dispersed across the farm in belts. Belts combine the efficiency of tree harvesting with the least amount of inconvenience to agricultural operations such as seeding of grain crops, weed control and harvesting.

Scenarios

Region: Medium rainfall Upper Great Southern agricultural region (450 mm)

Soil Type: Deep sandy soil

Project Life: 20 years

Scenario 1: A conventional agricultural land use consisting of a rotation of wheat followed by a lupin crop. In summer and autumn, after the grain is harvested, sheep graze the crop residues and stubbles. This two-year wheat/lupin rotation is repeated 10 times during the project life of 20 years.

Scenario 2: Oil mallee trees are planted in four row belts 10 m wide in an alley farming layout with 90 m wide alleys. Tree belts are established and managed by the landowner with trees machine-planted. The alleys are cropped in the same manner as Scenario 1. Mallees are harvested at ground level, first five years after planting, then on a three-year cycle. All of the above ground biomass is harvested and sold.

Main Sources: The data set reflects the analysis of the Integrated Tree Processing feasibility investigation conducted by Enecon (2001), and the experiences of the Oil Mallee Association, the Oil Mallee Company and Kalannie Distillers, all active developers of mallee production systems.

Assumptions

This section provides a list of key assumptions specific to the oil mallee project. Table 19 presents costs associated with establishing oil mallee belts. Table 20 shows the assumptions relating to the price of biomass from oil mallees. The quoted biomass price is an estimated factory gate price for

chipped unsorted biomass. The harvest cost includes chipping. Therefore the stumpage received by the grower is the difference between the price for delivered biomass and the cost of harvest and transport. Mallees are first harvested five years after planting and then on a three year cycle (Table 21). Harvesting cuts the mallees as close to the ground as possible and removes the above ground biomass of trees. Mallee height is interpolated between the after and before harvest heights (Table 21) to estimate the width of competition and shelter zones between mallee and adjacent crops or pastures (Table 22).

Table 19. Establishment and production costs# of oil mallee trees

Variable	Value	Units
Planning, mapping, site preparation, and weed and pest control year one	334	\$/ha
Seedlings and machine planting – a one-off operation in year one	1003	\$/ha
Weed management and control – Cost for years one and two combined	79	\$/ha
Pest management – in year two	33	\$/ha
Maintenance and monitoring – annual operation from year two onwards	20	\$/ha
Early growth monitoring – once only in year one	5	\$/ha
Post harvest maintenance cost - includes weed and pest control cost	67.50	\$/ha
Salvage value – NPV of harvests from year 21 in perpetuity.	3065	\$/ha

Costs are expressed per planted hectare of mallees, which is per km of 4-row belt.

Table 20. Price of the product of oil mallee trees and associated harvest costs of the product.

Variable	Value	Unit
Biomass delivered in chipped form to a processor	30	\$/t
Harvest and transport cost per unit of biomass	15	\$/t

Table 21. Yield of biomass from oil mallee trees and height of trees before and after harvest.

Variable	Value	Unit
Regular harvests start	5 th	year
Harvest schedule	every 3 years	
Yield of biomass harvested (1 st harvest) ¹	85	t/ha
Yield of biomass harvested (2 nd harvest)	69	t/ha
Yield of biomass harvested (3 rd harvest onwards)	53	t/ha
Height of tree just before harvest	5	metres
Height of tree just after harvest	0.1	metres

¹ It is assumed that mallees will get a yield boost for the first two harvests because they can obtain extra water from the unsaturated soil profile. Robinson and colleagues (2002) demonstrated that 5-7 year old oil mallees had used up plant available soil moisture 9-15m out from the edge of the mallee belt to a depth of 10m.

Table 22. Assumptions for competition and shelter between mallees and adjacent herbaceous plants.

Variable	Value
Competition width in mallee heights	2
Competition factor (average reduction across competition zone)	20%
Shelter width in mallee heights	20
Shelter factor (average boost across the shelter zone)	2%

Cash flow and profitability

This section describes results of a comparative financial analysis of conventional crop rotation (Scenario 1) and alley farming with oil mallees (Scenario 2). All results are for the complete farming system, i.e. for scenario 2 the results are per total hectare not per mallee hectare (Table 23). Scenario 2 generated an *AER* of \$125/ha per annum, which is \$4/ha more profitable per annum than conventional agriculture.

Table 23. Profitability and cash flows of oil mallee in an alley farming system compared with agriculture.

Scenarios	Products & System	<i>NPV</i> (\$/ha)	<i>AER</i> (\$/ha)	Peak debt (\$/ha)	Break-even period (years)	Payback period (years)
Scenario 1						
Agriculture	Grains, sheep	1285	121	180	N/A	1
Wheat/Wheat/Lupin	Continuous cropping					
Scenario 2						
Agroforestry	Biomass, grains, sheep	1334	125	289	20	3
Oil mallees	Alley farming			Year 1		

The cash flow consequences of alley farming with oil mallees are as follows:

- **Peak debt.** In scenario 2 a cumulative cash deficit of \$289/ha occurs in the first year of analysis, which is \$109 higher than the peak debt for scenario 1. This cash deficit is much lower than the mallee establishment costs (Table 19) because mallees cover only 10% of the paddock. The peak debt does not extend beyond the first year because income from the wheat crop in the alleys is sufficient to offset the debt in the first year.
- **Payback period.** It takes three years until the cumulative discounted cash flow becomes positive (Figure 3). This is a relatively short payback period when compared with typical agroforestry projects (Trapnell 2001). Again this is due to the low proportion of the agricultural system planted to mallees.
- **Break-even period.** It takes 20 years for the discounted cumulative cash flow of the system including oil mallees to equal that of conventional agriculture (Figure 3). The salvage value obtained at the end of the project was required to enable the agroforestry system to overtake the conventional agricultural land use system.

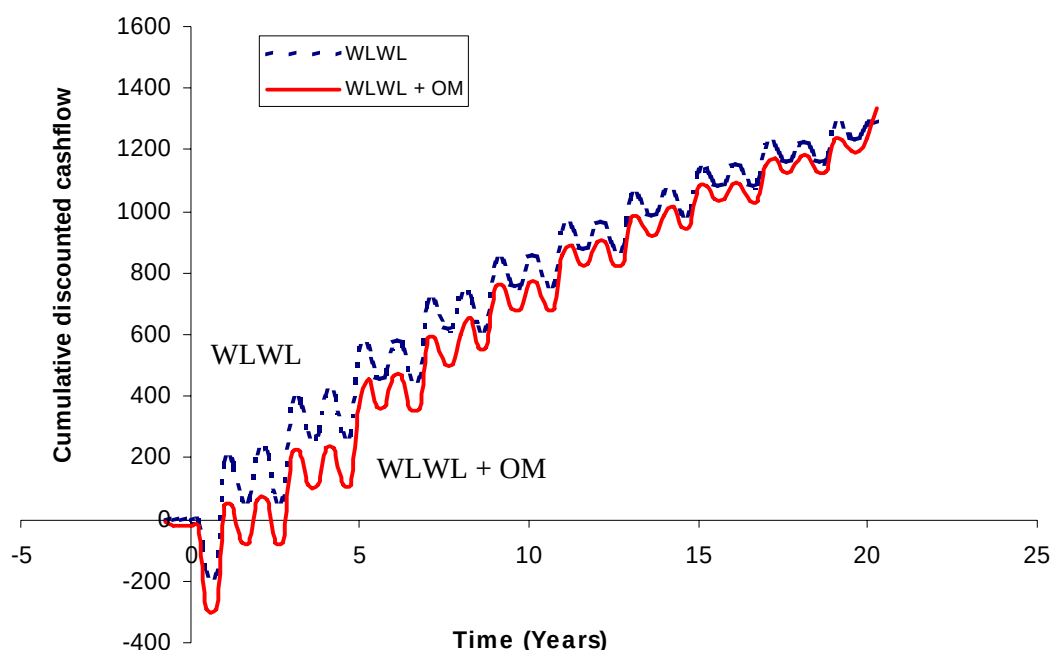


Figure 3. The cash flow of the oil mallee project compared to long sequence of wheat-lupin rotation.

Sensitivity analysis

This section describes the sensitivity of the results to variations in the assumptions of key production parameters and interaction effects of the oil mallee project (Table 24). Sensitivity analysis was performed for:

1. yield of biomass harvested from oil mallees
2. price of biomass
3. establishment cost for oil mallees
4. maintenance costs for oil mallees
5. harvest and transport costs for oil mallees
6. salvage value of oil mallees after 20 years
7. magnitude of the shelter benefit of oil mallee trees conferred on neighbouring agricultural enterprises
8. magnitude of the competition penalty from oil mallees conferred on neighbouring agricultural enterprises.

All parameters were varied by plus or minus 25% of the base case except for shelter benefit and competition penalty. The values for shelter and competition were varied from zero to 50% of the base value.

If the ranges of variation in parameters are equally likely to occur the relative importance of the parameters can be ranked (Table 25).

The price of biomass is clearly the most sensitive parameter tested for the system incorporating oil mallees. As a full scale integrated mallee processing plant (IMP) has not yet been built the price of biomass used in the analysis is not based on current pricing. The price may also vary based on the quality of the biomass. Three products are proposed to be produced in the IMP, each with different value and from different components of the biomass (Enecon, 2001). Therefore, the price paid for biomass may be dependent upon the proportions of wood, bark, twigs and leaves, and the oil percentage of the leaves.

Biomass yield, and harvest and transport cost were the next most important sensitivities. As mallees are yet to become a large scale commercial crop in Western Australia the likely yields are not well understood. Additionally, the harvester technology on which the prices are based is currently under development. Therefore it has not reached the stage of commercial use and hence the costs in this study are estimates.

Shelter benefits and competition penalties are the next most important parameters according to the rankings generated by the sensitivity analysis. Mallees are much shorter and have a different morphology to the trees commonly used in agroforestry. This combined with regular coppicing and extensive root systems may result in differences between mallee shelter and competition, and that reported for other species.

Salvage value is the next most important parameter in this sensitivity analysis. It has been assumed that the salvage value will be the value of a discounted cash flow of costs and returns from the end of this analysis period to infinity. The actual salvage value will be the difference in land value between a paddock with oil mallee belts and an equivalent paddock without oil mallees. In addition to the cash flow the salvage value will be affected by perceived inconvenience of the mallee belts, change in land degradation processes and change in aesthetics.

Establishment and maintenance costs were the least sensitive parameters. In addition establishment costs are probably the best understood costs in the analysis.

Table 24. Sensitivity of profitability and cash flows of alley farming with oil mallees to variations in some key assumptions.

Variable	Change in assumptions	NPV (\$/ha)	AER (\$/ha)	Peak debt (\$/ha)	Break-even period (years)	Payback period (years)	
Biomass yield	Original +25%	1422	133	289	year 1	18	3
	Original -25%	1246	117	289	year 1	Not Reached	3
Biomass price	Original +25%	1509	142	289	year 1	12	3
	Original −25%	1159	109	289	year 1	Not Reached	3
Establishment cost	Original +25%	1301	122	289	year 1	20	3
	Original −25%	1366	128	289	year 1	20	3
Maintenance cost	Original +25%	1313	123	289	year 1	20	3
	Original −25%	1355	127	289	year 1	20	3
Harvest + transport cost	Original +25%	1246	117	289	year 1	Not Reached	3
	Original −25%	1422	133	289	year 1	18	3
Salvage value	Original -50%	1295	122	289	year 1	20	3
	0	1256	118	289	year 1	Not Reached	3
Shelter benefit	5%	1424	134	289	year 1	15	2
	0%	1274	120	289	year 1	Not Reached	3
Competition penalty	50%	1242	117	289	year 1	Not Reached	3
	0%	1395	131	289	year 1	18	3

Table 25. Ranking of parameter sensitivity assuming ranges of sensitivities tested are equally likely to occur for each parameter tested.

Rank	Variable	Range ¹	Change in AER (\$/ha)
1	Biomass Price	50% of base case	33
2	Biomass Yield	50% of base case	16
2	Harvest and Transport Cost	50% of base case	16
3	Shelter Benefit	5% ¹	14
3	Competition Penalty	50% ¹	14
4	Salvage value	100% of base case	7
5	Establishment Cost	50% of base case	6
6	Maintenance Costs	50% of base case	4

¹ Range is expressed as a percentage of the base value, except for shelter benefit and competition penalty which are absolute values

Conclusions

Based on this analysis incorporating oil mallee belts into wheat-lupin paddocks will not have a large affect on the net present value for the paddock over the 20 year analysis period. However, the cash flow for the system incorporating oil mallees is always behind that for the cropping only system. Therefore, adoption of mallees will depend on the recognition, by land owners, of their hydrological and ecological benefits.

Based on the sensitivity analysis the most important area requiring research and development is the price of biomass. This analysis used a price of \$30 per green tonne for biomass but if that price could be improved by improving the quality of the biomass, e.g. more *Eucalyptus* oil, then mallees would become more attractive to land owners.

Other key areas for research and development are improving the yield estimates as well as harvest and transport costs. The third tier of research would be on estimating the shelter and competition effects.

WA case study 3 – tagasaste

Background

Tagasaste (*Chamaecytisus proliferus*) is an evergreen, perennial, leguminous shrub suited to deep, infertile sands. It is used as a fodder plant and increases livestock carrying capacity of soil types where annual pasture growth is usually poor. In WA, tagasaste has shown economic potential as a fodder source for livestock production. In addition to its value as livestock feed, there is interest in integrating tagasaste into broadacre, dryland farming systems for management of salinity, wind erosion and soil amelioration. In WA, the majority of tagasaste plantations were established for cattle production. However, tagasaste has also been used as a feed source in sheep production systems. Tagasaste can be integrated into farming systems either in blocks, or in belts where they form compact hedgerows in alley farming systems with annual crops or pastures in wide-spaced alleys (Lefroy 2001).

Lefroy *et al.* (1997) studied the farm scale economics of an alley cropping system in WA, based on tagasaste. They showed the feed value of tagasaste could, potentially, economically drive improvements in the ecological sustainability of sandplain farming systems through large-scale revegetation, providing the assumed tree/crop interactions were supported by empirical studies.

Scenarios

Region: Medium rainfall northern agricultural region (450 mm zone)

Soil Type: Deep infertile sands

Project Life: 33 years

Scenario 1: Conventional agricultural enterprise is cattle grazing an annual pasture with a mixture of annual grasses, brassica species and legumes. It is assumed the main economic value of the pasture is its feed value for cattle from January to June. The continuous pasture rotation is repeated for 33 years to match the project life.

Scenario 2: Alley farming with tagasaste planted in six-metre wide belts with 60 m wide alleys of pasture. Cattle graze the tagasaste from January to June. After planting, the paddock is locked up for one year allowing the tagasaste to establish. The continuous pasture rotation in the alleys is repeated for 33 years to match the project life. Assumptions about tree height before and after grazing and browsing by cattle are used in calculations of spatial interaction between tagasaste and pasture.

Scenario 3: Tagasaste in a plantation with some understorey of annual pastures. Cattle are assumed to graze from March to November. This period includes the 'feed gap' when other feed is scarce and low in nutritional quality. Some supplementary feeding is provided for one month when tagasaste is unpalatable.

Main Sources: Lefroy (2001), Ted Lefroy at CSIRO, Gross Margin Guides (DAWA 2002) and the MIDAS model inputs and outputs obtained from Felicity Flugge at the CRC for Plant-Based Management of Dryland Salinity.

Assumptions

This section provides a list of key assumptions specific to the tagasaste project. Table 26 describes establishment and production costs, harvest schedules, and expected production of tagasaste for cattle production in alley farming. Table 27 shows similar parameters for establishment of tagasaste in a plantation system.

Table 26. Establishment and production costs, harvest schedules, and expected tagasaste production for cattle production in an alley farming system.

Variables	Value	Units
Period of livestock grazing or browsing attributed to this feed source	6	month
Land preparation – a one-off operation in the year prior to planting	150	\$/ha
Pest control – a one-off operation in the 1 st year includes two applications	24	\$/ha
Seed/seedlings – a one-off operation in the 1 st year	50	\$/ha
Revenue from livestock attributable to this feed source	159.25	\$/head
Period of supplementary feeding required during late summer and autumn	1	month
Amount of supplementary feed required	116.67	kg/head
Cost of supplementary feeding	6	\$/head
Replacement cost of livestock	225.50	\$/head
Cost of husbandry, repair and maintenance	11.08	\$/head
Edible dry matter available to livestock under grazing in the specified period	300	kg/ha/month
First harvest	2 nd year	
Stocking rate or livestock yield of the specified feed source at the 1 st harvest	0.8	head/ha
Year when regular harvests begin	3 rd year	
Frequency of regular harvests	Every year	
Stocking rate or livestock yield of the specified feed source at regular harvests	1.65	head/ha
Height of tree just prior to harvest	1.5	metres
Height of tree immediately after harvest or at the end of grazing period	1	metres
Cleanup cost - removal of trees and stumps at the end of tree project	200	\$/ha

Table 27. Establishment and production costs, harvest schedules and expected tagasaste production for cattle production in a plantation system.

Variables	Value	Units
Period of livestock grazing or browsing attributed to this feed source	8	month
Land preparation – a one-off operation in the year prior to planting	134	\$/ha
Pest control – a one-off operation in the 1 st year two applications	24	\$/ha
Weed control – a one-off operation in the year prior to planting	50	
Seed/seedlings – a one-off operation in the 1 st year	100	\$/ha
Fertiliser – a one-off operation in the 1 st year	20	\$/ha
Fire break – a one-off operation in the 1 st year	2	\$/ha
Annual maintenance – an annual operation from 2 nd year onwards includes fertiliser	30	\$/ha
Revenue from livestock attributable to this feed source	424.67	\$/head
Period of supplementary feeding required during late summer and autumn	1	month
Amount of supplementary feed required	116.67	kg/head
Cost of supplementary feeding	14.78	\$/head
Replacement cost of livestock	300	\$/head
Cost of husbandry, repair and maintenance	8	\$/head
Edible dry matter available to livestock under grazing in the specified period	300	kg/ha/month
First harvest	2 nd year	
Stocking rate or livestock yield of the specified feed source at the 1 st harvest	0.55	head/ha
Year when regular harvests begin	3 rd year	
Frequency of regular harvests	every year	
Stocking rate or livestock yield of the specified feed source at regular harvests	1.1	head/ha
Height of tree just prior to harvest – harvest occurs through grazing cattle	1.5	metres
Height of tree immediately at the end of grazing period	1.0	metres
Cleanup cost - removal of trees and stumps at the end of tree project	200	\$/ha

Cash flow and profitability

This section describes results of a comparative financial analysis of the agricultural land use described in Scenario 1 and those involving tagasaste described in Scenarios 2 and 3. Both agroforestry scenarios were found to be more profitable than conventional agriculture. Scenario 2 involving tagasaste in alley farming generates an *AER* of \$37/ha per annum compared with conventional cattle production from annual pastures with an *AER* of \$31/ha (Table 28). Scenario 3 has a higher *AER* of \$44/ha.

Table 28. Profitability and cash flows of cattle production with or without tagasaste in both alley and plantation layouts.

Scenarios	Product & System	NPV (\$/ha)	AER (\$/ha)	Peak debt (\$/ha)	Break-even period (years)	Payback period (years)
Scenario 1	Cattle					
Annual pasture	Summer/autumn grazing	394	31	N/A	N/A	N/A
Scenario 2	Cattle					
Tagasaste	Summer/autumn grazing	466	37	28	6	1
Alley Farming				Year 1		
Scenario 3	Cattle					
Tagasaste	Summer/autumn grazing	555	44	360	16	8
Plantation				Year 1		

The cash flow consequences of the agroforestry projects involving tagasaste are as follows:

- **Peak debt.** Scenario 2 (alley farming) has a cumulative cash deficit of \$28/ha occurring in the year tagasaste is established. In alley farming systems where trees are planted in narrow belts, the cost of establishing the trees is proportional to the amount of land occupied by the tree belt per hectare of the paddock. The peak debt of this project does not extend beyond the first year because the income from pasture in the alleys is profitable enough to pay-off the cost of tagasaste establishment in one year. Scenario 3 (plantation) has a cumulative cash deficit of \$360/ha also occurring in the year of plantation establishment. From year two onwards the plantation begins to generate income as cattle feed. The plantation has a higher peak debt than alley farming because 100% of the paddock is planted to tagasaste compared with 9% for scenario 1.
- **Payback period.** The alley farming system requires one year for cumulative discounted cash flow to become a surplus. This short payback period is possible because the trees are in belts, occupying a smaller proportion of the paddock, with the remainder in agricultural production expecting positive net returns on an annual basis. These returns, from the cattle enterprise utilising the feed in the alleys, offset the deficits incurred during establishment. The tagasaste generates income from year two onwards through its availability as cattle feed. In the plantation it takes eight years until the cumulative discounted cash flow is clear of debt. This is because the entire paddock is planted to the shrubs, a large upfront establishment cost. The first harvest, in year two, is assumed to have half the livestock carrying capacity or stocking rate than subsequent years.
- **Break-even period.** In Scenario 2 (alley farming), it takes six years for cumulative cash flows of cattle production from tagasaste to overtake that of a typical cattle production system on annual pastures (Scenario 1). Although alley farming has a payback period of one year, it takes an additional five years for cattle production to generate sufficient net income to compensate for the establishment costs and the opportunity cost of pasture replaced by the shrubs. In Scenario 3 it takes 16 years for cumulative cash flows of cattle production to overtake that of Scenario 1. It takes an additional seven years, after the payback period of nine years, for cattle production from the plantation to generate sufficient net income to compensate for establishment costs and the opportunity cost of the annual returns from the conventional cattle production system lost due to the tagasaste plantation.

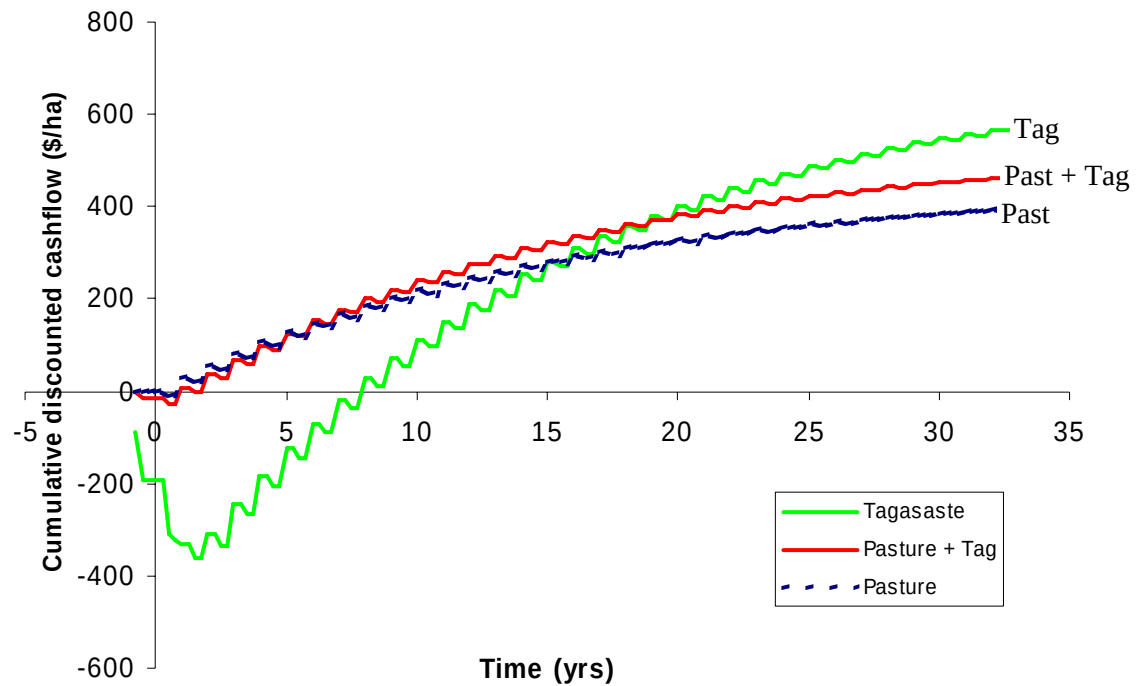


Figure 4. The cash flow of the tagasaste project compared to long sequence of pasture for cattle grazing in conventional agriculture.

Sensitivity analysis

This section describes the sensitivity of the results of the tagasaste case study to variations in assumptions of key production parameters and interaction effects (Table 29). These variations include:

1. livestock stocking rate or carrying capacity of the feed on offer from tagasaste in both alleys and plantations
2. price the landowner receives for cattle fed in tagasaste plantations or alleys
3. magnitude of shelter benefit of tagasaste conferred on neighbouring agricultural enterprises, being cattle grazing annual pasture
4. magnitude of the competition penalty from tagasaste conferred on neighbouring agricultural enterprises.

Table 29. Sensitivity of profitability and cash flows of cattle production with tagasaste to variations in assumptions regarding cattle price and stocking rates.

Variable	Change in assumptions	NPV (\$/ha)	AER (\$/ha)	Peak debt (\$/ha)	Break-even period (years)	Payback period (years)
Scenario 1: Cattle Grazing Annual Pasture						
Cattle sale price	Original +50%	1491	117	N/A	N/A	N/A
	Original -50%	-702	-55	N/A	N/A	N/A
Scenario 2: Tagasaste Alley Farming						
Carrying capacity or cattle stocking rate	Original +50%	553	43	31 year 1	4	1
	Original -50%	402	32	31 year 1	17	1
Cattle sale price	Original +50%	1773	139	31 at establishment	4	1
	Original -50%	-818	-64	2113 year 33	Not reached	Not reached
Scenario 3: Tagasaste Plantation						
Carrying capacity or cattle stocking rate	Original +50%	1193	94	359 year 1	7	6
	Original -50%	-83	-6	360 year 2	Not reached	Not reached
Cattle Sale Price	Original +50%	3214	252	360 year 1	5	4
	Original -50%	-2103	-165	5317 year 33	Not reached	Not reached

If the volume of feed produced by tagasaste in Scenario 2 was half that assumed in the original analysis then alley farming would still be worth establishing. In this sensitivity analysis, the stocking rate of tagasaste belts is halved and not the carrying capacity of the entire alley system, including the alleys. At the lower stocking rate, Scenario 2 generates \$32/ha per annum (Table 29) compared with \$31/ha per annum in Scenario 1 (Table 28). In this case, alley farming takes an additional 11 years to break-even with the conventional grazing system. If the tagasaste belts had 50% more carrying capacity than originally assumed then the landowner would earn an additional \$6/ha per annum from alley farming, which is \$12/ha more profitable than Scenario 1 and the break-even period is reduced by two years to four years.

When the sale price of cattle in Scenario 2 (alley farming) is 50% less than originally assumed the project makes a loss of \$64/ha per annum and has a peak debt of \$2113/ha. Similarly, Scenario 1 makes an annual loss of \$55/ha. If the cattle prices were 50% higher for the life of the project then Scenario 2 would generate an AER of \$139/ha per annum, which is \$22/ha per annum higher than Scenario 1 with 50% higher cattle prices. In this case the project would break-even with Scenario 1 in four years instead of six, making it even more attractive for a landowner.

If the volume of feed produced by tagasaste in Scenario 3 (plantation) was half that assumed in the original analysis then the plantation would not be worth establishing since it makes a loss of \$6/ha. Unlike Scenario 2 (alley farming), the carrying capacity of the entire paddock is halved rather than just the belts. If the tagasaste plantation had 50% more carrying capacity than originally assumed then the landowner would earn \$94/ha per annum. This is \$50/ha more per annum compared with net returns of the plantation under the original assumptions and \$57/ha more profitable than Scenario 1. The break-even period is reduced by nine years from 16 to seven and the payback period is reduced by three years from nine to six years.

When the sale price of cattle in the plantation is 50% less than the original assumption the project makes a loss of \$165/ha per annum and has a peak debt of \$5317/ha. If cattle prices were 50% higher then Scenario 3 would generate an AER of \$252/ha per annum, which is \$135/ha per annum higher than Scenario 1 at the higher cattle price. In this case the project would break-even with Scenario 1 in five years instead of 16 and the payback period is shortened from nine years to four, improving its attractiveness as an investment.

An interesting finding of this sensitivity analysis is that cattle production systems involving alleys or plantations of tagasaste (Scenarios 2 & 3) may increase the variance of income as a function of long term changes in cattle price, by virtue of higher carrying capacities resulting from increased availability of tagasaste feed.

The shelter benefit is the percentage increase in stocking rate of pasture in alleys within 20 tree heights from the tree. As tree height increases with the growth of trees so too does the shelter benefit. For the sensitivity analysis the question was, what if the shelter benefit resulted in either a nil or a 20% gain in carrying capacity within alleys, rather than the original assumption of a 2% gain in carrying capacity?

The results of the sensitivity analysis show there is only a small economic value in interaction effects (Table 30). The minor economic significance of interactions between tree belts and pasture in alleys is demonstrated by the magnitude of the difference between profitability with no shelter benefits versus profitability with 20% shelter benefit. The difference is only \$7/ha per annum as indicated by the *AER* of the project under the two assumptions. In other words, a 1% gain in carrying capacity of pasture in alleys within 20 tree heights of belts is worth \$0.35/ha per annum. Even if there were no shelter benefits, alley farming would still be more profitable than conventional agriculture (Scenario 1). A change in shelter benefit assumption from nil to 20% reduces the break-even period by only two years.

Table 30. Sensitivity of profitability and cash flows of cattle production with tagasaste to variations in assumptions concerning the spatial interactions in the alley farming system.

Variable	Change in assumptions	NPV (\$/ha)	AER (\$/ha)	Peak debt (\$/ha)	Break-even period (years)	Payback period (years)
Shelter benefit	20%	559	44	31 year 1	4	1
	0%	467	37	31 year 1	6	1
Competition penalty	100%	441	35	31 year 1	8	1
	0%	487	38	31 year 1	5	1

Competition penalty is the percentage decrease in the stocking rate of nearby pastures within two tree heights from tagasaste belts. As trees grow so too does the competition penalty. For the sensitivity analysis the question was, what if the competition penalty resulted in either a nil or a 100% (complete) loss in carrying capacity within alleys, rather than the original assumption of a 20% reduction in carrying capacity?

Results show competition effects of trees are also economically modest. The economic difference between no competition and total loss of stocking rate within two tree heights of tagasaste belts is only \$3/ha (Table 30). In other words, a 1% change in competition between trees and annual pasture in alleys within two tree heights of belts is worth \$0.03/ha to the landowner. Changing the competition penalty assumption from 100% to nil reduces the break-even period by only 3 years.

The sensitivity analysis shows competition effects and shelter benefits are unlikely to be the key factors in the decision to establish cattle grazing with a tagasaste alley system.

WA case study 4 – woody phase

Background

Woody perennial phase crops are a new concept for wheatbelt farming systems in Australia. The phase crop would dewater the plant available water from the unsaturated stored soil moisture to a depth much greater than the rooting depth of herbaceous crops and pastures. The dewatered zone would then act as a buffer, storing water that leaked through the crop rooting depth. The cycle of dewatering under a phase crop then recharging the unsaturated water store during the cropping phase would reduce recharge to the water table and hence reduce the advancement of dryland salinity.

Other potential benefits of woody phase crops include soil structure improvement, provision of weed and disease breaks for annual crops, and nitrogen fixation (Harper *et al.* 2000). To achieve any significant penetration into farming systems, woody perennial phase crops will need to generate a return to help offset establishment costs and temporary loss of productive land. The cost of removing tree stumps is another important consideration.

The search project at CALM is investigating a number of species with commercial potential as woody phase crops (Bartle *et al.* 2002). The desirable attributes of such crops include ease of establishment, rapid growth, and wood properties suited to the production of low cost biomass for industrial feedstock. Potential products include wood for pulp and paper, reconstituted wood products, and electricity generated from plant residues.

Reliable techniques for large-scale establishment via direct seeding are still experimental. The recommended planting design for a phase crop is a block planting of single species. Most species are susceptible to grazing damage so exclusion of stock is necessary for good establishment and subsequent growth.

As this study is a conceptual woody phase crop no specific product exists. Rather it is assumed that the whole biomass would be sold as an industrial feedstock. It is assumed that multiple products may be produced from the biomass, in a similar concept to the integrated mallee processing plant (Case study 2).

After harvesting the phase crop the stumps would need to be removed to allow cropping to occur in the following year. The stumps and root systems would be those of four year trees grown in a wheatbelt climate. Hence the cost of removal can be expected to be much lower than that for removal of blue gum stumps, where the trees are 10-12 years old and grown in a better climate.

Scenarios

Region: Medium rainfall northern agricultural region (450 mm zone)

Soil Type: Duplex soils consisting of sand over clay

Project Life: 20 years

Scenario 1: Conventional agricultural enterprise is a rotation of two years of wheat followed by two-years of pasture (a mixture of annual grasses, brassicas and legumes). The main economic value of the pasture is as a feed source for sheep from winter to early summer. This four-year agricultural rotation is repeated five times to achieve a project life of 20 years.

Scenario 2: An agroforestry system involving phase farming with a woody phase crop. In the first year, the paddock is planted to a woody phase crop. After four years, trees are removed and the entire tree biomass is sold off-farm. The paddock is returned to conventional agriculture as per Scenario 1. This rotation lasts for 16 years. After this period the stored soil moisture below the herbaceous crops and pasture root zone should have been recharged so another phase crop can be planted.

Main Sources: The dataset reflects a hypothetical tree crop. Don Cooper, CALM, developed the assumptions in this scenario.

Assumptions

This section provides a list of key assumptions specific to woody phase farming. Table 31 describes costs associated with establishing a woody phase crop. Table 32 shows assumptions relating to the price of biomass from the woody phase crop. The quoted price is estimated mill door price for unsorted chipped biomass. The stumpage earned by growers would be the difference between the mill door price and the combined harvest, chipping and transport cost. Table 33 describes the harvest schedule and yield of biomass from the plantation. Table 34 describes the temporal interactions of the woody phase crop on yield of cereal crops or livestock carrying capacity of pastures following the woody phase. The authors were unable to find any empirical data for this interaction effect, so no interaction was assumed for the base case.

Table 31. Establishment and maintenance costs of a plantation of a woody phase crop.

Variable	Value	Units
Pest management and control in year one	33	\$/ha
Direct seeding – a one-off operation in year one	200	\$/ha
Weed management and control – Total cost of three applications across years one and two	114	\$/ha
Maintenance and monitoring – annual operation	15	\$/ha
Fertiliser application after harvest and removal of trees to prepare land for subsequent agriculture	40	\$/ha
Cleanup cost - removal of stumps and preparing the land for agriculture	200	\$/ha

Table 32. Biomass and harvest costs from a woody phase crop.

Variable	Value	Unit
Biomass delivered in chip form	30	\$/t
Harvest, chipping and transport cost	15	\$/t

Table 33. Yield of biomass from a woody phase crop.

Variable	Value	Unit
Age of tree at harvest	4	years
Yield of biomass harvested	67	t/ha

Table 34. Temporal interactions between a woody phase crop and subsequent agricultural activities.

Temporal effect of the acacia phase on the yield of cereal crops or the livestock carrying capacity of pastures	Value
Immediately following the tree phase	Nil
Two years after the tree phase	Nil
Three years after the tree phase	Nil
Four years after the tree phase	Nil
Five or more years after the tree phase	Nil

Cash flow and profitability

This section describes results of a comparative financial analysis of a conventional agricultural land use (Scenario 1) and the agroforestry land use (Scenario 2). Scenario 2 generated an *AER* of \$140/ha per annum, \$36/ha per annum less than Scenario 1 (Table 35).

Table 35. Profitability and cash flows of acacia phase farming compared with a conventional agricultural rotation.

Scenarios	Product & System	<i>NPV</i> (\$/ha)	<i>AER</i> (\$/ha)	Peak debt (\$/ha)	Break-even period (years)	Payback period (years)
Scenario 1						
Agricultural Rotation	Sheep from winter/spring grazing of pastures, grain from wheat crop	1861	176	180 year 1	N/A	1
Scenario 2						
Woody phase crop followed by a wheat-pasture rotation	Biomass from woody phase crop Sheep from winter/spring grazing of pastures, grain from wheat crop	1485	140	371 year 4	Not reached	4

The cash flow consequences of a farming system incorporating a woody phase crop are as follows:

- **Peak debt.** A discounted cumulative cash deficit of \$371/ha occurs in the fourth year of the analysis just before harvesting the woody phase crop.
- **Payback period.** The cumulative discounted cash flow enters surplus after the harvest of the woody phase crop in year four (Figure 5).
- **Break-even period.** The farming system incorporating the woody phase crop never breaks even with the farming system from scenario 1 (Figure 5).

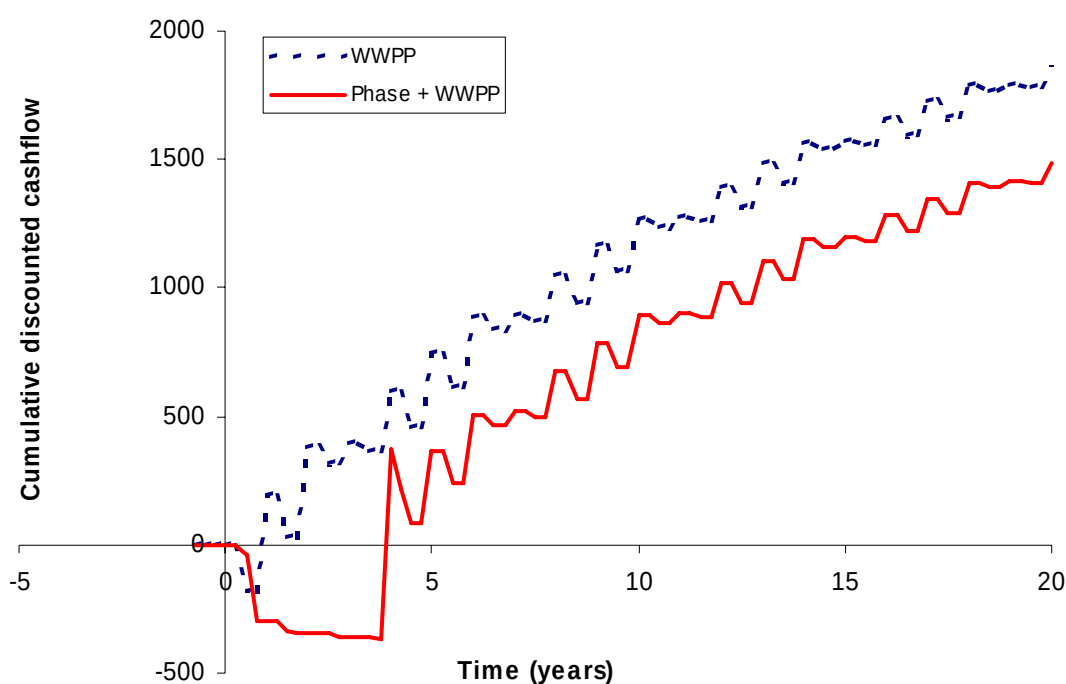


Figure 5. The cash flow of an agroforestry project with the woody phase crop compared with a conventional agricultural land use sequence of wheat and pasture.

Sensitivity analysis

This section describes the sensitivity of the results to variations in the assumptions of key production parameters and interaction effects of the woody phase crop project (Table 36). Sensitivity analysis was performed for:

1. yield of biomass harvested from woody phase crop
2. price of biomass
3. establishment cost for the woody phase crop
4. harvest and transport costs for the woody phase crop
5. cleanup cost after the woody phase crop
6. magnitude of the temporal interaction s between the woody phase crop and following herbaceous crops and pastures.

All parameters were varied by plus or minus 25% of the base case except for cleanup and establishment costs which were varied by plus or minus 50% of the base case and temporal interaction. The temporal interaction was tested for a 30% yield boost for the following crop and a 10% yield boost for the second crop after the woody phase crop and for a 30% yield penalty for the following crop and a 10% yield penalty for the second crop after the woody phase crop.

If the ranges of variation in parameters are equally likely to occur, the relative importance of the parameters can be ranked (Table 37).

Table 36. Sensitivity of profitability and cash flows of a farming system incorporating a woody phase crop to variations in some key assumptions.

Variable	Change in assumptions	NPV (\$/ha)	AER (\$/ha)	Peak debt (\$/ha)	Break-even period (years)	Payback period (years)
Yield	Original +25%	1677	158	371	Not reached	4
	Original –25%	1292	122	year 4 371	Not reached	5
Price	Original +25%	1870	176	371	4	4
	Original –25%	1100	104	year 4 371	Not reached	6
Establishment costs	Original +50%	1320	125	535	Not reached	5
	Original –50%	1649	156	year 4 207	Not reached	4
Harvest and transport costs	Original +25%	1292	122	371	Not reached	5
	Original –25%	1677	158	year 4 371	Not reached	4
Cleanup costs	Original +50%	1410	133	371	Not reached	4
	Original –50%	1560	147	year 4 371	Not reached	4
Temporal benefits	following crop 30% boost	1600	151	371	Not reached	4
	following crop 30% penalty	1369	129	year 4 371	Not reached	4

Table 37. Ranking of parameter sensitivity assuming ranges of sensitivities tested are equally likely to occur for each parameter tested.

Rank	Variable	Range ¹	Change in AER (\$/ha)
1	Biomass Price	50% of base case	72
2	Biomass Yield	50% of base case	36
2	Harvest and Transport Cost	50% of base case	36
4	Establishment Cost	100% of base case	34
3	Temporal interaction	Year after 60% ¹	22
5	Cleanup cost	100% of base case	14

¹ Range is expressed as a percentage of the base value, except for temporal interactions which are absolute values.

The price of biomass is clearly the most sensitive parameter tested for the system incorporating a woody phase crop. As this is a conceptual crop the price for the biomass is not based on an actual market price. The price will vary based on what the biomass is to be used for and what percentage of the biomass is usable. For example, the wood fraction may be saleable as a wood chip fraction, the leaf fraction may have fodder value and the residue may have a small value as bioenergy. In this case the price of biomass will be dependent on the percentages of wood, leaf and residue in the total biomass.

Biomass yield, and harvest and transport cost were the next most important sensitivities. Again as this is a conceptual new crop the likely yields are not well understood. Additionally, the harvester technology on which the prices used in this study are based is currently being developed for the oil mallee industry, case study 2. Therefore it has not reached the stage of commercial use and hence the costs in this study are estimates.

Establishment costs are based on direct seeding, which has not been proven on the scale required for commercial woody phase crops. Direct seeding suggests that the species chosen as woody phase crops should be large seeded and germinate readily.

The temporal interaction between the woody phase crop and the following cereal crop(s) will depend on several factors. These include:

1. changes in soil profile moisture, but as this is a duplex profile the top sandy layer would typically dry out during the summer months through evaporation so the woody phase crop may not have a large impact on the moisture content of the sandy horizon
2. changes in soil nutrient levels. These may be positive or negative, as the woody crop may remove some nutrients but may also fix nitrogen if a nitrogen fixing species is chosen
3. a break from crops and pastures may impact on pests, weeds and diseases
4. an increase in soil organic matter.

Cleanup costs will be determined by several factors. These include stump size, rooting architecture, requirements for the following crop and soil type. It is envisaged that a blade plough may be used to knock out the stumps, which can then be raked together and burnt.

Conclusions

Based on this analysis incorporating a woody phase crop into wheat-pasture paddocks on duplex soils will have a negative impact of almost \$400/ha on the net present value for the paddock. Additionally, the cash flow for the system incorporating a woody phase crop takes almost four years to become positive. Therefore, woody phase crops will rely on recognition of their land care benefits to encourage planting.

Based on the sensitivity analysis the most important area requiring research and development is the price of biomass. This analysis used a price of \$30 per green tonne for biomass but if that price could be improved by improving the quality of the biomass, e.g. a high value extractive then woody phase crops are more likely to be attractive to farmers.

Other key areas for research and development are improving the yield estimates and harvest and transport costs. The third tier of research would be on estimating the temporal interactions.

NSW case study 1 – blue mallee

Background

Traditionally, the oil mallee industry of NSW and Victoria has relied on mechanical harvesting of naturally occurring blue mallees (*Eucalyptus polybractea*) and extracting leaf oils by steam distillery. *E. polybractea*, the major source of oil from NSW and Victoria, grows well on the light sandy soils of the western plains of NSW and west of Bendigo in Victoria. It can grow in rainfall as low as 350 mm/yr but would probably do better in slightly higher rainfall areas (Davis 1997).

Davis (1997) suggests that static demand and over-production, mainly in China, will result in lower prices for *Eucalyptus* oil from blue mallees in the foreseeable future. Although the higher quality Australian oil commands a higher price, the demand is strictly limited at the current price. A dramatic increase in the demand for *Eucalyptus* oil will only occur if new large-scale uses are developed and the new use may be in lower priced markets.

Scenarios

Region: The central west region of NSW (450 mm)

Soil Type: Red Brown Earths

Project Life: 21 years

Scenario 1: A conventional agricultural land use consisting of a seven-year rotation of barley and wheat grain crops and a pasture phase as described earlier in section 3.3.

Scenario 2: Blue mallee trees planted in belts for alley farming with a conventional agricultural rotation (as above) in 60 m wide alleys. Trees are machine-planted in 15 m wide belts. The tree belts are established and managed by the landowner with harvesting to ground level on an 18-monthly cycle. The harvested biomass includes woody components such as stems, branches, sticks and twigs, leaves and bark. The harvested biomass is distilled on-farm to produce pharmaceutical grade oil. The seven-year agricultural rotation in alleys is repeated three times to achieve a project life of 21 years.

Main Sources: Peter Milthorpe at NSWAG Condobolin.

Assumptions

This section provides a list of key assumptions specific to the blue mallee project. Table 38 describes costs associated with establishing blue mallees belts. The costs are those that would be incurred when the farmer carries out the work. This is in contrast with case study 2 where the costs were the costs farmers would have to pay contractors to do the work. Table 39 shows assumptions relating to the price of oil extracted from biomass harvested from blue mallee belts. The price quoted is the farm-gate price received by the grower net of all delivery costs. Table 40 describes the harvest schedule and yield of oil from mallee belts. It also shows the specifications for tree height before and after each harvest. These estimates are used in calculating the width of competition and shelter zones in the alleys of adjacent crops and pastures.

Table 38. Establishment and production costs of blue mallee trees, all costs based on area planted to mallees.

Variable	Value	Units
Planning site mapping and set up including land preparation	20	\$/ha
Seed bed scarification	25	\$/ha
Ripping	30	\$/ha
Fertiliser applied when ripping	10	\$/ha
Seed to produce seedlings and planting	261	\$/ha
Weed management and control – total cost for applications in year 1 and year 2	60	\$/ha
Watering	24	\$/ha
Ripping along tree belts to reduced competition of trees with agriculture – annual cost	25	\$/km
Harvest cost	10.9	\$/ha
Salvage value – NPV of harvests from year 22 in perpetuity.	7,384	\$/ha

Table 39. Price of the product of blue mallee trees and associated harvest costs.

Variable	Value	Unit
Price of oil from the harvested and distilled biomass (3% of biomass)	7	\$/kg
Harvest cost per unit of oil produced – includes operating and repair and maintenance cost of the distilling equipment	0.85	\$/kg

Table 40. Yield of biomass from blue mallee trees and height of trees before and after harvest.

Variable	Value	Unit
First harvest starts	2 nd	year
Regular harvests start	3 rd	year
Harvest schedule	18	monthly
Oil yield from the 1 st harvest	0	kg/ha
Oil yield from the 2 nd and subsequent harvests	130	kg/ha
Height of tree just before 1 st harvest	1	metres
Height of tree just after 1 st harvest	0.1	metres
Height of tree just before 2 nd and subsequent harvests	1.8	metres
Height of tree just after 2 nd and subsequent harvests	0.1	metres

Cash flow and profitability

This section describes results of a comparative financial analysis of the agricultural land use (Scenario 1) and alley farming with blue mallees (Scenario 2). Alley farming generated an *AER* of \$186/ha per annum, which is \$83/ha more profitable than conventional agriculture (Table 41). Conventional agriculture generated \$103/ha per annum producing grain (barley and wheat) and sheep.

Table 41. Profitability and cash flows of blue mallees in an alley farming system compared with agriculture.

Scenarios	Products & System	NPV (\$/ha)	AER (\$/ha)	Peak debt (\$/ha)	Break-even period (years)	Payback period (years)
Scenario 1						
Agriculture	Grains, sheep	1117	103	109	N/A	1
Wheat barley and pasture rotation	Cropping and livestock			year 1		
Scenario 2						
Agroforestry	Biomass, grains, sheep	2018	186	104	6	1
Blue mallees and an agricultural rotation in alleys	Alley farming			year 1		

The cash flow consequences of alley farming with blue mallee trees are as follows:

- **Peak debt.** A cumulative cash deficit of \$104/ha occurs in the first year of the project. This is \$5/ha lower than the peak debt for scenario 1. The reduction in peak debt is because 20 percent of the paddock is taken out of cropping and hence does not have the crop establishment costs. This 20 percent of the paddock is prepared for mallee planting but the mallees are not planted until the following year and the mallee preparation costs incurred in the first year are lower than the cost of crop establishment. Peak debt does not occur in the second year when the mallees are planted because the income from the cereal crop in the first year is profitable enough to inject revenues reducing the negative cash flow associated with establishing the tree belts.
- **Payback period.** Only one year is required for cumulative cash deficits of establishing the blue mallee belts to become surpluses (Figure 6). This short payback period is possible because mallee belts only occupy a small proportion of the paddock leaving the remainder in agricultural production, generating positive net returns on an annual basis. The positive returns offset the deficits incurred in establishing the trees, significantly reducing the payback period.
- **Break-even period.** The cumulative cash flow of alley farming with blue mallees overtakes that of a typical agricultural land use in the 6th year (Figure 6). The high returns from blue mallee harvests combined with their 18 months harvest intervals makes them very profitable. This high level of profitability allows the system incorporating blue mallees to quickly catch up to cash flow of agriculture.

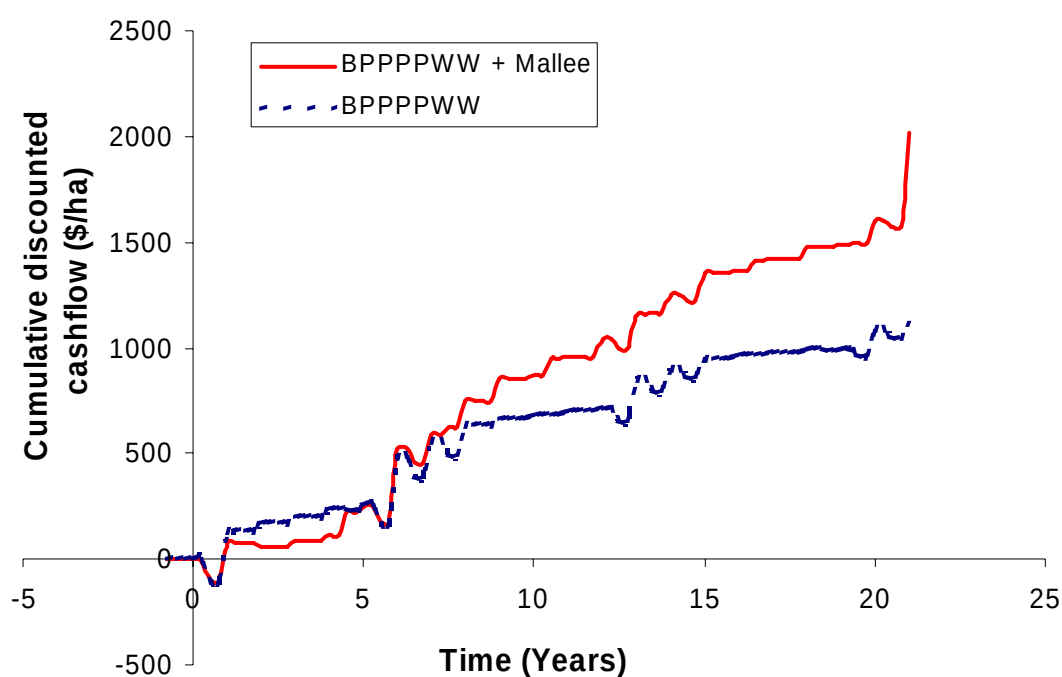


Figure 6. The cash flow of alley farming with blue mallees compared to a typical agricultural land use in NSW

Sensitivity analysis

This section describes the sensitivity of results of the blue mallee study to variations in key assumptions of key production parameters and interaction effects (Table 42). These variations included:

1. yield of oil from blue mallee trees
2. price of *Eucalyptus* oil
3. establishment costs for blue mallees
4. salvage value of blue mallees after 21 years
5. magnitude of the shelter benefit of blue mallee trees conferred on neighbouring agricultural enterprises.
6. magnitude of the competition penalty from blue mallees conferred on neighbouring agricultural enterprises.

Yield and price were varied by plus or minus 25% of the base case. Establishment costs were varied by plus or minus 50% of the base case. A larger range for sensitivity was used for costs due to the nature of the costs for blue mallees. No allowance was made for the cost of farmer time or the use of existing farm plant e.g. boom sprays. Hence, farmers may view the costs differently. Salvage value was tested for zero and half of the base case value. The values for shelter and competition were varied from zero to 250% of the base value.

If the ranges of variation in parameters are equally likely to occur, the relative importance of the parameters can be ranked (Table 43).

Table 42. Sensitivity of profitability and cash flows of alley farming with blue mallees to variations in some key assumptions.

Variable	Change in assumptions	NPV (\$/ha)	AER (\$/ha)	Peak debt (\$/ha)	Break-even period (years)	Payback period (years)
Oil yield	Original +25%	2324	214	104 year 1	5	1
	Original -25%	1713	158	104 year 1	8	1
Oil price	Original +25%	2366	218	104 year 1	5	1
	Original -25%	1671	154	104 year 1	8	1
Establishment costs	Original +50%	1980	183	113 year 1	8	1
	Original -50%	2057	190	96 year 1	5	1
Harvest and processing costs	Original +25%	1972	182	104 year 1	8	1
	Original -25%	2064	191	96 year 1	5	1
Salvage value	50% of original	1840	170	104 year 1	6	1
	0	1662	153	104 year 1	6	1
Shelter benefit	5%	2047	189	104 year 1	6	1
	0%	1999	184	104 year 1	6	1
Competition penalty	50%	1989	184	104 year 1	6	1
	0%	2038	188	104 year 1	6	1

Table 43. Ranking of parameter sensitivity assuming ranges of sensitivities tested are equally likely to occur for each parameter tested.

Rank	Variable	Range ¹	Change in AER (\$/ha)
1	Oil Price	50% of base case	64
2	Oil Yield	50% of base case	56
3	Salvage value	100% of base case	17
4	Harvest and processing Cost	50% of base case	9
4	Establishment Cost	100% of base case	7
5	Shelter Benefit	5% ¹	5
5	Competition Penalty	50% ¹	4

¹ Range is expressed as a percentage of the base value, except for shelter benefit and competition penalty which are absolute values

The price of oil and oil yield are clearly the two most sensitive parameters for the farming system incorporating blue mallees. The high profitability of blue mallees makes them very attractive to farmers as long as the costs, prices and yields used in this analysis can be achieved. In which case the area planted to blue mallees will dramatically increase, resulting in market over supply and a price crash. This scenario has already occurred in the tea tree (*Melaleuca alternifolia*) industry. Therefore, the high profitability of the blue mallee industry in this report is unlikely to be sustainable.

Yields of oil are determined by the growth rate of the mallees between harvests. This in turn is rainfall dependent. Therefore, as with most if not all agricultural industries the profitability of farming systems incorporating blue mallees will be very sensitive to drought.

Salvage value is the next most important parameter in this sensitivity analysis. It has been assumed that the salvage value will be the value of a discounted cash flow of costs and returns from the end of this analysis period to infinity. Therefore, the salvage value will be determined by the price and yield of oil at the end of this analysis period. The actual salvage value will be the difference in land value between a paddock containing oil mallees and an equivalent paddock without oil mallees. In addition to the cash flow the salvage value will be affected by perceived inconvenience of the mallee belts, change in land degradation processes and change in aesthetics.

The harvest and processing costs were not sensitive parameters in this analysis. This is because they are much smaller than the revenue. The price of oil used in this analysis is more than seven times the cost of harvest and processing (Table 42 and 43).

The establishment cost was not a very sensitive parameter for the agricultural system incorporating blue mallees. This is because the system has regular harvests from a young age (from a tree crop perspective) and the establishment cost hurdle is very low.

Shelter benefits and competition penalties were the least sensitive parameters. In this analysis the width of adjacent crop or pasture subject to competition and shelter is a multiple of tree height. Blue mallees are harvested very regularly (every 18 months) keeping their height low and hence reducing the effects of competition and shelter.

Conclusions

Based on this analysis planting blue mallees on the red-brown earths of the central west region of NSW would greatly increase farm profitability. Additionally, the cash flow penalties for a blue mallee belt system are much lower than for most tree crops, with very low upfront costs and a rapid break-even with agriculture period of six years.

The greatest concern for potential blue mallee growers would be “how achievable are the returns presented in this study in the long-term”. The current market for *Eucalyptus* oil is not large and could easily be swamped by Australian growers chasing the high profits reported here. The high sensitivity of blue mallees to *Eucalyptus* oil price would see systems incorporating blue mallee rapidly become less attractive in an over supplied market.

NSW case study 2 – jojoba

Background

The following introduction to jojoba (*Simmondsia chinensis*) is a summary of extracts from DAWA Farm Notes and personal communications with experts in jojoba production (Denham and Rowe 1999, and Peter Milthorpe pers. comm.). Much of the information for this introduction was downloaded from the DAWA web site.

Jojoba is a shrub suited to well-drained soils. It is grown for seed from which a valuable liquid wax is extracted. The wax is used in cosmetics, pharmaceuticals, lubricants and surfactants. Jojoba is an evergreen shrub capable of extracting water deep in the soil profile. It is resistant to drought and most pests but is susceptible to waterlogging, frost and low soil pH. Jojoba is well adapted to the subtropical regions of Australia. It can be grown in medium to low rainfall zones of southern Australia with a minimum annual rainfall as low as 250 mm but with regular seed production on 420 mm rainfall. Information specific to Australia, particularly in areas of marketing and cultivation in southern areas, is scarce or limited to the experience of few growers.

Jojoba is a wind-pollinated, dioecious species with female plants producing seed. To ensure adequate cross-pollination, 5% of the population must be male. The most commonly used plantation layout is 5 m between rows and 1.6 m to 2 m between seedlings. Fruit harvesting begins in the third to fifth year after establishment. Peak production is reached by year 12 with current management systems. The jojoba plant is unique in producing a long chain wax ester that in its natural form is highly valued in the cosmetic industry. Pharmaceuticals, lubricants and surfactants are produced by further modification of the wax through a process of sulphurisation or halogenation. Further developments in the genetic engineering of canola to produce long chain wax esters may affect the market for jojoba products.

Annual world consumption of jojoba is difficult to determine with production estimates ranging from 700 to 1100 tonnes during the mid-1990's. Major producing countries are USA, Mexico, Israel and Argentina. World demand has slowly increased over the last 15 years.

Denham and Rowe (1999) reported conservative fruit yield estimates of 1.1 t/ha are possible from irrigated plantations in Carnarvon in the Gascoyne Region of WA. According to Peter Milthorpe (NSWAG Condobolin), extracted jojoba oil comprises 45% of the fresh weight of fruit.

Scenarios

Region: The Central West Region of NSW (450 mm)

Soil Type: Red Brown Earths

Project Life: 36 years

Scenario 1: A conventional agricultural land use consisting of a seven-year rotation of barley and wheat grain crops and a pasture phase as described earlier in section 3.3.

Scenario 2: A jojoba plantation of 1000 shrubs/ha for oil production.

Main Sources: Peter Milthorpe at NSWAG Condobolin, Dean Patton at NSWAG Trangie, Denham and Rowe (1999), and fact sheets from the DAWA website:
<http://www.agric.wa.gov.au/agency/Pubns/factsheets/>

Assumptions

This section provides a list of key assumptions specific to the jojoba project. Table 44 describes costs associated with establishing a jojoba plantation. Table 45 shows assumptions relating to the price of oil extracted from fruit harvested from the plantation. The price quoted is the farm-gate price received by the grower net of all delivery costs. Table 46 describes the harvest schedule and yield of oil from jojoba stands.

Table 44. Establishment and production costs of a jojoba plantation.

Variable	Value	Units
Fencing	120	\$/ha
Site preparation	45	\$/ha
Pest management and control – once only cost of tree guards	1200	\$/ha
Seedlings and machine planting – a one-off operation in year one	4240	\$/ha
Weed management and control – year of establishment	48	\$/ha
Weed management and control – year two onwards	99	\$/ha
Watering – once only in year one involving three applications	15	\$/ha
Fertiliser – at planting	125	\$/ha
Fertiliser – every four years from year three onwards	80	\$/ha
Pruning every year from year four onwards	80	\$/ha
Harvest cost – amortised value of equipment incurred at every harvest	1040	\$/ha

Table 45. Price of jojoba oil and associated harvest costs.

Variable	Value	Unit
Price of oil	16	\$/litre
Harvest cost per unit of oil produced – includes operating and repair and maintenance cost of the equipment	1.115	\$/litre

Table 46. Yield of oil from a jojoba plantation at different harvests.

Variable	1 st harvest	2 nd harvest	3 rd harvest	4 th harvest	5 th and subsequent annual harvests	Unit
Scheduled harvest year	6	7	8	9	10 onwards	year
Oil	55	110	165	220	340	litres/ha

Cash flow and profitability

This section describes results of a comparative financial analysis of the conventional agricultural land use (Scenario 1) and the jojoba plantation (Scenario 2). The jojoba plantation generated an AER of \$1,256/ha per annum, which is 12 times more profitable than conventional agriculture (Table 47).

Table 47. Profitability and cash flows of a jojoba plantation compared with conventional agriculture.

Scenarios	Products & System	NPV (\$/ha)	AER (\$/ha)	Peak debt (\$/ha)	Break-even period (years)	Payback period (years)
Scenario 1						
Agriculture	Grains, sheep	1117	103	109	N/A	1
Cereal and pasture rotation	Cropping and livestock			year 1		
Scenario 2						
Jojoba	Oil from fruit	13683	1256	5881	12	11
Jojoba plantation				year 6		

The consequences of establishing a plantation of jojoba on the cash flow of the farm are as follows:

- **Peak debt.** A cumulative cash deficit of \$5,881/ha occurs in the sixth year, with the debt exceeding \$5,000 for years two to seven.
- **Payback period.** It takes eleven years for cumulative cash flow of a jojoba plantation to become surpluses (Figure 7). Five annual harvests are necessary under current assumptions to generate positive net returns offsetting large deficits incurred in establishing jojoba.
- **Break-even period.** The cumulative cash flow of the jojoba plantation exceeds that of conventional agriculture by the end of year 12 (Figure 7).

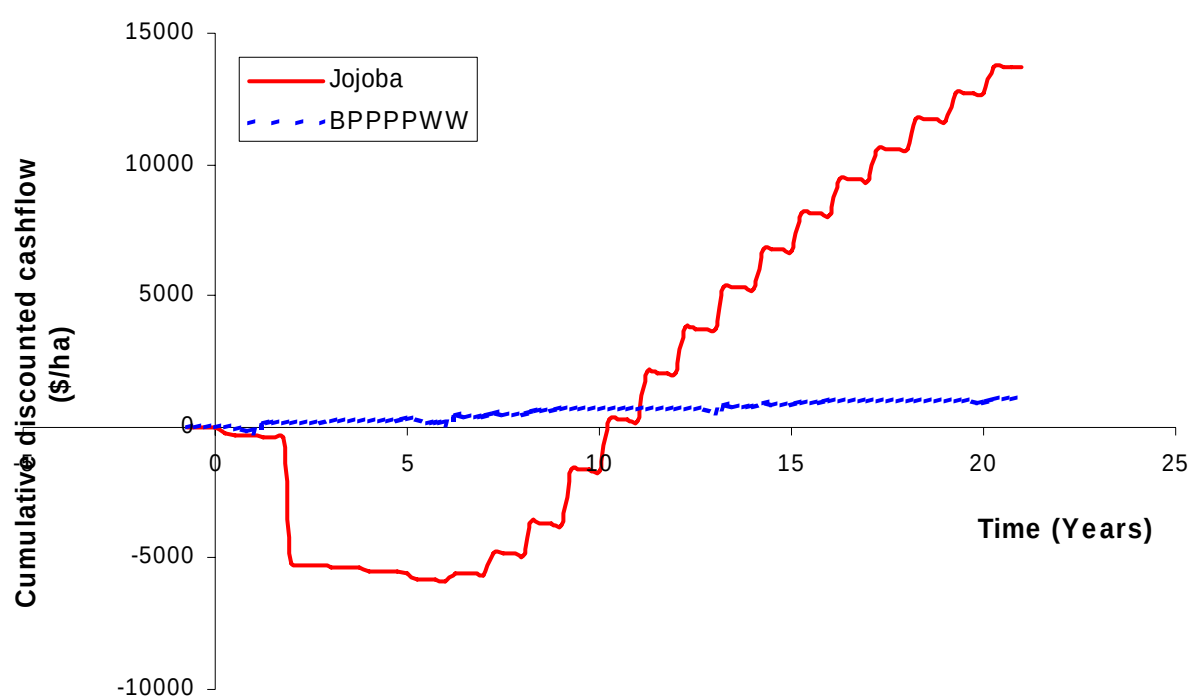


Figure 7. The cash flow of the jojoba plantation compared with conventional agriculture

Sensitivity analysis

This section describes the sensitivity of results of the jojoba case study to variations in key assumptions of key production parameters and interaction effects (Table 48). These variations included:

1. yield of oil harvested from the jojoba plantation
2. price the landowner received for jojoba oil
3. establishment costs of the plantation
4. harvest costs.

Yield and price were varied by plus or minus 25% of the base case. Harvest and establishment costs were varied by plus or minus 50% of the base case. A larger range for sensitivity was used for costs due to the nature of the costs for used for jojoba. No allowance was made for the cost of farmer time or the use of existing farm plant e.g. boom sprays.

If the ranges of variation in parameters are equally likely to occur, the relative importance of the parameters can be ranked (Table 49).

The price of oil is the most sensitive parameter tested for jojoba. Although the annual equivalent return of jojoba is more than five times that of conventional agriculture at the lowest value used in the sensitivity analysis the high sensitivity of jojoba to price is an important concern. A 25% reduction in selling price for oil has reduced the annual equivalent return per hectare by \$691.

Oil yield is the next most sensitive parameter. As with oil price this analysis of jojoba produces attractive returns even at the lowest yields analysed in the sensitivity analysis but the high sensitivity to changes in yield advise caution. A 25% reduction in yield of oil reduced the annual equivalent return per hectare by \$648.

Harvest cost was the next most sensitive parameter. The change in AER observed in this sensitivity analysis is approximately two thirds of that for price or yield of oil. Additionally a greater range of input values was tested for harvest costs. This suggests that although important harvest costs are not as crucial to the success of jojoba as yield and price.

Annual equivalent return was much less sensitive to changes in establishment costs than to oil yield or price. However, establishment costs had a greater affect on the peak debt to be carried when growing jojoba. Therefore, changes in establishment costs will be important in determining how much self financed jojoba farmers can afford to grow.

Table 48. Sensitivity of profitability and cash flows of a plantation of jojoba shrubs to variations in some key assumptions.

Variable	Change in assumptions	NPV (\$/ha)	AER (\$/ha)	Peak debt (\$/ha)	Break-even period (years)	Payback period (years)
Yield of oil	Original +25%	20,742	1,904	5,685 year 6	11	10
	Original -25%	6,624	608	6,119 year 7	14	14
Price of oil	Original +25%	21,214	1,947	5,726 year 6	11	10
	Original -25%	6,151	565	6,097 year 7	15	14
Harvest costs	Original +50%	8,962	823	6,421 year 7	13	13
	Original -50%	18,403	1,689	5,604 year 6	11	10
Establishment costs	Original +50%	11,091	1,018	8,472 year 6	13	13
	Original -50%	16,275	1,494	3,289 year 6	10	10

Table 49. Ranking of parameter sensitivity assuming ranges of sensitivities tested are equally likely to occur for each parameter tested.

Rank	Variable	Range	Change in AER (\$/ha)
1	Oil Price	50% of base case	1,382
2	Oil Yield	50% of base case	1,296
3	Harvest and processing Cost	100% of base case	866
4	Establishment Cost	100% of base case	476

Conclusions

Based on this analysis planting the red-brown earths of the central west region of NSW to jojoba would greatly increase farm profitability. However, there is a significant cash flow hurdle to be cleared. The cumulative discounted cash flow for jojoba does not become positive until the 11th year with a debt of more than \$5,000 per hectare carried for half of this time.

The greatest concern for potential jojoba growers would be “how achievable are the returns presented in this study in the long-term”. If the yields presented in this study cannot be achieved or the price of jojoba oil falls then it will be difficult to pay back the costs of setting up jojoba plantations.

NSW case study 3 – *Eucalyptus camaldulensis*

Background

The following introduction to river red gum (*Eucalyptus camaldulensis*) is a summary of extracts of farm notes and personal communications with experts in the field (Bennett and George 1996, Alan Smith pers. comm.) as well as information downloaded from the DAWA website.

E. camaldulensis is a medium to tall tree growing as high as 40 m. It is the most widely distributed eucalypt in Australia growing on most soil types. It is widely used on farms in woodlots and shelterbelts. The minimum annual rainfall for *E. camaldulensis* can be as low as 150 mm on moisture-gaining sites although it is not suited to very dry sites. *E. camaldulensis* is widely used as a plantation species around the world with its hard, durable wood for production of pulp, particleboard, firewood, and structural and furniture timber. These trees coppice well after cutting. River red gum is used for saltland rehabilitation as it is extremely tolerant of waterlogging and salt, and it is considered valuable for nature conservation as it is an important habitat tree.

Scenarios

Region: The Central West Region of NSW (450 mm)

Soil Type: Red Brown Earths

Project Life: 36 years

Scenario 1: A conventional agricultural land use consisting of a seven-year rotation of barley and wheat grain crops and a pasture phase as described earlier in section 3.3.

Scenario 2: A plantation of *E. camaldulensis* for wood and timber such as firewood, posts and sawlogs. The plantation is established with six-month-old seedlings at a density of 1000 trees/ha.

Main Sources: Alan Smith from the State Forests of NSW and Fact Sheets from the DAWA website: <http://www.agric.wa.gov.au/agency/Pubns/factsheets/>

Assumptions

This section provides a list of key assumptions specific to the *E. camaldulensis* case study. Table 50 describes costs associated with establishing an *E. camaldulensis* plantation. Table 51 shows assumptions relating to the price of wood and sawlogs harvested from the plantation. The price quoted is the farm-gate stumpage price received by the grower, net of all harvest and delivery costs. It is assumed trees are contract harvested. Table 52 describes the harvest schedule and yield of products from *E. camaldulensis* stands.

Table 50. Establishment and production costs of an *E. camaldulensis* plantation.

Variable	Value	Units
Planning and site mapping and set up including land preparation	443	\$/ha
Seedlings and machine planting – a one-off operation in year one	504	\$/ha
Weed management and control – two applications at establishment	222	\$/ha
Weed management and control – one application in year two	56	\$/ha
Watering – once only in year one	200	\$/ha
Fertiliser – once only in year one	107	\$/ha
Maintenance and monitoring – every year after year two	110	\$/ha
Early growth monitoring – once only in year one	10	\$/ha
Pruning – once only in year two	35	\$/ha
Thinning – once in year eight	100	\$/ha

Table 51. Price of wood and timber harvested from an *E. camaldulensis* plantation.

Variable	Value	Unit
Firewood	8	\$/m ³
Posts	20	\$/m ³
Sawlogs – small	25	\$/m ³
Sawlogs – medium	35	\$/m ³
Sawlogs – large	55	\$/m ³

Table 52. Yield of wood and timber from a plantation of *E. camaldulensis* at different harvests.

Variable	1 st harvest	2 nd harvest	Unit
Scheduled harvest year	20	35	year
Firewood	6	6	m ³ /ha
Posts	5	6	m ³ /ha
Sawlogs – small	9	0	m ³ /ha
Sawlogs – medium	14	25	m ³ /ha
Sawlogs – large	0	57	m ³ /ha

Cash flow and profitability

This section describes results of a comparative financial analysis of conventional agriculture (Scenario 1) and a plantation of *E. camaldulensis* (Scenario 2). An *E. camaldulensis* plantation generated a negative AER of \$181/ha per annum, which is \$70/ha less profitable than conventional agriculture (Table 53). This is due mainly to the assumption about its establishment and maintenance costs (over \$4000). There is also no income until the first harvest in year 20 with revenues of only \$863/ha, which is not enough to offset establishment costs resulting in negative cash flows until the final harvest in year 35. Under the assumptions driving this analysis an *E. camaldulensis* plantation would be a very unwise investment if the landowner had other alternatives such as a conventional agriculture, jojoba or *E. radiata*.

Table 53. Profitability and cash flows of a plantation of *E. camaldulensis* compared with agriculture.

Scenarios	Products & System	NPV (\$/ha)	AER (\$/ha)	Peak debt (\$/ha)	Break-even period (years)	Payback period (years)
Scenario 1						
Agriculture	Grains, sheep	1333	103	109	N/A	1
Cereal and pasture rotation	Cropping and livestock			Year 1		
Scenario 2						
Agroforestry	Wood and timber	-2353	-181	2716	Not reached	Not reached
<i>E. camaldulensis</i> plantation				Year 35		

The consequences of establishing a plantation of *E. camaldulensis* on cash flow are as follows:

- **Peak debt.** A cumulative cash deficit of \$2,716/ha occurs in the 34th year after establishment. A landowner wishing to establish a 100 ha plantation carries a peak debt of around \$271,600 for 35 years. The peak debt extends beyond the first harvest in year 20 because income from harvesting trees in the 20th year is not enough to inject sufficient revenue reducing the negative cash flow associated with plantation establishment.
- **Payback period.** Because the final harvest does not take place until year 35, the cumulative effect of discounting cash flows means cumulative cash deficits of establishing the *E. camaldulensis* plantation do not become surpluses during the 36-year life of the project (Figure 8).
- **Break-even period.** The cumulative cash flow of the *E. camaldulensis* plantation does not reach that of conventional agriculture (Scenario 1). The two harvests of *E. camaldulensis* do not generate the kind of income required to compensate for the opportunity cost of agricultural enterprises replaced by the plantation and the establishment costs (Figure 8).

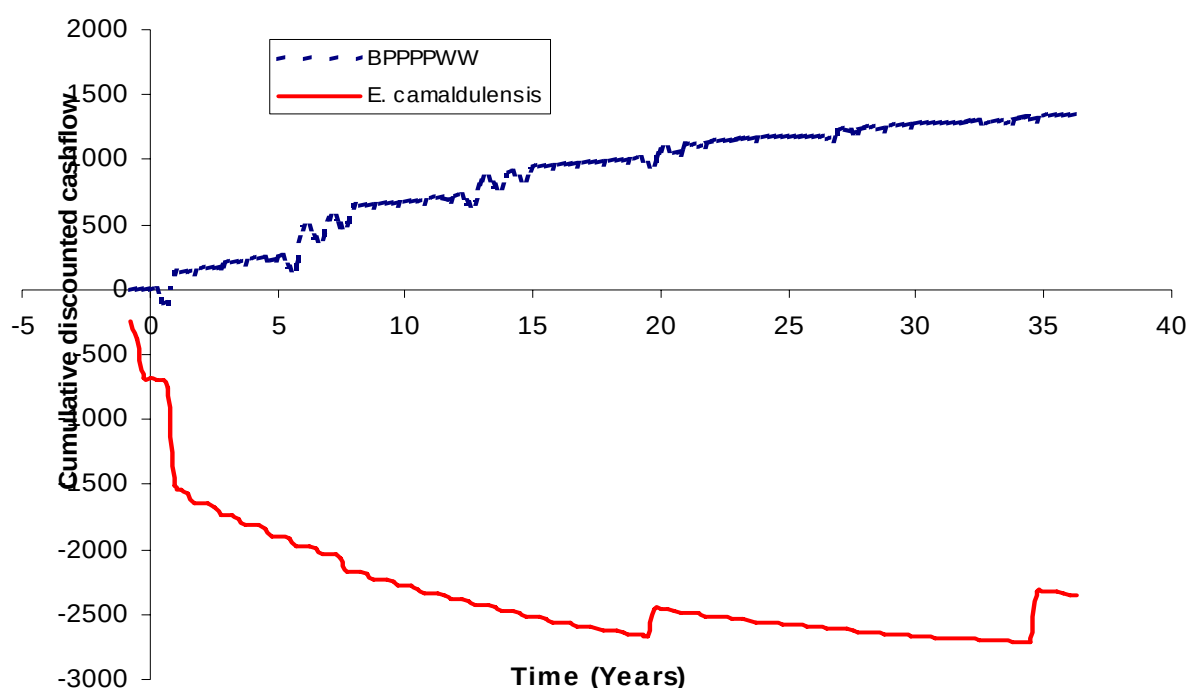


Figure 8. The cash flow of the *E. camaldulensis* plantation compared with conventional agriculture

Sensitivity analysis

This section describes the sensitivity of results of the *E. camaldulensis* case study to variations in key assumptions of key production parameters and interaction effects (Table 54). These variations included:

1. yield of wood products harvested from the *E. camaldulensis* plantation
2. price the landowner received for firewood, posts and sawlogs
3. establishment costs of the plantation
4. silviculture and maintenance costs.

Under the current assumptions, the *E. camaldulensis* plantation makes such a loss that, even when price or yield of harvested wood products is increased by 50%, the project is still far less profitable than conventional agriculture. Increasing the yield of products from the *E. camaldulensis* plantation by 50% increases the *AER* to a loss of \$157/ha per annum and the payback and break-even periods are still not reached (Table 54). Increasing the price of wood products by 50% increases the *AER* but is unprofitable, making a loss of \$160/ha per annum.

The sensitivity analysis of the effect of variations in establishment costs produces similar results. Changing establishment costs significantly affects profitability of the *E. camaldulensis* plantation, to a larger extent than changes in yield and price, because establishment costs are incurred at the beginning of the project. A 50% lower establishment cost makes a loss of \$67/ha per annum and is less profitable than a conventional agricultural rotation.

Conclusions

The conclusion from this sensitivity analysis is that an *E. camaldulensis* plantation would be a very unwise investment even if more favourable bio-economic conditions than those originally assumed were to prevail in establishing and harvesting this tree species.

Table 54. Sensitivity of profitability and cash flows of a plantation of *E. camaldulensis* to variations in some key assumptions.

Variable	Change in assumptions	NPV (\$/ha)	AER (\$/ha)	Peak debt (\$/ha)	Break-even period (years)	Payback period (years)
Yield of wood and timber	Original +50%	-2040	-157	2665	year 20	Not reached
	Original -50%	-2665	-204	2830	year 35	Not reached
Price of wood and timber	Original +50%	-2040	-156	2665	year 20	Not reached
	Original -50%	-2665	-204	2830	year 35	Not reached
Establishment costs	Original +50%	-3833	-294	4188	year 35	Not reached
	Original -50%	-873	-67	1332	year 19	Not reached

Conclusions

The results of the economic analysis of the eight case studies show the importance of reporting not only profitability indicators but also indicators summarising cash flow streams. Decision makers need to know the length of time a project is projected to have negative cash flows. Sometimes the magnitude and length of time the project has negative cash flow may make it less attractive than an alternative cash flow with a smaller overall project NPV but steady and smaller positive cash flows. The decision makers are likely to ask questions such as:

- When are negative cash flows likely to be experienced?
- What is the magnitude of negative cash flows in each period?
- How long will the streams of negative cash flow last?
- When will the first positive cash flow be observed?
- At what stage in the life of the project will it break-even?
- When will positive cash flows offset negative cash flows?

In farming systems, trees usually replace conventional annual agricultural enterprises such as wheat or pasture. Therefore it is important to consider the opportunity costs of the land. For instance, in planting oil mallees in alley farming situations, the net returns from the trees must be at least as much as a conventional crop rotation on that land. We find on sandy soils in northern WA, tree crops such as maritime pine are as commercially competitive, if not more profitable than, conventional agriculture. However, on more fertile sandplain soils, tree crops such as pines would not be economical since the opportunity cost on those soils is relatively high net returns generated from rotating cereal crops with legume crops or pastures.

This study shows the least viable agroforestry systems require landowners to forego returns from conventional agriculture by completely replacing it with an agroforestry project, with high up-front costs and little or no income until the end of the project. The most attractive projects offset the costs of establishment e.g. share-farming, or where trees are integrated with conventional agriculture and regularly harvested for biomass or grazed by livestock e.g. alley farming.

Where conventional agriculture is highly profitable, the value of spatial and temporal interactions between trees and neighbouring or subsequent agricultural crops and pastures becomes economically significant. Our findings highlight the importance of viewing agroforestry projects such as alley farming systems as a complex land use sequence of both annual and perennial enterprises. Viewed in this way the economic evaluation of an agroforestry land use would include the sum of the expenditures and revenues of each of the phases of the rotations and the economic impact of positive and negative interactions between the constituent enterprises of the rotation in both space and time. This would avoid the erroneous comparison of profitability of a woody perennial component of an alley farming system compared with the agricultural component, leaving the often-significant spatial interactions of the trees with the inter-rows. This project shows there are good economic grounds for directing research toward identifying interactions between trees and other enterprises. We have conclusively shown interactions in alley farming systems, which are economically competitive with traditional agriculture, can make a significant economic difference.

The results of this study can be used to determine the extent to which agroforestry systems require institutional incentives, market instruments, alternative credit facilities and environmental credits required to compete with current practice.

The arithmetic of discounting is hard to do off the top of one's head. Considering profitability of a short sequence of land use (rotation) with agricultural enterprises with undiscounted cash flows may not cause major financial problems since the life of the projects are short. However, for tree crops

with long project lives, the inability to account for discounting can give extremely false impressions of the feasibility and commercial viability of the project.

This project has provided a general economic analysis technique and tool to evaluate many other tree species in various edaphic and agroclimatic zones of Australia. Field trials in agroforestry farming systems require long lags compared with field trials of annual herbaceous crops. This type of economic research methodology is useful in identifying key profitability drivers and important farming systems issues before field trials are designed and executed. Economic analyses can identify niches where trees have reasonable prospects of being adopted to generate higher returns than from current land uses.

The conclusions of this project are contingent on a number of assumptions. In the analyses reported here it was assumed yields of agricultural crops remained constant over 30 or more years. However, if the gradual rise in groundwater caused salinity and waterlogging to such an extent that the yields of crops and carrying capacity of pastures were significantly diminished then the agroforestry options may become comparatively more profitable.

Recommendations

1. Oil mallee has the greatest potential for further development in the WA cropping zone given the area of soils suited to their cultivation. Further research to determine the market size for mallee biomass and oil is required.
2. Jojoba and blue mallee were the most promising commercial prospects for the NSW cropping zone. Further research to determine potential yield, market size and demand elasticity for the products from these trees is required.
3. The development of alternative debt financing and capital development funding schemes should be investigated for agroforestry systems generating products for on-farm use, where they represent the most profitable perennial land use options for a particular land management unit or region. Perennial fodder species, like tagasaste, require further whole-farm economic analysis. They provide valuable feed during the feed gap in autumn and early winter and can affect the carrying capacity of the entire farm.
4. Joint venture financing arrangements should be investigated where there are large up-front establishment costs. Such arrangements, making annuity payments to growers, provide incentives for adoption through early cash flow. These payments could be extended to include environmental services when institutional arrangements and markets have been established for credits associated with carbon sequestration or salinity.
5. Industry level business analysis and farm-level business analysis needs to be conducted for the most promising agroforestry systems reported here, taking in the perspectives of different stakeholders including the landowner, the investor with the financial capital for whole or part of the project, the buyers, processors and manufacturers of the tree products. For a more complete analysis, the analytical framework should be further developed to incorporate modules on debt financing, capital budgeting, taxation subsidies and groundwater impact.
6. Additional empirical data needs to be collected to firm up estimates of commercial yields of trees evaluated in this project, particularly for NSW. Estimates of various parameter values varied widely among agronomists, forest researchers and tree crop advocates. There was a diversity of expert opinion about the production of trees and their likely responses to edaphic and climatic conditions and to silvicultural management. This points to a problem for the industry as it is unlikely landowners would seriously consider tree cropping investment projects without sound and credible production and cost estimates.

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